Comparing Isometric Strength of Selected Lower Extremity Muscles in Hyperpronated Foot With Healthy Male Athletes

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ABSTRACT

Purpose: The proper neuromuscular recruitment patterns of hip and knee muscles are essential for dynamic stabilization of the knee. According to the kinematic chain, weakness in the performance of one motor segment can affect other segments of motion. Thus, the aim of this study was to compare the isometric strength of selected muscles of lower extremities in the hyperpronated foot with the same muscles in healthy male athletes.

Materials and methods: The present study is descriptive and correlational. Forty male athletes in two groups of hyperpronated foot and healthy male athletes (20 in each group) participated in this study. Pronated foot was examined by navicular drop and isometric strength of selected muscles in lower extremities was examined by Manual Muscle Test system (MMT). Then, the ratio of isometric strength of each muscle to body weight was compared between two groups. Data were analyzed by SPSS software, version 20 and the independent t test was used to compare the variables between the two groups.

Results: The results showed that isometric strength of muscles, hip abductors (P = .002), external rotators of hip (P = .007), and quadriceps muscles (P = .031) have decreased significantly in the the group of hyperpronated foot.

Conclusion: The hyperpronated foot changes the muscle strength of lower extremity. These changes may be due to neuromuscular compensation because of the changes in the medial longitudinal arch. More research is needed to determine whether these changes in muscle strength are related to lower extremity injury.

1. Introduction

Hyperpronated foot is defined as the structural change of foot with lower longitudinal arch. In this situation, talus moves to pronation and forefoot to abduction [1]. The change in foot biomechanics alters the activity of lower extremity and trunk muscles [2] and affects pelvic alignment [3]. These lower extremity abnormalities may lead to the development of scoliosis or pathological lumbar conditions [3, 4]. Structure and function of the ankle and foot to absorb force and pressure have a large impact on upper parts of the lower extremities [5]. They are the first components that decrease the ground reaction force during heel contact phase and prevents the transfer of a large part of the pressure to other components of motor chain [6]. Because the body's musculoskeletal system is an interconnected series, any change in every sector can affect other parts and cause pain and other disorders.

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In the hyperpronated foot, the abnormality due to rotational force transfers from the subtalar joint to tibia joint and leads to internal rotation of the tibia and knee flexion [7]. These changes in the mechanics of lower extremity result in repeated and improper force, which can lead to disorders such as iliotibial band syndrome, patellofemoral joint dysfunction and tensile stresses to the ligaments of the knee joint [8]. The pronation is coupled with internal rotation of the tibia and femur that leads to changes in the Q angle of knee. This change affects the mechanical condition of joint and predisposes it to the musculoskeletal disorders [7]. Following this process, the balance is broken between the forces of the muscles to the patella, which sliding in the femoral groove during extension movements and knee flexion is accompanied with a high pressure that eventually appears as pain and musculoskeletal disorders [9].

Hip musculature plays a significant role in the kinetic chain, particularly in motor activity. The activity of these muscles is essential to maintain the performance of lower extremities as well as trunk and pelvic stability during closed chain activities [10-12]. The muscles of this part act as a link in the kinetic chain and transfer forces from the lower extremities to the pelvic and spine and vice versa [10-12]. Weakness of the hip muscles is related to lower extremity injury, lower back pain, and patella femoral pain in athletes [12-14]. The hip muscle weakness as a risk factor is taken into consideration for anterior knee pain iliotibial band syndrome, leg injury like shin splint, particularly in intense, and repetitive movements [13-15]. Assessment of hip muscle strength may play an important role in injury prevention and rehabilitation in athletes [12]. Proper neuromuscular recruitment patterns of hip and knee muscles are essential for the dynamic stability in knee. The muscles surrounding the knee prevent knee injuries by feed forward activities [16].

Any factor that impairs the neuromuscular system can give a new knee injury. However, biomechanical and neuromuscular aspects play an important role in performance and prevention of knee injuries. As it was mentioned, the extra pronation of foot is one of the factors that can cause changes in the neuromuscular function around the knee and makes it vulnerable to injury [2]. Finally, according to what was mentioned and the point that changes in strength and neuromuscular patterns of lower extremity muscles can cause injury in the lower extremities, we decided to compare the strength of selected muscles of lower extremity in people with hyperpronated foot with the same muscles in healthy athletes to answer that whether increased pronation of foot can cause a change in lower extremity muscle strength.

2. Materials & Methods

This study is descriptive and has been implemented by comparative descriptive method .The population of this research consisted of all 18-25 year old athlete students of Tehran University. Forty people were purposefully selected as the sample and then based on the criteria, they were divided into two groups of 20 healthy participants and 20 ones with hyperpronated foot. The number of samples based on a preliminary study was calculated with society variance by the following formula [36].

$$N=\frac{Q^2+Z^2}{D^2}$$

Where, Q is the society variance that achieved on 50 persons on the preliminary study (3.74), Z is the confidence interval to sampling and (1.96) and D is the amount of error that is tolerable (0.05). The following factors were the criteria to enter into the study: an increased pronation of ankle in both feet for a pronation group, no history of ankle sprain in the last year, no history of surgery in the lower limbs, having no deformity and abnormalities (structural) that can be observed in the knees alignment (genu varum, genu valgum and genu recurvatum) in a static condition, no history of neurological and musculoskeletal disease that causes restriction of motion, having no pain in the lower limbs before and during testing time, no history of ligamentous or meniscal injury in the knee.

Information about age, height, weight, and navicular drop were recorded and isometric strength of lower extremity muscles was measured by Manual Muscle Test system (Model 01163, Manufacturing Lafayette Instrument Company of America). Each test was repeated 3 times and the participants were asked to perform movement with maximum strength. Each contraction was held for 5 seconds and the observable maximum strength was recorded [14]. Then, the muscle strength was divided by the body weight in order to normalize strength and to compare two groups correctly [17]. The repeatability of muscles isometric strength measurement was performed by handheld dynamometer on 10 volunteers who had good reproducibility (ICC between 0.85 - 0.96).

Flat-arched foot was determined by the navicular drop test, which is used to evaluate the function of the medial longitudinal arch, based on measurements of the height differences of the navicular tuberosity between sitting and standing positions. The measurement of navicular drop involves placing the fully weight-bearing subject in the talar head congruent position and measuring the distance between the navicular tuberosity and the supporting surface. The subject is then asked to relax, and the sagittal plane excursion of the navicular is measured with a ruler. Three measurements for each foot were recorded, and the mean value was calculated. An average navicular drop of 5–9 mm was classified as normal feet and an average exceeding 10 mm indicated flat feet [18]. The conditions of muscle handheld tests were as follows:

Isometric strength testing of the hip flexors and extensors; hip flexion was tested in a seated position with the hip and knee at 90°. Resistance was applied at the knee approximately 2 cm proximal to the femoral condyles. Hip extension was tested in a prone position with the knee extended. Resistance was applied approximately 2 cm proximal to the popliteal crease [13].

Isometric strength testing of the hip abductors and adductors was performed with each subject lying on her side, with the hip in a neutral position and the knee extended. Resistance was applied approximately 2 cm proximal to the lateral femoral condyle. Adduction was tested with each subject lying on her side, with the hip in a neutral position and the knee extended. Resistance was applied approximately 3 cm proximal to the medial femoral condyle [19].

Isometric strength of the hip external and internal rotators was tested in a seated position with both hip and the knee flexed at 90°. Resistance was applied approximately 2 cm proximal to the medial malleolus of the ankle for external rotation and 2 cm proximal to the lateral malleolus of the ankle for internal rotation [13, 14].

Quadriceps and hamstring muscles are tested while the person sitting on the chair and his knee and hip were in 90° flexion. The dynamometer was placed at 2 cm proximal of ankle on the leg front in order to test Quadriceps muscle. The person was asked to make extension his knee at front of resistance. The dynamometer was placed at 2 cm proximal of ankle to leg back to test hamstring muscle. The person was asked to bend his knee at front of resistance [20].

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Figure 1. Manual Muscle Test system

Statistical analysis was performed by using SPSS, version 19. A significance level of 0.05 was used for all comparisons. According to normality of data that was determined by Kolmogorov-Smirnov test, so the independent t test was used to compare two groups.

3. Results

Demographic and Physical characteristics such as age, height, weight, navicular drop, and tested isometric strength of participants are shown in Tables 1 and 2.

In comparing isometric strength between two groups, the results of independent t test showed that the means of muscle isometric strength of hip abductors, hip adductors, internal rotators, and quadriceps, in the group with increased ankle pronation were less than that of the healthy people. There was a significant difference between two groups regarding only the hip abductors, hip external rotators, and quadriceps muscles ($P < .05$).

4. Discussion

The hip muscles activity is essential in the performance and maintenance of lower extremity as well as trunk and pelvic stability during closed chain activities [10-12]. According to Janda theory, the disorders in a joint can also affect the other closer joints and change their biomechanical and neuromuscular functions [6]. In the present study, the isometric strength of the hip abductors, external rotators of hip, and quadriceps was low in the hyperpronated foot compared to that of healthy athletes

Table 1. Comparison of demographic variables [mean± SD).

Variable	Subjects healthy	Subject whit hyper pronated foot	P value
Age ,(y)	2.41 ± 23.4	2.27 ± 23.9	0.635
Height, (cm)	8.24 ± 165	6.76 ± 169	0.291
Body weight, (kg)	5.9 ± 63	6.47 ± 66.4	0.494
Navicular drop	1.4 ± 7	2.1 ± 13	0.007*

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Table 2. Mean Isometric muscle strength comparisons normalized to body weight [kg] between hyperpronated foot subjects and subjects' healthy [mean ± SD).

Isometric muscle strength	Mean ± SD		P value
	Subjects healthy	Subject whit hyper pronated foot	
Hip abductor	0.036 ± 0.401	0.034 ± 0.365	0.002*
Hip adductors	0.039 ± 0.259	0.030 ±0 .252	0.96
Hip external rotators	0.029 ± 0.234	0.038 ± 0.208	0.007*
Hip internals rotators	0.026 ± 0.264	0.020 ± 0.253	0.148
Hip flexors	0.024 ± 0.357	0.046 ± 0.365	0.74
Hip extensors	0.026 ± 0.310	0.039 ± 0.310	0.64
Hip quadriceps	0.043 ± 0.326	0.040 ± 0.335	0.031*
Hip hamstring	0.033 ±0.727	0.031 ± 0.270	0.87

*Significant difference (P ≤ 0.05)

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and difference was significant (P < .05). The isometric strength of internal muscles of hip rotators, hip adductors, hip extensors, and hamstring did not show any significant difference between the two groups.

Some studies on the relationship between muscle strength and lower extremity injury showed that people with these injuries have unstable support surface to counter the generated forces in the lower extremities, which makes them more prone to injury [14, 17, 22]. Some researchers have pointed out that the increased pronation of foot changes "screw home" mechanism during the functional activities. Accordingly, the assumption is that the people with hyperpronation, as soon as the knee began to extend in the closed chain motor, the tibia remains more in the internal rotation.

The femur should have more internal rotation to compensate the internal rotation of the tibia, so this compatibility makes further the Q angle [22,23]. Change in Q angle of knee and internal rotation of the hip may lead to mechanical inefficiency of extensor mechanism of the knee joint and the weakness of quadriceps muscle. On the other hand, the weakness of the hip muscle as a risk factor is regarded as a risk factor for anterior knee pain, friction syndrome of iliotibial band, leg injuries like internal tibia stress syndrome, especially in severe and repetitive movements [13-15].

The stabilization muscles of the hip and pelvis are responsible for the proper stability of lower extremity during dynamic movements. The most important muscles in this regard are abductor and lateral rotator muscles of the hip [14, 24]. Abductors of the hip should counteract more than twice of the weight of the body in order to maintain the stability of pelvic in the frontal plane because the effort arm of the hip abductors is the half of effort arm of gravity [25]. Gluteus medius is the main muscle of the hip abductor and is responsible for control of the femur movement on the pelvic and the pelvic on the hip as well as prevention of the internal rotation and hip adductors [26]. The decrease in the feed forward activity or in the muscle strength of the hip abductor decreases the stiffness of the hip in the frontal plane.

Weakness of the hip abductor muscle causes an increase load on the hip adductor, then the adductor muscles, and finally on the valgus when landing on one foot, which can lead to knee injuries like strain anterior cruciate ligament, anterior knee pain, and hamstring strain [27, 28]. The weakness of the muscles makes the movements in a closed chain such as ascent or descent stairs with low eccentric control [29]. Changes in the neuromuscular activity of gluteus medius muscle is associated with injuries such as hypermobility of ankle [11], ankle joint injury [30], iliotibial band syndrome, patellofemoral pain syndrome [31], and lower back pain [14, 32]. On the other hand, the weakness of external rotator muscles of the hip causes the femur to have more rotation during movement tasks in the closed chain in which the distal part was the fixed member and just femur moves [33].

This overly internal rotation increases Q angle and joint pressure and consequently causes pain [19]. Quadriceps muscles are important in the opening of knee and maintenance of patellar alignment. The sum of all forces from the different sections of quadriceps muscle leads to compression of the patella to the femur and holds fixed the patella in its position during femur cavity [34]. The quadriceps muscle tendon situation and decrease in their efficiency change the normal pattern of the exerted forces on the patella, so it leads to abnormal movement of the patella, increase of the contact area between the articular surfaces, and also increase of the compressive stress on the surface of patellofemoral joint [35]. It can be inferred from what was mentioned that the pronation of foot by changing the strength of the hip abductors, external rotators of hip, and quadriceps muscles can make a person susceptible to injuries such as patellofemoral pain, iliotibial band syndrome, ankle sprains, and anterior cruciate ligament injury.

In conclusion, this study showed that the hyperpronated foot changes the strength of lower extremity muscles. These changes may reflect the neuromuscular compensation for the loss of overload on the medial longitudinal arch and these neuromuscular and strength changes can put the person at risk of injuries. Considering these results, it can be possible to prevent the injuries of lower extremity through appropriate steps and address this deficiency by designing corrective programs. Researchers are recommended to do further study to determine whether changes in muscle strength are directly related to lower extremity injury. They are also recommended to determine strength changes in muscles of other parts of the body in people who have hyperpronated foot.

Our study design and methods had several limitations. In this study, the "Manual Muscle Test" system was used to assess muscle strength but in future studies we recommend using isokinetic devices. Also, in this study, Brady method was used to measure the posture of the foot but in future studies, we recommend using valid methods such as X-ray and photographic imaging. Moreover, a larger sample size would be suggested in future studies in this area of research.

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