Research Paper

Investigate the Effect of a Comprehensive Warm-up Program on the Functional Movement Patterns and Landing Error of Young Male Wrestlers

Mehdi Babaei Jafari[1], Amirhosein Barati[2*], Mahdieh Akoochakian[1], Mohammad Hosein Alizadeh[3]

1. Department of Sports Science, Kish International Campus, University of Tehran, Kish, Iran.
2. Department of Sports Rehabilitation, Faculty of Sports Sciences and Health, Shahid Beheshti University, Tehran, Iran.
3. Department of Sports Medicine and Health, Faculty of Physical Education and Sports Sciences, University of Tehran, Tehran, Iran.

Use your device to scan and read the article online

Citation Babaei Jafari M, Barati A, Akoochakian M, Alizadeh MH. Investigate the Effect of a Comprehensive Warm-up Program on the Functional Movement Patterns and Landing Error of Young Male Wrestlers. Physical Treatments. 2024; 14(3):201-216. http://dx.doi.org/10.32598/ptj.14.3.565.1

http://dx.doi.org/10.32598/ptj.14.3.565.1

Article info:
Received: 22 Jul 2023
Accepted: 24 Jan 2024
Available Online: 01 Jul 2024

ABSTRACT

Purpose: The current study aims to investigate the effect of a comprehensive warm-up program on functional movement (FM) patterns and landing errors of young male wrestlers.

Methods: For this purpose, 50 wrestlers from Karaj City, Iran were selected as available to participate in the research and then randomly divided into two equal experimental groups (25 people) and a control group (25 people). Then, the landing error scoring system (LESS) test was used to evaluate the landing error, and deep squat, lunge, shoulder mobility, and rotational stability tests were used to measure the quality of movement patterns, and finally, the Nordic questionnaire was used to measure musculoskeletal pain. The experimental group performed special wrestling warm-up exercises for eight weeks and three sessions of 30 minutes per week.

Results: The results of the chi-square test showed that the musculoskeletal pain in the knee area of the subjects in the experimental group improved significantly after eight weeks of training (P=0.04), but the musculoskeletal pain in the shoulder and trunk of the wrestlers did not improve significantly (P>0.05). The results of the U-Man-Whitney U test showed that among the variables related to performance, no significant difference was observed in the post-test in the right and left shoulder mobility test (P<0.05) and in other research tests, a significant difference was observed between the two groups (P<0.05).

Conclusion: We conclude that trainers can use the training protocol of the present research to improve landing error and musculoskeletal pain in the knee joint, along with other common training protocols.

Keywords:
Wrestler, Warm up, Neuromuscular exercises

*** Corresponding Author:**
Amirhosein Barati, MD.
Address: *Department of Sports Rehabilitation, Faculty of Sports Sciences and Health, Shahid Beheshti University, Tehran, Iran.*
Phone: *+98 (912) 1930811*
E-mail: *ahbarati20@gmail.com*

Highlights

• A comprehensive wrestling warm-up program can reduce musculoskeletal pain, improve functional movement (FM) patterns, and reduce landing errors in young male wrestlers.

Plain Language Summary

Wrestling is one of the most popular Olympic sports that requires special physical fitness and also has a special injury pattern. Fifty wrestlers from Karaj City were selected as available to participate in the research. Then, the landing error scoring system test (LESS) test was used to evaluate the landing error, deep squat, lunge, shoulder mobility, and rotational stability tests were used to measure the quality of movement patterns, and finally, the Nordic questionnaire was used to measure musculoskeletal pain. The experimental group performed special wrestling warm-up exercises for eight weeks and three sessions of 30 minutes per week. The results showed comprehensive warm-up program improves landing error and musculoskeletal pain of the knee joint, and trainers can use the training protocol along with other common training protocols.

Introduction

Wrestling is one of the oldest Olympic sports with a large following. It is the national sport of Iran and one of the most successful sports in the country. However, it is also a physically demanding sport with a high risk of injury. Studies have shown that the most common injuries among young wrestlers are shoulder injuries (8.2%), ankle injuries (6.4%), and knee injuries (5.3%) [1].

The rising popularity of competitive and recreational sports has led to a significant increase in the incidence of joint injuries, especially in the ankles and knees. This has resulted in significant psychological and financial losses for sports clubs and athletes.

Epidemiological studies have indicated that wrestlers' training injuries are associated with various risk factors. These include weight loss [2], low physical fitness [2], excessive fatigue, Previous injury, incorrect technique, non-sporting movements, inappropriate mental states [3], as well as the opponent's errors and inadequate warm-up routines [4]. Therefore, based on previous research, it has been established that one crucial aspect for athletes, coaches, and even individuals engaging in basic sports activities to maintain their well-being is how they commence their physical endeavors and the specific type of warm-up employed during training or competition. While it has been advised over the past few decades that athletes should incorporate preliminary exercises and warm-up routines before embarking on intense training sessions or participating in competitive events, the results of certain studies have given rise to some disagreement among researchers regarding the required level of intensity and duration associated with these warm-up activities [5].

In today's world, most athletes view warming up as an integral component of their expertise. They firmly believe that engaging in warm-up routines both during training sessions and actual competitions leads to enhanced physical and mental performance, while also effectively minimizing the risk of injuries during exercises. From a physiological standpoint, scientific evidence has solidly established that elevating body temperature triggers the release of oxygen from both myoglobin and hemoglobin. Additionally, it promotes a heightened blood flow to the muscles, amplifies the receptiveness of nerve receptors, accelerates the speed of nerve impulses, diminishes the energy required for fuel reactions, and decreases muscle viscosity [6]. Researchers have also explored variables that influence heating effects, such as the duration of the warm-up program, the intensity of the warm-up, and the time interval between the warm-up and the main activity. The impact of these variables is contingent upon various factors, including the athlete's characteristics, the type and nature of the sport, weather conditions, and the objective of the training session or competition.

Multiple studies have been conducted to examine the impact of specialized warm-up exercises in various sports, such as soccer, basketball, handball, and others [7-10]. However, the researcher's findings indicate that very limited research has been conducted to understand the effects of specialized warm-up exercises in wrestling. For instance, Bayati et al. conducted a study to explore the influence of a 12-week wrestling + warm-up program on the dynamic balance of young wrestlers. The experimental group followed the wrestling + warm-up program three times a week, over 12 weeks, while the control group adhered to their usual warm-up routine during the same duration. Ultimately, the researchers concluded that implementing a specific warm-up program for wrestling can enhance the balance of wrestlers [11].

Polat et al. [12] in their study, investigated how ballistic warm-up impacts various aspects of performance, including isokinetic strength, balance, agility, flexibility, and speed, in freestyle wrestlers who had a mean age of 20 years. The participants were divided into two groups, with one group performing 10 minutes of submaximal running as part of their warm-up and the other group performing 10 minutes of ballistic exercises that engaged most of their muscle groups. The researchers found significant differences in flexibility, right-hand grip strength, dynamic balance, and the strength of the quadriceps and hamstring muscles in the right and left legs. Accordingly, the study concluded that ballistic warm-up exercises are more beneficial than regular warm-up exercises for improving muscle strength and other variables [12].

As previously mentioned, multiple studies have looked into the impact of warm-up exercises on wrestlers' performance and have found conflicting results. However, there has been a lack of research on the effects of these exercises on injury prevention in wrestlers. Additionally, previous studies have shown that coaches and players are often reluctant to implement preventive programs unless there is a direct impact on performance [13]. As a result, this research aims to examine the effects of a comprehensive warm-up program specifically designed for young male wrestlers, including its impact on musculoskeletal pain, landing error, and overall performance.

Materials and Methods

The research is designed as a field trial. The wrestlers were selected between the ages of 20 and 30 years with at least three years of experience in this field our statistical population. Using G*Power software and referring to previous studies [12, 14, 15], a statistical sample of 45 individuals has been obtained. The sample was chosen with a power of 0.95 to 0.05 and an impact factor of 0.50. Ultimately, 50 individuals participated in the study, considering a 10% chance of dropouts. These individuals were selected based on specific entry and exit criteria and were randomly assigned to either an intervention group or a control group, with each group comprising 25 individuals. The test has a power of 0.80 and the selection of the effect size is based on previous research. The starting point for the effect size is 1.02. It is essential to mention that previous studies on LESS tests and functional movements (FMs) [11, 14, 16-19] found effect sizes ranging from 0.69 to 2.5. The starting point for the effect size was determined to require a significant sample size of 1.02, resulting in a calculated sample size of 50 people. To be eligible for this research, individuals must meet several criteria. Firstly, they must fall within the age range of 20-30 years. In addition, they must have a minimum of three years of sports experience in the field of wrestling. Furthermore, participants must provide voluntary consent to take part in the research. It is also required that they do not exhibit any pathological symptoms or have a history of surgical fracture or joint diseases in their lower limbs or spine within the past five years [20, 21]. Moreover, individuals should not have a history of knee and ankle ligament damage within the past 18 months [22]. Lastly, they should not have any sensory or motor disorders as diagnosed by a specialist doctor [23]. On the other hand, certain exclusion criteria must be met. Participants must not miss more than three training and competition sessions during the research period. Additionally, they should not have a previous injury at the start of the research. Lastly, individuals who are older than 30 years or younger than 20 years are also not eligible for participation.

After selecting the subjects and their consent, the test was conducted on them. The individuals who took part in this study were duly informed about the purposes, methods, and advantages of their participation. They were assured that all of their personal information and data would be kept confidential, and they were also given the option to decline participation in the research at any given moment.

The research samples were instructed to go to the wrestling hall at the designated schedule to obtain measurements for the pre-test. Once the subjects arrived, they were required to fill out a basic information form, and then each person underwent anthropometric measurements. To assess landing error, the LESS was employed. Padua et al. reported that the intra-examiner reliability of this test was excellent, with an intraclass correlation coefficient (ICC) value of 0.91 [24]. Additionally, Hanzlíková and Hébert-Losier (2011) reported moderate to excellent self-validity of this test [25]. During the test, the subject was instructed to stand on a 30 cm box. The target line was drawn on the surface, with a distance equal to half the person's height. The subject was then instructed to jump forward from the box and land with both feet simultaneously on the surface, in front of the marked line, followed immediately by a maximum vertical jump.

The subject must maintain a continuous motion from landing on the ground to starting the vertical jump without any pauses. After the examiner demonstrated the test, each subject was given two opportunities to practice. The examiner did not provide any instructions to the subject regarding proper landing mechanics. Overall, the subject made four attempts, and the examiner observed and evaluated the subject from both the front and side views. During the first and second attempts, the examiner captured a picture of the subject from the front view, while during the third and fourth attempts, a picture was taken from the side view. Based on the existing errors, the subject's landing error was graded, determining their score. The scoring method for the LESS test is explained below. It is important to note that the score increases with more mistakes, with the highest possible score being 17 and the lowest score being 5.

Experts can successfully use the LESS as a systematic and easy-to-use format to evaluate specific movement patterns that typically occur during ACL and lower limb injuries, such as knee valgus, excessive leg rotation, and decreased knee flexion, which can be seen, for instance, in flat-footed landing [26]. They can then adopt a corrective strategy for this movement disorder based on the information obtained from LESS.

The performance tests used to assess athletes included deep squats, lunges, shoulder mobility, and rotational stability tests. These tests, which are part of the FM screening tests [27, 28], are effective in identifying any restrictions or deviations from the usual movement patterns. They are specifically designed to evaluate the correlation between the mobility of the movement chain and the stability required for executing FM patterns [29].

Below, an explanation of the motor performance test can be observed, including instructions on how to carry it out and how to score it. In this test, subjects are awarded two points if they perform the required movements correctly and without any compensatory movements. However, if subjects perform the movements with compensatory actions, they will not receive the full two points. Instead, they will earn one point for their inability to perform the movements without compensatory actions. Furthermore, if a subject experiences pain while performing any of the movements, they will not be awarded any points at all [30].

To perform the lunge test, the participants were required to hold the balance stick against the back of their head, upper back, and hips. They were instructed to place their right hand behind their neck and their left hand behind their waist while assuming this position. Then, they would take a step forward. This movement was repeated for both legs. If the stick remained in contact with the head, back vertebrae, and sacrum, there would be no observable movement in the trunk. In addition, the leg and the stick would remain in the sagittal plane. Finally, if the knee behind the front leg made contact with the board, the person would receive a score of three. On the other hand, if the stick was not in contact with the head, back vertebrae, and sacrum, there would be no observable movement in the trunk. Moreover, the leg and the stick would deviate from the sagittal plane, and the knee behind the front leg would not touch the board. In this case, the person would receive a score of two. If the individual executed the motion while experiencing imbalance, a score of one was assigned to them; ultimately, if they were unable to execute the motion altogether, they received a score of zero [30].

To conduct the shoulder range of motion test, an individual should stand with their legs together and their hands hanging by their sides. They should then wrap their fingers around their thumbs and form a fist. Then, the person should raise their right hand, with the fist still clenched, above their head and lower it as much as possible. Simultaneously, they should also move their left-fisted hand from behind their back as far as they can. During this test, if the distance between the fists is 20 cm or less, the person will receive three points. If the distance is between 20 and 30 cm, they will receive two points, and if the distance is >30 cm, they will be given one point.

For the rotational stability test, the subject is positioned with the elbow underneath the shoulder and the knee underneath the pelvis. In this specific stance, the hands, knees, and toes on one side of the body are placed on the balance board. The individual then extends their right hand forward while simultaneously moving their right foot backward. Without touching the ground, they proceed to bring the elbow of their right hand in contact with their right foot and return to the original position. This sequence is also repeated for the opposite side. The correct execution of the movement occurs when the spine is parallel to the ground, the knees and elbows are in contact with each other, and there is no contact with the ground [30]. The person can earn a score of three by performing a one-sided repetition while keeping their spine parallel to the board. Additionally, they need to bring their knees and elbows together and have minimal rotation of the trunk. If they perform a two-way repetition while keeping their spine parallel to the board and also reaching their knees and elbows together, they will receive a score of two. If they cannot perform a two-way repetition, they will receive a score of one. Finally, if the person is unable to perform the movement at all, they will receive a score of zero [30].

During the deep squat test, the individual positions themselves by standing with their feet placed shoulder-width apart and toes pointing forward. Subsequently, while ensuring that the shoulders and elbows form a 90-degree angle, the person grasps a horizontal balance stick with both hands and holds it above their head. Simultaneously, they maintain their heels firmly planted on the ground while descending as far as possible without compromising their balance. Once in this lowered position, they maintain their stance until the examiner counts to one, after which they return to their initial standing position.

If the upper body is aligned with the tibia or is at a right angle to the ground, and the thigh is positioned lower than the horizontal level and aligned with the knee and foot, a score of three is given. If the individual meets all the requirements for grade three but is unable to execute the movement on the ground or place the heels on the board, a score of two is given. However, if the upper body and tibia are not parallel, the thigh is not positioned lower than the horizontal level, the knee is not aligned with the leg, and there is flexion of the vertebral column, a score of one is given. In cases where the person is unable to perform the movement at all, a score of zero is assigned to them [30].

Researchers investigated the prevalence of musculoskeletal disorders by utilizing the Nordic questionnaire, a self-report method consisting of two sections: Individual information and specific inquiries. This questionnaire was originally developed at the Institute of Professional Health in Scandinavian countries and its Persian version's validity was deemed good (ICC=0.70) by Mokhtarinia et al. [31]. The questionnaire has a dual-completion method, either through an interview or a self-administered format. It consists of two parts, a general questionnaire and a specific questionnaire. The general questionnaire aims to assess and evaluate overall musculoskeletal disorder symptoms in the entire body. The specific questionnaire, on the other hand, focuses on a detailed analysis of these symptoms in specific areas, such as the neck, shoulder, waist, wrist, and hand [32]. Only the results from the specific questionnaire were analyzed for this research. The standard questionnaire covers nine body parts, including the neck, shoulder, upper back, elbow, wrist, lower back, thigh, knee, and ankle. Each section contains relevant questions related to the respective body parts.

1. Have you experienced any issues like pain, discomfort, or numbness in these areas within the past 12 months?

2. Have you encountered any problems in these areas over the past year that hindered your ability to carry out your daily activities, at work and at home?

3. Have you faced problems, such as pain, numbness, etc. in these specific body regions during the past week? The current study examined the musculoskeletal pain experienced by wrestlers last week.

Process of doing exercises

The participants in the experimental group began their exercises immediately after their initial measurement session. These exercises were conducted for 8 weeks, with three sessions taking place each week and every other day in Mehrshahr, Karaj Wrestling Club. In addition, all participants were instructed to refrain from engaging in any form of exercise other than the designated exercise program during this period. However, they were permitted to carry out their normal daily activities. It was crucial for the participants to not miss three consecutive training sessions, as failure to adhere to this rule would result in their exclusion from the research process. Furthermore, a qualified examiner was present at all training sessions, directly supervising the exercises. This decision was based on previous results indicating that exercising under the guidance of an expert yields better results compared to unsupervised workouts [33].

The researcher implemented a warm-up exercise routine for the participants in wrestling. The exercises had a duration of 23 minutes, with rest periods between sets lasting almost 30 minutes. The first part of the warm-up consisted of running exercises for seven minutes, aimed at increasing the athletes' heart rate. The second part included joint mobility and rotation exercises, focusing on the joints used in wrestling, for one minute. The third part involved stretching exercises to improve flexibility in the muscles used during the activity, lasting 2.5 minutes. In the fourth part, participants completed gymnastic exercises to simulate the target activity, lasting about one minute. The fifth section involved central stability exercises for 2.5 minutes, followed by balance exercises in the sixth section for the same duration. The seventh section included strength exercises for approximately 2.5 minutes, while the eighth section focused on agility exer-

Table 1. Comprehensive warm-up exercise protocol

Part 1: Running Exercise, 7 Minutes

Exercise No.	Exercises	Frequency (m)
1	Running forward and straight	2
2	External thigh internal rotation and rotation with running	1
3	Running both sides to the side and butterflying (foot boxing)	1
4	Running on the guard and forward	1
5	Running on the guard to the side	1
6	Back and forth with fast-running	1

Part 2: Joint rotation exercises, 1 minute

Exercise No.	Exercises	Frequency (s)
7	Rotation of the ankle joint	Each foot 10 repetitions (10)
8	Rotation of the knee joint in two directions	10
9	Back rotation	10
10	Rotation of the shoulder joint	10
11	Elbow rotation	10
12	Wrist rotation	10

Part 3: Stretching exercises, 2.5 minutes

Exercise No.	Exercises	Frequency (s)
13	Stretching the neck muscles (bending on all four sides with hands)	10
14	Stretching the hands above the head	10
15	Stretching the arms and bending to the sides on both sides	10
16	Stretching the arms towards the front of the bent upper body	10
17	Stretching the arms in front of the chest with the other hand	10
18	Stretching the fingers and forearm with the other hand up and down in an outstretched hand position	10
19	Stretching the sides (bending to the side)	10
20	Bending the upper body on the legs (do not bend the knees), stretching the gluteal muscles and hamstrings	10
21	Leg muscle stretching (pulling the tip of the foot with the hand in a straight knee position)	10
22	Stretching the inner leg muscles (bending one knee and leaning to the same side)	10
23	Giant swing	4×10
24	Stretching of the muscles of the forearm, shoulder and chest (kneeling position and hands on the sides)	10

Part 4: Gymnastics exercises, about 1 minute

Exercise No.	Exercises	Frequency (s)
25	Front leg roll together	5
26	Back leg roll together	5
27	Open front roll	5
28	Open leg back roll	5
29	Skip step	5

Part 5: Central stability exercises, 2.5 minutes

Exercise No.	Exercises	Frequency (s)
30	Plank movement (elbows and toes on the floor)	3×20
31	Bridging the back and reversing the movement (such as sitting and standing still)	3×20
32	Lateral bridge	2×15

Part 6: Balance exercises, 2.5 minutes

Exercise No.	Exercises	Frequency (s)
33	One foot on the balance	2×20 per foot
34	A balancing exercise, standing on one leg	2×20 per foot
35	Standing on the palms and ankles with the help of a wheel-barrow (Fourgon)	2×25

Part 7: Strength training, about 2.5 minutes

Exercise No.	Exercises	Frequency (s)
36	Squat	2×20
37	Lunge	2×20
38	Swedish swimming	2×20
39	Nordic hamstring outward contraction movement	2×10

Section 8: Agility exercises, about 1 minute

Exercise No.	Exercises	Frequency (s)
40	4×9 agility exercise	2 iterations
41	Passing between a friend or an obstacle to the left and right (foot box)	2×20

Part 9: Explosive power (plyometric), 1 minute

Exercise No.	Exercises	Frequency (s)
42	Jumping over players or obstacles	2×15
43	Jump over the side to the left and right	2×15

Part 10: Running exercises, 2 minutes

Exercise No.	Exercises	Frequency (m)
44	Soft running	2

PHYSICAL TREATMENTS

cises for approximately one minute. The ninth part of the warm-up routine included plyometric exercises for one minute, and the tenth part ended with a two-minute slow-running activity (Table 1). Throughout the warm-up, the researcher controlled the timing of exercise and rest periods using a stopwatch. After completing the training period, all subjects underwent post-test measurements. Figure 1 displays some exercises.

The researchers used the Shapiro-Wilk test to determine the normality of the data. Additionally, they employed the chi-square and Mann-Whitney U tests to compare the results between the different groups in the post-test. Moreover, they conducted a marginal mean test to assess and compare the impact of exercises.

Results

Table 2 presents the demographic characteristics of the subjects, illustrating the results.

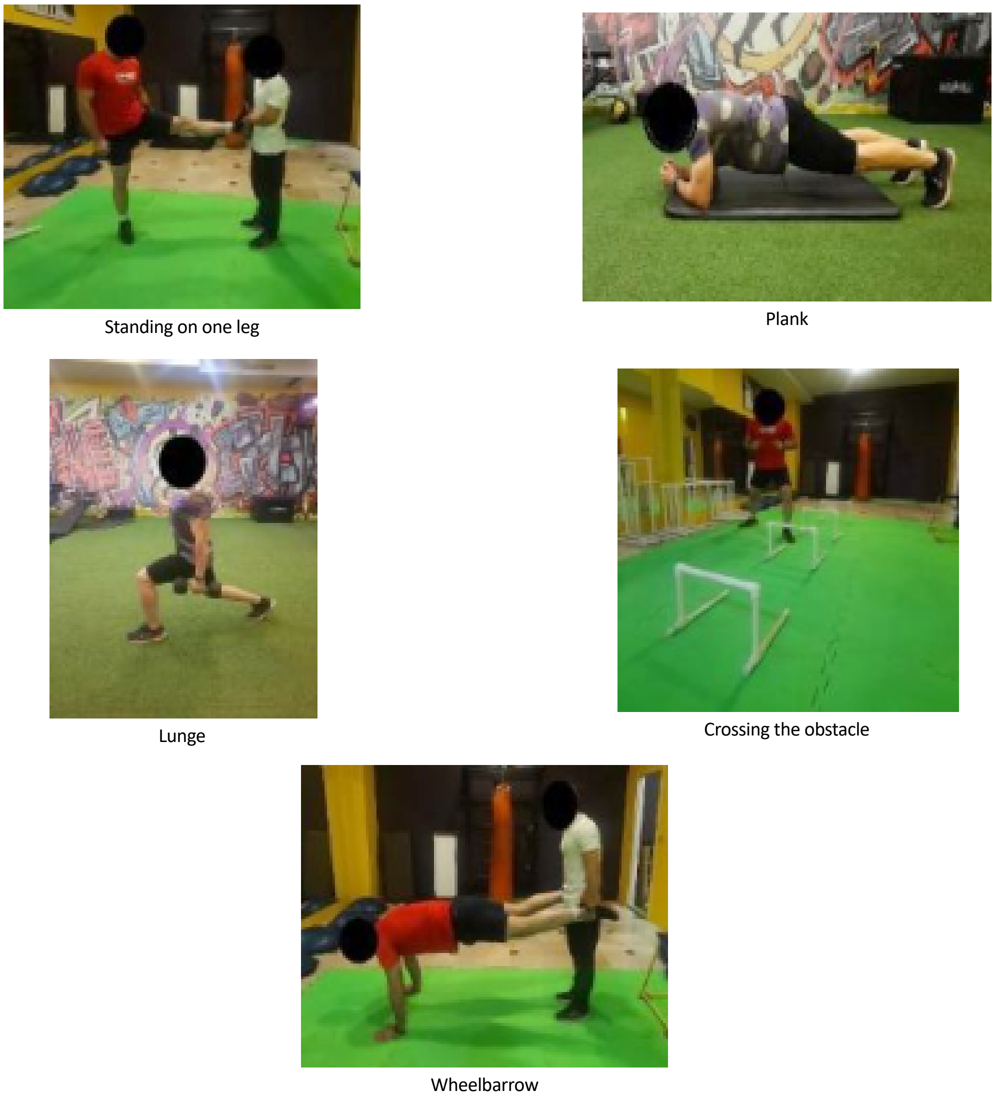

Figure 1. Some exercises

PHYSICAL TREATMENTS

Table 2. The anthropometric characteristics of the research subjects

Group	Mean±SD		P
	Experimental (n=25)	Control (n=25)	
Age (y)	24.24±2.94	25.36±2.92	0.18
Height (m)	1.71±0.06	1.71±0.07	0.75
Weight (kg)	68.20±7.74	70.76±9.18	0.29
BMI (kg/m²)	23.21±1.10	23.86±1.14	0.08

PHYSICAL TREATMENTS

BMI: Body mass index.

The Shapiro-Wilk test results indicated that the data for all variables in the research did not follow a normal distribution (P<0.05). As a result, non-parametric statistical methods were used to analyze the research hypotheses. After conducting the chi-square test (Table 3), it was determined with 95% confidence that a significant difference is observed in musculoskeletal pain levels of wrestlers' knee joints between the pre-test and post-test, specifically after eight weeks of engaging in dedicated wrestling warm-up exercises within the experimental group (P=0.001). Conversely, this difference was statistically insignificant in the control group (P=0.16). In addition, the subjects within the experimental group experienced significantly less knee pain than those in the control group during the post-test. Furthermore, the results demonstrated a significant difference between the two groups regarding the number of musculoskeletal pains experienced during both the post-test and the period of eight weeks following the intervention (P=0.04). Conversely, no significant difference was observed in the occurrence of musculoskeletal pain in the shoulder joint of wrestlers in either the experimental group or the control group before or after the intervention involving specific warm-up exercises for eight weeks (P=0.16 in the experimental group and P=0.84 in the control group).

Additionally, the results of the group comparisons revealed no significant difference in musculoskeletal pain during the post-test and after eight weeks of intervention between the two groups (P=0.39). It is noteworthy that neither the experimental group nor the control group exhibited any significant difference in musculoskeletal pain before the intervention, after the intervention, and after eight weeks of specific warm-up exercises for wrestling (P=0.84 in the experimental group and P=0.54 in the control group, respectively). Moreover, the results

Table 3. Chi-square test results to investigate the difference in musculoskeletal knee joint pain in two groups

Desired Joint	Groups	Pre-test				Post-test				Total Observed Frequency	Intragroup P	Inter-Group P
		Observed Frequency		Expected Frequency		Observed Frequency		Expected Frequency				
		Injured	Non-injured	Injured	Non-injured	Injured	Non-injured	Injured	Non-injured			
Knee injury	Experimental	11	14	12.5	12.5	3	22	12.5	12.5	25	0.001	0.04
	Control	9	16	12.5	12.5	9	16	12.5	12.5	25	0.16	
	Total	20	30	25	25	12	38	25	25	50		
Shoulder injury	Experimental	13	12	12.5	12.5	16	9	12.5	12.5	25	0.16	0.39
	Control	14	11	12.5	12.5	13	12	12.5	12.5	25	0.84	
	Total	27	23	25	25	29	21	25	25	50		
Trunk injury	Experimental	15	10	12.5	12.5	13	12	12.5	12.5	25	0.84	0.77
	Control	13	12	12.5	12.5	14	11	12.5	12.5	25	0.54	
	Total	28	22	25	25	27	23	25	25	50		

PHYSICAL TREATMENTS

Table 4. Mann-Whitney U test results to compare injury risk variables between two groups in the post-test

Variables	Mann-Whitney U Test	Z Statistic	P
Right rotational stability	165.00	-3.46	0.001
Left rotational stability	133.00	-3.89	0.001
LESS	43.00	-5.31	0.001
Right shoulder mobility	279.50	-0.74	0.45
Left shoulder mobility	243.50	-1.79	0.07
Lounge on a line	129.50	-4.07	0.001
Deep squat	142.50	-3.74	0.001

PHYSICAL TREATMENTS

Table 5. Test results of the marginal mean of movement patterns and landing error score in the post-test

Variables	Experimental	Control	Standard Error
LESS (number of errors)	3.37	4.10	0.21
Lounge on a line	2.76	1.96	0.08
Deep squat	2.66	1.86	0.09
Right rotational stability	2.26	1.78	0.07
Left rotational stability	2.48	1.67	0.10
Right shoulder mobility	2.15	2.13	0.10
Left shoulder mobility	2.22	2.01	0.08

PHYSICAL TREATMENTS

of the group comparisons demonstrated that no significant difference was observed in musculoskeletal pain in the trunk region during the post-test and after eight weeks of intervention between the two groups (P=0.77).

Since the data related to rotational stability, lunge, deep squat, shoulder mobility, and landing error of wrestlers were not normally distributed, the Mann-Whitney U test was used to compare the differences between the two groups in the post-test. The results indicated significant differences in the variables of deep lunge squat, LESS, and right and left rotational stability after eight weeks of comprehensive exercises between the two groups (P=0.001 for all variables). However, no significant difference was observed in the variable of right and left shoulder mobility in the post-test (P=0.45 and P=0.07, respectively) (Table 4).

The estimated marginal mean revealed that comprehensive warm-up exercises have a greater impact on reducing landing errors in the experimental group (37.3), enhancing lunge performance on a line (2.76), deep squat (2.66), as well as improving the right (26.2) and left (2.48) rotational stability compared to the control group. Furthermore, in terms of right and left shoulder mobility variables, although the differences between the groups were not significant, the experimental group demonstrated a performance increase of 15.2 and 22.2 respectively, which was only marginally higher compared to the control group (Table 5).

Discussion

The present study was conducted to examine how a comprehensive warm-up program impacts FM patterns and errors in young male landers. The results demonstrated a significant improvement in musculoskeletal knee pain among the subjects in the experimental group after eight weeks of training. However, no substantial improvement was observed in musculoskeletal shoulder and trunk pain among the wrestlers following the same duration of training. The results of the Mann-Whitney U test revealed that among the FM pattern variables, no significant difference was observed in the post-test for the right and left shoulder mobility test. However, in the tests for rotatory stability of lunge and deep squat, a significant difference was observed between the two groups in the post-test, following eight weeks of specific warm-up exercises. Additionally, a significant decrease was observed in LESS after eight weeks of performing the exercises. These results are consistent with previous research conducted by Rahimi et al. [34], Bayati et al. [15], and Jahanshahi et al. [35].

In their research titled "comparing the effect of central and neuromuscular stability exercises on the functional screening test of 9-12-year-old boy wrestlers", Rahimi et al. investigated 45 wrestlers in Esfrayen City. The wrestlers underwent the FM screen (FMS) test and were then randomly divided into three groups, control group, experimental group 1, and experimental group 2. The control group engaged in common wrestling exercises, while the experimental group 1 performed neuromuscular exercises and the experimental group 2 performed central stability exercises. These exercises were conducted over six weeks. The overall results demonstrated the impact of central stability and neuromuscular stability exercises on the FMS scores of the wrestlers [34].

One of the reasons why Rahimi's research is consistent with the current research is the inclusion of specific training protocols. In Rahimi's study, the experimental group underwent a single neuromuscular exercise, while the control group engaged in two central stability exercises. In the current research, participants were assigned to perform both central and neuromuscular stability exercises, which included activities focused on balance, agility, and plyometrics.

Bayati et.al examined how standard warm-up exercises in wrestling impact the scores of young wrestlers on the FMS test. The results of their research revealed a significant improvement in scores for the deep squat test, stepping over the obstacle, and lunge test, both immediately after the test and after 12 weeks of performing the exercises, when compared to the pre-test. However, no significant difference was observed between the two groups in terms of shoulder flexibility, active lifting, Swedish foot swimming, and rotational stability tests [15]. These results were consistent with the results of the current research, and one possible reason for this alignment could be the presence of similar exercises in both studies.

The shoulder mobility test assesses the range of motion of the shoulder joint by measuring both unilateral and reciprocal movements. It involves performing internal rotation and adduction in one shoulder, and external rotation and abduction in the other shoulder. This test requires proper mobility of the scapula bone and extension of the spine. Inadequate performance in this test can be attributed to various factors, one of which is an imbalance in the range of motion between external and internal rotation in the shoulder joint [36].

Regarding the impact of the current exercise protocol on subjects' performance, the results of this study indicate that after 8 weeks of exercise, no significant difference was observed in shoulder flexibility between the two groups.

Since exercises 13 to 18 included stretching exercises for the upper limb in the injury prevention program of this research, it is essential to note that the number of sets and the duration of holding each stretch (10 s) were likely low. Moreover, it is crucial to highlight that the flexibility of the rotator cuff muscles in the shoulder is of great importance in the shoulder mobility test. None of the stretching exercises in the research specifically targeted these muscles. As a result, considering the principle of exercise similarity, it can be concluded that the stretching exercises used in the program do not align with the measured test.

During the rotational stability test, it is essential to assess neuromuscular coordination and energy transfer throughout the entire body, specifically from the upper to lower limbs and vice versa. In addition, it is crucial to evaluate the stability of the trunk in multiple planes. Weakness in trunk stability, as well as difficulties in scapula and hip stability, and limitations in knee, thigh, and trunk mobility, are identified as factors contributing to weakness in this test [36]. It is plausible that incorporating central stability exercises into the training protocol addressed these issues and subsequently led to improved outcomes and higher scores during the post-test.

The deep squat test requires coordination, mobility between organs and muscles, central stability, and general body mechanics to control neurovascular movement, as well as stability in the shoulders, shoulder area, and thoracic region of the spine [36]. A person who performs poorly in the deep squat can be attributed to three factors, limitations in upper limb mobility and weakness in the glenohumeral joint, and limitations in lower limb mobility and motor control in the central stability region [36]. In the single-line lunge test, restrictions in the thoracic spine area and reduced mobility in the hips, knees, and ankles can contribute to lower FMS scores. By incorporating exercises like squats and lunges (while maintaining similar movement patterns), along with central stability and balance exercises, improvements can likely be observed in the scores of these mentioned tests.

As previously stated, in most aforementioned tests, the performance and timely activation of the central stabilizing muscles hold significant importance. Confirming the first hypothesis of the research, which suggests that engaging in exercises results in enhanced endurance of the central stability muscles, it is plausible to consider that one of the contributing factors to the improvement in the quality of movement patterns observed in the mentioned tests is the enhanced performance of the central stability muscles. In addition, it is possible to refer to the mechanisms outlined in the closed movement chain when discussing the control of movement. Richardson et al. conducted a study on the sequence of muscle activity during lower limb movements, and their results revealed that before lower limb movements, several central stabilizing muscles remain consistently contracted [37].

Central stability plays a crucial role in enhancing power generation in the thigh and trunk muscles across different movement planes [38]. If the central muscle structure is weak, it can result in reduced effectiveness of accurate movement patterns and the development of compensatory movement patterns [39]. Moreover, proper coordination among these muscles is essential to generate, transfer, and control forces under body movements. Coordinated activation of the central muscles likely facilitates improved movement patterns, postural stability, and enhanced functional efficiency [40]. Hence, the improvement in movement pattern quality observed in the post-test and after eight weeks of exercises can be justified.

One reason why special warm-up exercises in wrestling affect reducing the landing error score of wrestlers between two groups is that the wrestling warm-up program includes exercises like lateral plank exercises, standing on one leg, squats, and jumping exercises. These exercises can improve the activity of certain central stabilizing muscles and thighs, leading to increased neuromuscular control [41]. Another task of the central body area is to aid in preventing incorrect movement patterns and maintaining body alignment and dynamic postural balance during dynamic movements [42].

If the central region of the body functions optimally, the relationship between the length and tension of the agonist and antagonist muscles is maintained. This aspect serves as one of the reasons for enhancing the kinematics of the joints in the lumbar-pelvic-thigh complex and providing maximum stability for lower limb movements [43]. In this study, the lower limb muscles, particularly the external rotators and hip abductors, were not strengthened in isolation. However, the researcher emphasized to the subjects the importance of correct landing techniques during single-leg plyometric and balance exercises, as well as cutting movements. Additionally, the focus was on maintaining proper movement patterns and alignment of the lower limbs during all exercises. These measures may potentially improve abnormal movements of the hip joint, such as excessive approximation and internal rotation of the thigh [44], as well as knee valgus and external rotation of the subjects' tibia [45]. If the exercise is performed incorrectly, the researcher will provide feedback to the wrestler to help them correct their technique. According to Dallinga et al., the use of training and feedback is crucial in accelerating the learning of new movement patterns, including jumping and landing techniques [46]. The research conducted by Dallinga et al. concluded that feedback has a positive impact on modifying landing strategies in men [46]. The reduction in the number of landing errors in the post-test after eight weeks of warm-up exercises can be attributed to the inclusion of strengthening and endurance exercises for the central muscles, along with targeted training and necessary feedback to correct improper movement patterns during the exercise.

Conclusion

As a result, trainers are recommended to incorporate the training protocol from this study into their practice to enhance knee joint landing error and alleviate musculoskeletal pain, in addition to other commonly used training protocols. However, the reduction of musculoskeletal pain in the shoulder and trunk joints of wrestlers is not significantly affected by it. There is a severe lack of research on the optimal and all-encompassing warm-up training protocol specifically tailored for wrestling, indicating the need for additional investigation.

One of the limitations of the research can be attributed to the lack of control and isolation of the control group while performing their exercises. Additionally, the research process cannot account for the psychological and nutritional issues of the subjects, which potentially influenced the results. Lastly, the research was constrained by the small number of subjects.

Ethical Considerations

Compliance with ethical guidelines

This article was approved buy the Sport Sciences Research Institute of Iran (Code: 1873-2209-SSRI REC).

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Conceptualization and study design: Mehdi Babaei Jafari, Amir Hossein Barati, and Mahdieh Akoochakian; Data collection: Mehdi Babaei Jafari and Mohammad Hossein Alizadeh; Data analysis: Mehdi Babaei Jafari.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank all the students and individuals who have assisted in accomplishing this thesis.

References

[1] Powell JR, Boltz AJ, Robison HJ, Morris SN, Collins CL, Chandran A. Epidemiology of injuries in national collegiate athletic association men's wrestling: 2014-2015 through 2018-2019. Journal of Athletic Training. 2021; 56(7):727-33. [DOI:10.4085/1062-6050-429-20] [PMID] [PMCID]

[2] Rahmanian I, Gasemianpuor M, Arzeshmand M, Yarahmadi J. [Investigating incidence, type and causes of injury in elite university wrestlers (Persian)]. Paper presented in: The first national conference of educational sciences and psychology. 13 December 2014; Marvdasht, Iran. [Link]

[3] Akbari Nejad A. [Investigating the prevalence and causes of physical injuries among wrestlers at the national level of the country (freestyle) (Persian)]. Harakat. 2000; 6(6):121-35. [Link]

[4] Yalfani A, Naderi E, Anbarian M, Beglarbegi A. [Comparison of prevalence, type and severity of injuries in professional and amateur wrestlers (Persian)]. Research in Rehabilitation Sciences. 2013; 9(4):12-22. [Link]

[5] Lotfi Hossein Abad G, Gaeini AA. [The effect of active warm-up program content on changes in agility and flexibility (Persian)]. Olympic Quarterly. 2006; 12(2):85-94. [Link]

[6] Fradkin AJ, Gabbe BJ, Cameron PA. Does warming up prevent injury in sport? The evidence from randomised controlled trials? Journal of Science and Medicine in Sport. 2006; 9(3):214-20. [DOI:10.1016/j.jsams.2006.03.026] [PMID]

[7] McKinlay M. Keeping Kids in the game: Neuromuscular training-A new standard for warming up. In: Runner, 2019; 50(1):33-5. [Link]

[8] Grooms DR, Palmer T, Onate JA, Myer GD, Grindstaff T. Soccer-specific warm-up and lower extremity injury rates in collegiate male soccer players. Journal of Athletic Training. 2013; 48(6):782-9. [DOI:10.4085/1062-6050-48.4.08] [PMID] [PMCID]

[9] Padua E, D'Amico AG, Alashram A, Campoli F, Romagnoli C, Lombardo M, et al. Effectiveness of warm-up routine on the ankle injuries prevention in young female basketball players: A randomized controlled trial. Medicina. 2019; 55(10):690. [DOI:10.3390/medicina55100690] [PMID] [PMCID]

[10] Romaratezabala E, Nakamura FY, Castillo D, Gorostegi-Anduaga I, Yanci J. Influence of warm-up duration on physical performance and psychological perceptions in handball players. Research in Sports Medicine. 2018; 26(2):230-43. [DOI:10.1080/15438627.2018.1431536] [PMID]

[11] Bayati R, Shamsi Majelan A, Mirzaei B. The effect of 12 weeks of wrestling+specific warm-up program on dynamic balance in cadet wrestlers. Journal of Sport Biomechanics.2018; 4(1):63-73. [DOI:10.29252/aassjournal.7.1.39]

[12] Polat SC, Cetin E, Yarim I, Bulgay C, Cicioglu HI. Effect of ballistic warm-up on isokinetic strength, balance, agility, flexibility and speed in elite freestyle wrestlers. Age. 2018; 20:2-11. [Link]

[13] Zarei M, Alizadeh MH, Rahnama N, Seif-Barghi T. The effect of FIFA warm-up comprehensive program 11+ on performance and physical fitness of Iranian adolescent male soccer players. Journal of Sport Sciences and Health Research. 2016; 8(1):15-36. [DOI:10.22059/JSMED.2016.58861]

[14] Arı Y. [Effects of different stretching methods on speed, jump, flexibility and upper extremity performance in wrestlers (Slovenian)]. Kinesiologia Slovenica. 2021. 27(1):162-76. [DOI:10.52165/kinsi.27.1.162-176]

[15] Bayati R, Shamsi Majelan A, Mirzaei B, Barbas I. The effect of 12 weeks of wrestling+warm-up program on functional movement screen scores in cadet wrestlers. Annals of Applied Sport Science. 2019; 7(1):39-47. [DOI:10.29252/aassjournal.7.1.39]

[16] Barbas I, Gioftsidou A, Gkrekidis T, Makri E, Malliou P, Beneka A. [The effects of wrestling+ injury prevention program on lower limbs strength and balance (Russian)]. Paper presented in: Extrability as a phenomenon of inclusive culture: The formation of an inclusive culture in organizations. 2020 December 12; Yekaterinburg, Russia. [Link]

[17] Demirci N, Demi PT. The effect of static and dynamic warm-up protocols on fitness component and body fat percentage of athletes in different branches. International Journal of Disabilities Sports and Health Sciences. 2018. 1(1):13-22. [DOI:10.33438/ijdshs.436899]

[18] Eroğlu, Ş., Acute Effects of post-activation potentiation on explosive strength performance in wrestling athletes. Pakistan Journal of Medical & Health Sciences. 2022; 16(5):532. [DOI:10.53350/pjmhs22165532]

[19] Tatlici A, Lima Y, Çiftçi B, Aktas S, Badak T. The effect of 8-weeks wrestling training on unilateral muscle imbalances. Physical Education of Students. 2021; 25(4):205-11. [DOI:10.15561/20755279.2021.0401]

[20] Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. Journal of Athletic Training. 2007; 42(1):42-6. [PMID] [PMCID]

[21] Yun YD, Shin HJ, Kim SJ, Lim SW, Choi SJ, Seo DK, et al. The effects of resistance exercise and balance exercise on proprioception and WOMAC index of patients with degenerative knee osteoarthritis. Journal of International Academy of Physical Therapy Research. 2010; 1(2):169-75. [Link]

[22] Michell TB, Ross SE, Blackburn JT, Hirth CJ, Guskiewicz KM. Functional balance training, with or without exercise sandals, for subjects with stable or unstable ankles. Journal of Athletic Training. 2006; 41(4):393-8. [PMID] [PMCID]

[23] Pánics G, Tállay A, Pavlik A, Berkes I. Effect of proprioception training on knee joint position sense in female team handball players. British Journal of Sports Medicine. 2008; 42(6):472-6. [DOI:10.1136/bjsm.2008.046516] [PMID]

[24] Padua DA, Marshall SW, Boling MC, Thigpen CA, Garrett WE Jr, Beutler AI. The landing error scoring system (LESS) is a valid and reliable clinical assessment tool of jump-landing biomechanics: The JUMP-ACL study. The American Journal of Sports Medicine. 2009; 37(10):1996-2002. [DOI:10.1177/0363546509343200] [PMID]

[25] Hanzlíková I, Hébert-Losier K. Is the landing error scoring system reliable and valid? A systematic review. Sports Health. 2020; 12(2):181-8. [DOI:10.1177/1941738119886593] [PMID] [PMCID]

[26] Shultz SJ, Schmitz RJ, Nguyen AD, Chaudhari AM, Padua DA, McLean SG, et al. ACL research retreat V: An update on ACL injury risk and prevention, March 25-27, 2010, Greensboro, NC. Journal of Athletic Training. 2010; 45(5):499-508. [DOI:10.4085/1062-6050-45.5.499] [PMID] [PMCID]

[27] Frost DM, Beach TA, Callaghan JP, McGill SM. Using the functional movement screen™ to evaluate the effectiveness of training. Journal of Strength and Conditioning Research. 2012; 26(6):1620-30. [DOI:10.1519/JSC.0b013e318234ec59] [PMID]

[28] Beardsley C, Contreras B. The functional movement screen: A review. Strength & Conditioning Journal. 2014; 36(5):72-80. [DOI:10.1519/SSC.0000000000000074]

[29] Budnar Jr RG, Birdwell R, Moody C, Hill DW, Duplanty AA, Jackson AW, et al. Functional movement screentm scores in collegiate track and field athletes in relation to injury risk and performance. International Journal of Exercise Science. 2013; 2(5):68. [Link]

[30] Cook G. Movement: Functional movement systems: Screening, assessment, corrective strategies. Aptos: On Target Publication; 2011. [Link]

[31] Mokhtarinia H, Shafiee A, Pashmdarfard M. [Translation and localization of the Extended Nordic Musculoskeletal Questionnaire and the evaluation of the face validity and test-retest reliability of its Persian version (Persian)]. Iran Journal of Ergonomics. 2015; 3(3):21-9. [Link]

[32] Health, Division of Biomedical, and Behavioral Science. Work practices guide for manual lifting. Washington: United States Department of Health and Human Services; 1981. [Link]

[33] Turner E, Passmore J. Ethical dilemmas and tricky decisions: A global perspective of coaching supervisors' practices in coach ethical decision-making. International Journal of Evidence Based Coaching and Mentoring. 2018; 16(1):126-42. [Link]

[34] Rahimi M, Elmi S, Piry H. [The comparison of the effect of core stability and neuromuscular exercises on functional movement screening of male wrestlers aged 9 to 12 years (Persian)]. Studies in Sport Medicine. 2021; 13(29):133-56. [DOI:10.22089/smj.2021.10370.1488]

[35] Jahanshahi M, Nasermelli MH, Baker RL, Rabiei P, Moen M, Fredericson M. Comparing functional motor control exercises with therapeutic exercise in wrestlers with iliotibial band syndrome. Journal of Sport Rehabilitation. 2022; 31(8):1006-15. [DOI:10.1123/jsr.2020-0541]

[36] Cook G, Burton L, Hoogenboom B. Pre-participation screening: the use of fundamental movements as an assessment of function - part 1. North American Journal of Sports Physical Therapy. 2006; 1(2):62-72. [PMID] [PMCID]

[37] Richardson C, Hodges P, Hides JA. Manipulation association of chartered physiotherapists. therapeutic exercise for lumbopelvic stabilization: A motor control approach for the treatment and prevention of low back pain. London: Churchill Livingstone; 2004. [Link]

[38] Robinson RL, Nee RJ. Analysis of hip strength in females seeking physical therapy treatment for unilateral patellofemoral pain syndrome. Journal of Orthopaedic and Sports Physical Therapy. 2007; 37(5):232-8. [DOI:10.2519/jospt.2007.2439] [PMID]

[39] Fredericson M, Moore T. Muscular balance, core stability, and injury prevention for middle- and long-distance runners. Physical Medicine and Rehabilitation Clinics of North America. 2005; 16(3):669-89. [DOI:10.1016/j.pmr.2005.03.001] [PMID]

[40] Kavcic N, Grenier S, McGill SM. Quantifying tissue loads and spine stability while performing commonly prescribed low back stabilization exercises. Spine. 2004; 29(20):2319-29. [DOI:10.1097/01.brs.0000142222.62203.67] [PMID]

[41] Tsukagoshi T, Shima Y, Nakase J, Goshima K, Takahashi R, Aiba T, et al. Relationship between core strength and balance ability in high school female handball and basketball players. British Journal of Sports Medicine, 2011. 45(4):378. [DOI:10.1136/bjsm.2011.084038.191]

[42] Thijs Y, Van Tiggelen D, Willems T, De Clercq D, Witvrouw E. Relationship between hip strength and frontal plane posture of the knee during a forward lunge. British Journal of Sports Medicine. 2007; 41(11):723-7. [DOI:10.1136/bjsm.2007.037374] [PMID] [PMCID]

[43] Lederman E. The myth of core stability. Journal of Bodywork and Movement Therapies. 2010; 14(1):84-98. [DOI:10.1016/j.jbmt.2009.08.001] [PMID]

[44] Mascal CL, Landel R, Powers C. Management of patellofemoral pain targeting hip, pelvis, and trunk muscle function: 2 case reports. The Journal of Orthopaedic and Sports Physical Therapy. 2003; 33(11):647-60. [DOI:10.2519/jospt.2003.33.11.647] [PMID]

[45] Piva SR, Goodnite EA, Childs JD. Strength around the hip and flexibility of soft tissues in individuals with and without patellofemoral pain syndrome. The Journal of Orthopaedic and Sports Physical Therapy. 2005; 35(12):793-801. [DOI:10.2519/jospt.2005.35.12.793] [PMID]

[46] Dallinga J, Benjaminse A, Gokeler A, Cortes N, Otten E, Lemmink K. Innovative video feedback on jump landing improves landing technique in males. International Journal of Sports Medicine. 2017; 38(2):150-8. [DOI:10.1055/s-0042-106298] [PMID]

This Page Intentionally Left Blank