# Research Paper: The Effect of Corrective Feedback Exercise on Knee Kinematics and EMG of Lower Limbs of Female Wushu Players

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## ABSTRACT

**Introduction:** Recent studies have examined the risk factors associated with lower limb injuries. This study aimed to explore the effect of 12 sessions of feedback corrective exercises on the kinematic indicators of the knee and the Electromyography Activity (EMG) of the muscles of the lower limbs of female wushu players. The present study has a quasi-experimental design with a pre-test/post-test design and a control group.

**Materials and Methods:** In this study, 16 female wushu players were selected by the available sampling method and placed in two groups of exercise and control. The exercise group performed feedback correction exercises for 12 sessions. Before and after the knee varus exercises, we measured, pelvic drop, and EMG of the lower limb muscles of both groups in the SLS movement. The independent two-sample t-test was used to examine intergroup differences and the two-group correlated t-test was used to compare intra group sizes. To analyze the statistical data, SPSS V. 23 was used ($P \leq 0.05$)

**Results:** The results showed a significant difference in knee varus between the experiment group and the control group in the pre-test and there was a significant difference between the pelvic drop in the pre-test and post-test of the experiment group compared with the control. The angle of the knee varus in the exercise group showed a significant difference with the control group. The EMG results of the muscles in the pre-test and post-test were significantly different.

**Conclusion:** Based on the findings of the present study, the feedback correction exercise may improve motion control in wushu players. It also improved neuromuscular weakness in the subjects. According to the results and based on less muscle activity during movements, this exercise will reduce fatigue and the risk of injury.

## 1. Introduction

The knee joint plays a key role in supporting the body and transferring its weight during static and dynamic activities [1]. Since the foot is the body's contact area with the ground, structural deviations, especially in the knee, increase the risk of injury in athletes and may prevent people from participating in activities [2].

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The knee varus is one of the most common deformities of the lower limb where the knees are spaced apart [3]. Research shows that the knee varus on the one hand causes the destruction of the articular cartilage in the inner part of the articular joint and on the other hand, it causes osteoarthritis [4].

The slightest biomechanical change in the direction of the lower limbs affects muscle function and posture control [5]. Alterations in the correct direction of the lower limbs can change in muscle function and decrease its performance [4].

Feedback training is a kind of motion-dependent sensory data that provides information about movement [6]. Based on this information, it is possible to change and modify the movement.

Feedback is a kind of information that is recorded when the person is moving and is received in various forms such as visual, auditory, and tactile. In most studies, feedback is given instantly in the form of biomechanical motion information (using display motion analysis systems) so that the person voluntarily corrects his or her movements [7]. Researchers have used these exercises to correct movement patterns and reduce the risk of injury or correct musculoskeletal problems [8].

Implementing motion and skill patterns during practice and long history can cause negative adaptations in the structure of the skeletal system, including the knee [9]. A lot of pressure exerts on the athlete's knee and these pressures can cause abnormalities in a long time. When a person is in good physical condition, the direction of her body is adjusted so that the pressure on different parts of the body is minimized. On the other hand, when a person has an unfavorable physical condition, due to the high pressure on some parts of the body compared to other parts, the posture of her or his body will be out of balance [9].

These constant pressures, even if relatively low, cause non-anatomical adaptation and limitations during sports activities. Also, knee abnormalities lead to secondary disorders in other parts of the lower extremities [10].

There is not enough information in wushu sport about abnormalities that may result in injury, but research shows that disorders of the natural direction in the joints such as the knee and ankle leads to injuries such as osteoarthritis of the knee joint and anterior knee pain [11].

Biomechanically deviation of knee varus applies inward or outward pressure to the knee joint more than the other side. Also, in intense and repetitive activities in which the quadriceps muscle is involved, the vector of the incoming forces go out of the natural direction. This abnormality destroys the tissues of the limbs and can lead to lower limb injury [12].

Sports injuries often occur in moving forward, jumping, or cutting movements. Particularly, cut movements are necessary for successful participation in most sports activities. Lateral cut movement is done when the athlete steps to sideway to change direction quickly, which is referred to as cutting [13].

Side jump will usually be accompanied by a complete knee extension and a large internal or external rotation of the tibia. The rupture of the ankle ligaments often occurs during this movement [14].

Lateral cut movement is commonly used to assess the kinematics and kinetics of the knee joint in the presence of anterior cruciate ligament injury. The amount of the least required acceleration in lateral cutting depends on the angle and speed at which this maneuver is performed. To reduce speed and change direction during the jump, proper adjustments are necessary throughout the body which is determined by the speed and position of the body, and in particular the position of the center of mass relative to the center of pressure, the force of the earth's reaction, and the impact of the earth's reaction force [15]. No study on preventing injury in athletes has ever used corrective exercises with feedback to improve the dynamics of the lower limbs or improve muscle activity during movement was done to non-injured people and healthy people with the risk of lower limb injury agents. Therefore, this study aimed to investigate the effect of 12 sessions of feedback corrective exercises on the knee varus, pelvic prolapse rate, and Electromyographic (EMG) activity of the muscles of the lower limbs of female wushu players.

## 2. Materials and Methods

This was a quasi-experimental study with a pre-test/post-test design and a control group. The samples were selected according to inclusion and exclusion criteria after the screening test. The study population was the players of Isfahan City, Iran female wushu team. Out of them, 16 female wushu players were included in the study: 8 people in the experiment group and 8 in the control group.

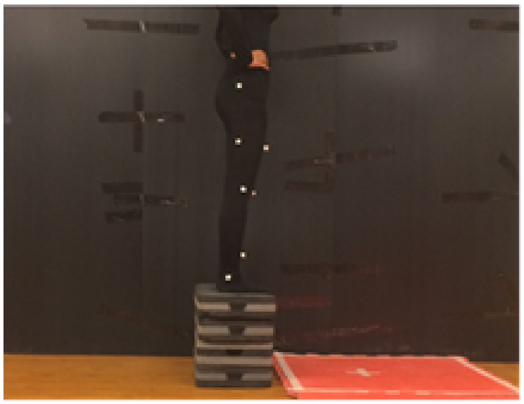

Figure 1. Landmarks from the side view

Figure 2. Landmark from the front view

The inclusion criteria included a 3-year membership in the wushu team of Isfahan Province for the experiment group, regular physical exercise for at least 4 sessions a week for 1 hour, homogeneity of the two groups of experiment and control in terms of height, weight, and body mass index. The exclusion criteria included having a history of lower limb surgery and developing pain and injury during exercise for the experiment group. In the beginning, in a training session, the research objectives and the necessary training for familiarizing and using the correct methods of implementing the research were taught to the participants. In the next step, a list of all subjects was prepared. After signing the consent form, the participants completed a personal profile questionnaire, including height, weight, body mass index, dynamic balance similarity, and appropriate knee size varus. Then, putting the electrodes and kinematic operation of the knee and pelvic plane was performed on the front page by the high-speed camera (HZ300) of the Casio model before and after the exercise on the desired points to record the data.

After putting the electrodes, the control group was asked to take a few steps in the laboratory environment so that the possible limitations caused by the electrodes be identified. The screening included a Single-Leg Landing (SLL) test; subjects performed the single-leg Scott landing move three times on the dominant foot at the desired speed and drop the pelvic to such an extent that the subject could maintain her balance.

Finally, the motion was recorded by the Casio's high-speed camera (HZ300), and the angle of the pelvis and the knee varus were recorded in this movement by the software of angle measurement.

Figure 3. How to land a single leg squat


Figure 4. Electromyography of wave Quest M16P model, 16 channels

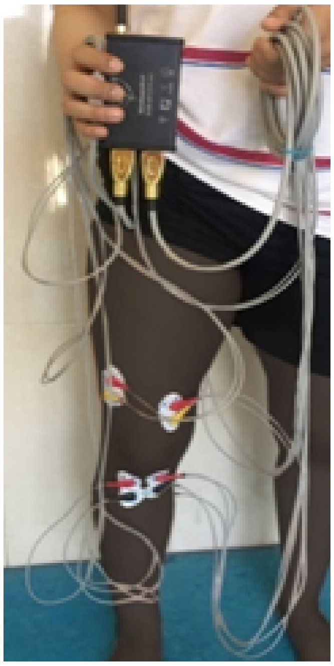

**Figure 5.** Muscle electromyography JMR

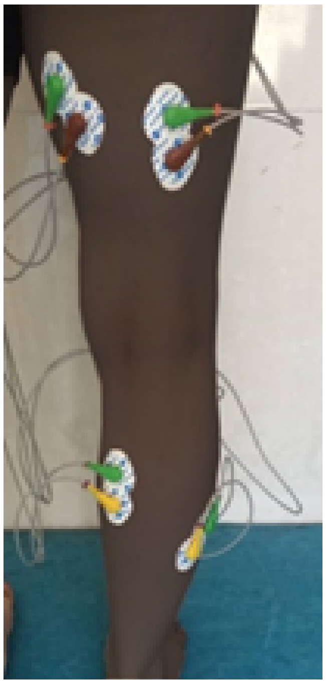

**Figure 6.** Running test by receiving verbal and visual feedback JMR

## Information collection method

In this study, after collecting basic information, we described the method of warming up and test materials, the correct way to run on the treadmill, considering the movement of the pelvis and knees and the correct way of looking at the person, and the correct way of placing the knees (do not lean in). After explaining the steps, the subjects performed 15 minutes of running on a treadmill for 4 sessions at a speed that they felt comfortable with. The subjects used verbal feedback during these sessions. They also used their visual feedback using a mirror in front of the treadmill. Afterward, from the fourth to the eighth session, the running time was 25 minutes and they had verbal and visual feedback. From sessions 8 to 12, the running time was 30 minutes, and the verbal feedback provided to the subjects was canceled to focus on visual feedback.

Knee varus was measured by colic. Then, the landmarks were attached to the desired muscles (internal and direct extensor muscles, twin muscles [internal and external], hamstring muscles [double and semi-vertebral muscles], and buttock muscles [large and middle]) and the location of the EMG electrodes on the muscles of the lower limbs of the dominant leg was considered according to the source (Seniam).

Knee varus and pelvic drop on the frontal and sagittal planes were recorded by the high-speed camera (HZ300, Casio model) at the pre-test and post-test on target points. After completing the electrode placement process to calculate RMS and MVC muscle activity, the experiment group was asked to take a few steps in the laboratory environment.

This way, possible limitations through the electrodes that may have been present, were identified. RMS and MVC neuromuscular activities were recorded by a 16-channel electromyography machine (Wave quest M16P manufactured by Pars Bioengineering Engineers Company).

The obtained data were analyzed in SPSS version 23, and descriptive and inferential analyses were performed. The mean and standard deviation were used to present the subjects' data. The Kolmogorov-Smirnov test was used to determine the normal distribution of data. The Levene's test was used to compare the data variance, the independent t-test was used to examine intergroup differences, and the correlated t-test was used to compare intragroup sizes. A significant level for alpha was considered to be less than 0.05.

## 3. Results

Table 1 shows the morphological features of the subjects of the study.

According to the significant levels reported in the above Table 2 sessions of feedback correction exercises have a significant effect on knee kinematics, knee varus, and EMG activity of the muscles of the lower extremities of women practicing wushu (P=0.04). In terms of between-group differences, the results of the independent t-test showed a significant difference between the mean of the pelvic drop of the two groups (P=0.003).

According to Table 3, between the results of EMG of the muscles of the lower extremities of the pre-test and the EMG of the muscles of the lower limbs after the test in the experiment group, the significance level is less than 0.05. In other words, there is a significant difference between the EMG of the muscles of the lower limbs before the test and after the test. Therefore, 12 sessions of feedback correction exercises have a significant effect on the EMG activity of the muscles of the lower limbs of women practicing wushu.

According to Table 4, the rate of the pelvic drop from pre-test to that in the post-test is significant in the experiment group. In other words, there is a significant difference between the two groups in the pre-test pelvic drop and post-test pelvic drop. Besides, knee varus is significant from pre-test to post-test in the experiment group. In other words, there is a significant difference between the two groups in pre-test knee varus and post-test knee varus.

According to the significant levels reported in the above tables, 12 sessions of feedback corrective exercises have a positive and significant effect on knee varus, pelvic drop, and EMG activity of the muscles of the lower limbs of women wushu players. In terms of between-group differences, the results of the independent t-test showed a significant difference between the two groups in the mean values of knee varus, pelvic drop, and muscle activity of the subjects.

**Table 1.** Features of body assessment of research subjects

| Index | Groups | Mean±SD |
|---|---|---|
| Age (y) | Experiment | 16.91±1.98 |
| | Control | 17.20±1.13 |
| Height (cm) | Experiment | 162.83±5.43 |
| | Control | 164.51±4.42 |
| Weight (kg) | Experiment | 58.13±8.16 |
| | Control | 56.43±6.45 |
| Body mass index(kg/m2) | Experiment | 22.48±7.3 |
| | Control | 23.5±3.81 |
| Sport activity History (y) | Experiment | 3.51±1.22 |
| | Control | 2.60±2.00 |

JMR

**Table 2.** Results of the independent t-test for knee kinematic

| Variable | Group | Means Difference | SD | t | df | P |
|---|---|---|---|---|---|---|
| Knee varus | Experiment<br>Control | 0.725 | 0.235 | 1.761 | 14 | 0.04 |
| Pelvis drop | Experiment<br>Control | -4.62 | 1.03 | -2.246 | 14 | 0.003 |

JMR

**Table 3.** Results of the paired samples t-test for muscles electromyography

| Group | Muscle | Mean±SD | t | df | Sig. |
|---|---|---|---|---|---|
| Experiment | Pre-test vastus medialis<br>Post-test vastus medialis | -0.406±0.438 | -2.627 | 7 | 0.034 |
| Control | Pre-test vastus medialis<br>Post-test vastus medialis | -0.364±0.307 | -3.346 | 7 | 0.012 |
| Experiment | Pre-test semitendinosus<br>Post-test semitendinosus | -0.344±0.472 | -1.062 | 7 | 0.078 |
| Control | Pre-test semitendinosus<br>Post-test semitendinosus | -0.244±0.277 | -2.499 | 7 | 0.041 |
| Experiment | Pre-test gluteus maximus<br>Post-test gluteus maximus | -0.163±0.547 | -0.842 | 7 | 0.427 |
| Control | Pre-test gluteus maximus<br>Post-test gluteus maximus | 0.033±0.412 | 0.232 | 7 | 0.832 |
| Experiment | Pre-test gastrocnemius lateral head<br>Post-test gastrocnemius lateral head | -0.255±0.324 | -2.231 | 7 | 0.061 |
| Control | Pre-test gastrocnemius lateral head<br>Post-test gastrocnemius lateral head | -0.404±0.405 | -2.818 | 7 | 0.026 |
| Experiment | Pre-test vastus lateralis<br>Post-test vastus lateralis | -0.227±0.458 | -1.402 | 7 | 0.204 |
| Control | Pre-test vastus lateralis<br>Post-test vastus lateralis | -0.0416±0.378 | -0.31 | 7 | 0.765 |
| Experiment | Pre-test biceps femoris<br>Post-test biceps femoris | 0.16433±0.40311 | 1.153 | 7 | 0.287 |
| Control | Pre-test biceps femoris<br>Post-test biceps femoris | 0.327±0.312 | 2.967 | 7 | 0.021 |
| Experiment | Pre-test gluteus medius<br>Post-test gluteus medius | 0.062±0.392 | 0.447 | 7 | 0.668 |
| Control | Pre-test gluteus medius<br>Post-test gluteus medius | 0.243±0.482 | 1.425 | 7 | 0.197 |
| Experiment | Pre-test gastrocnemius medial head<br>Post-test gastrocnemius medial head | 0.182±0.486 | 1.063 | 7 | 0.323 |
| Control | Pre-test gastrocnemius medial head<br>Post-test gastrocnemius medial head | 0.236±0.459 | 1.452 | 7 | 0.19 |

JMR

**Table 4.** Results of paired samples t-test for knee kinematic variables

| Group | Variable | Mean±SD | t | df | Sig. |
|---|---|---|---|---|---|
| Experiment | Knee varus | 4.093±1.146 | 1.421 | 7 | 0.006 |
| Control | Knee varus | 1.113±0.012 | 0.242 | 7 | 0.198 |
| Experiment | Pelvis drop | -4.626±1.507 | -2.376 | 7 | 0.049 |
| Control | Pelvis drop | -4.244±1.050 | -1.327 | 7 | 0.226 |

JMR

## 4. Discussion

In this study, the kinematic indicators of the knee and pelvis and the activity of some lower limb muscles were examined. Then, the effect of a feedback correction exercise on changes in these parameters was investigated. Regarding kinematic variables, the results of the initial comparison showed that the two groups of experiment and control differed only in terms of knee varus and the experiment group showed about 3 degrees more varus.

Holman et al. did not report a significant difference between lower limb muscle activity during the Scott-test. Their results are inconsistent with the present study because, in the present study, the experiment group had less muscle activity after 12 sessions of feedback correction exercises after the single-leg Scott-test, which showed significant changes in this study [16].

Regarding the middle serine muscle, due to the role of muscle in controlling pelvic movements in the frontal plane and the difference in pelvic drop between the two groups, the results seem logical that there is a difference between muscle activity. The gluteus medius muscle is the muscle that stabilizes the pelvis and abducts the thigh. The activity of this muscle increases as the task becomes more difficult. The center of gravity of the body, while standing on one foot, is placed inside the surface of the reliance, and the weight of the body creates an external and adducting torque, which is the destructive force of stability.

This force adducts the thigh and lowers the opposite pelvis and knee to the varus. Since there is an interruption between the onset of muscle electrical activity and the creation of force in it, the adductor muscles must be activated before the destructive force of stability to be effective. In this way, the central nervous system predicts the time of this disruptive force and contracts these muscles with anticipatory muscle strategies [16].

Patrick et al. reported no change in landing kinematics after the fatigue of the thigh abductor muscles. But the delay time of the gluteus medius muscles increased. Since in coxsackie valga, the torque arm of the thigh muscles is reduced, these muscles need to be more active to compensate and hold the pelvis horizontally while bearing weight. As these muscles become overactive, the pressure on the femoral head increases, making the person more prone to osteoarthritis of the hip. When a muscle is weak, the central nervous system compensates for this weakness by increasing the level of neural stimulation (neural drive) to achieve similar strength, resulting in increased muscle activity [17].

Regarding the quadriceps muscle, there were differences between internal and external oblique muscles. The findings of Sigward et al. (2006) are inconsistent with the present study. They showed that in the accelerated reduction phase, despite the lack of kinematic differences in the knee, women had more torque on the frontal knee plane and quadriceps also showed more activity. Therefore, changes in neuromuscular control (muscle recall) may alter the kinetics of the joints without altering the knee kinematics, which has not been evaluated here. Because of the short duration of these exercises and the insufficient time for hypertrophy and increased muscle strength, it seems that the mechanism of action of these exercises, instead of an increase in strength, involves a change in neuromuscular control [18]. Zeller et al. reported that women activated the rectus femoris muscle in both maximal isometric voluntary contraction and on one leg during the Scott-test more than men. These researchers said that during the lowering phase in the Scott-test, the rectus femoris muscle is activated eccentrically, since women use rectus femoris muscles to control the knee on the transverse plane due to neuromuscular control defects, they activate this muscle more, but still lose control [19]. Dyer et al. reported more rectal femoris muscle activity in women than in men. The reason for this result was that women have less power, because the lower the muscle strength, the more active the person must be to perform the task properly [20]. Probably the changes observed in the present study are the result of motion learning through the function of mirror neurons. Mirror neurons are a special group of neurons that are activated when they observe a movement and cause observational learning. Therefore, the use of mirrors to provide feedback can probably activate mirror neurons, stimulate motion learning, and alter neuromuscular function during exercise, which has also been transferred to squats on one leg. Rabi'izadeh et al. reported a significant difference in the parameter of angular position in the sagittal and frontal planes in the three joints of the thigh, knee, and ankle. In this study, the results showed that these exercises had a significant change in the angle of the knee and pelvic drop, as well as improving the angle of the hip joint in the angular positions of the sagittal and frontal planes with these exercises [21]. The results of DJ Robertson et al. (2018) study are similar to the present study. Previous studies have shown increasing intermediate pressures at the level of the knee varus. Choosing the right treatment for knee non-alignment should be a priority. In this study, which was based on rehabilitation strategies to improve the kinematic knee of children with knee varus in walking and according to the women with knee varus, feedback correctional exercises were performed to prevent the progression and help to improve the deformity of the knee varus and knee kinematics and pelvic drop. The obtained results are consistent with this study results [22]. Cody J. Brockato (2018) in a step-test study reported a connection between the heel of the foot and the ground and the middle position during running. In the present study, during exercise with wushu players with knee varus, the greatest focus was on how to perform knee and pelvic movements correctly so the results of the 12 sessions of feedback correction exercises had a significant effect on the EMG activity of the muscles of the lower limbs of female wushu players. Therefore, the results of Cody J. Broccato are the same as ours [23]. In a study examining the effect of slow kneeling on the kinematics of running, Poly Tire et al. reported that the use of tape at the beginning of running affected the hip joint and the curvature angles of the knee (such as jumping time).

According to the results of our study, 12 sessions of feedback correction exercises have a significant effect on the EMG of the muscles of the lower limbs of female wushu players. Therefore, the results are in line with the results of other people [24]. The results of Rahmatian et al. [25] study on the control of the position of the ankle and knee joints based on electromyography signals are consistent with the results of this study on knee varus. In a study, Nyland et al. (2002) showed that people with normal knees had an average anterior-posterior displacement of COPP less than the average anterior-posterior displacement of COPP. The present study, which reduced the angle of the knee varus and also kept the direction better and increased the balance on one leg, is consistent [26]. According to the one leg Scott movement on both the sagittal and frontal planes performed by women wushu players after learning how to walk and run correctly, which had a significant effect this research can be considered in line with Shirvanipour and Sadeghi (2016) [27]. Samaei et al. (2012) examined the effect of knee varus on dynamic and static postural stability. The results of this study showed that people with knee varus have weaker dynamic and static stability in the internal-external direction. But the dynamic and static stability of these individuals did not differ from those of normal individuals in the anterior-posterior direction. Besides, people with a braced knee were significantly more likely to be at risk than normal people. They concluded that knee varus abnormalities could increase external-internal postural oscillation [28]. According to Samaei et al. research and our results, they taught the subjects of the research the correct pattern of keeping the direction while walking and running and at the same time they can have a special focus on knee movement and pelvic drop. The results showed a decrease in the knee varus and a decrease in the pelvis drop. The present results can be considered in line with Samaei et al. [28] results. According to the research of Hebert Lozier et al. (2019) in line with neuromuscular changes and the present study, feedback correction exercises caused significant changes in neuromuscular activity of the lower limbs. These studies are in line with each other [29]. Yelfani and Raisi (2016) showed in a study that reinforcement of the twin muscles in eccentric contractions and reinforcement of peroneus longus muscle for maintaining the level of activity in fatigue can be useful in preventing injuries caused by inappropriate landing in female wushu players and obtaining their

optimal function. Therefore, feedback correction exercises in the present study on female wushu players reduced the neuromuscular activity of the gluteus maximus and vastus medialis and twin muscles. Also, it had a significant effect on reducing muscle fatigue, which is consistent with this study [30]. Holman et al. (2014) reported that the angle of thigh abduction, large buttock electromyography, and thigh abduction power was associated with the frontal valgus of the knee. They concluded that using a large buttock may be associated with a decrease in knee valgus in women during landing. They also suggested that moderate buttock strength may be associated with increased knee valgus. In the present study, it was found that learning how to walk and run correctly can reduce the neuromuscular activity of the lower limbs and at the same time reduce the angle of the knee varus. This result is in line with the mentioned research [16]. Rostami (2017) examined and compared the effects of fatigue on electromyographic, kinetic, and functional indicators of the knee joint in athletes with a history of Anterior Cruciate Ligament (ACL) rupture with and without reconstructive surgery. According to the research results, fatigue seems to create adaptations in the neuromuscular and biomechanical strategies used by athletes with a history of ACL injury. In general, athletes with a history of ACL rupture are more likely to use active muscles and protective mechanisms (reducing ground reaction forces) to stabilize the knee joint. Therefore, the present study is in line with this research [31].

In the present study, it appears that knee varus increases the neuromuscular activity of the lower extremities. It even has a great effect on how the muscles move. Therefore, to control the movement and decrease the neuromuscular activity of the lower limbs and to improve this abnormality in the above-researched subjects (female wushu players), running feedback exercises were performed on the treadmill in front of the mirror, in addition to proper control of the kinematic knee. It taught how to improve SLL jumping and reduce neuromuscular activity and these exercises showed a significant effect.

## 5. Conclusion

The findings show some form of neuromuscular weakness which improved to some extent following the exercise because activity and less muscle energy to perform a particular movement with the same kinematics indicate improved mobility or learning. Before and after 12 training sessions, muscle activity (RMS) of the great buttock muscles, middle buttock, twins (internal and external), internal tendon, external tendon, dorsiflexion, pelvic angle, knee varus, and knee kinematic at the end of the SLS squat single movement of the leg was recorded. It seems that the feedback correction exercise against the mirror is responsible for this learning by activating the mirror neurons. On the other hand, less muscular activity in movements leads to reduced fatigue and since many injuries are associated with fatigue, by reducing fatigue, the risk of injury is likely to decrease. Also, these exercises caused positive changes in the knee varus and the neuromuscular activity of the lower limbs. Based on the findings of the present study, the feedback correction exercise has improved the motion control of the wushu players, and this issue was associated with improving neuromuscular weakness in the subjects. According to the results (less muscle activity in performing movements), this exercise will reduce fatigue and possibly reduce the risk of injury. Feedback correction exercises can improve knee varus.

## Ethical Considerations

### Compliance with ethical guidelines

All ethical principles were observed in this article.

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### Authors contributions

Conceptualization, methodology, writing, review, and editing: All authors; Investigation, writing the original draft: Abdolrasoul Daneshjoo; Resources: Abdolrasoul Daneshjoo, Fahimeh Rashidi; Supervision: Abdolrasoul Daneshjoo.

### Conflict of interest

The authors declared no conflict of interest.

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