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Original Article

Effects of muscle strength asymmetry between left and right on isokinetic strength of the knee and ankle joints depending on athletic performance level

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Abstract. [Purpose] The aim of this study was to collect basic data on the effect of asymmetry on the muscle strength of the left and right knee and ankle joints of soccer players at varying athletic performance levels, to guide the development of improved exercise programs. [Subjects and Methods] Forty-nine soccer players at three athletic performance levels participated: 15 professional, 16 amateur, and 18 college. Knee extensor and flexor strength were measured at 60°/sec and 180°/sec, and ankle plantar flexor and dorsiflexor strength were measured at 30°/sec and at 120°/sec. Variables were analyzed by one-way ANOVA. [Results] College soccer players showed greater muscle strength at 60°/sec and 180°/sec in the knee extension muscles of both the right and the left sides, lower muscle strength at 30°/sec and 120°/sec in the dorsiflexor of the right ankle, and similar levels of asymmetry between left and right. The maximum muscle strength on the same side significantly differed in the right ankle joint, with asymmetry between left and right at 30°/sec and 120°/sec. [Conclusion] These findings suggest that muscle strength asymmetry in the ankle joint may lead to counterbalancing muscle strengthening of the knee joint to maintain the center of body mass.

Key words: Knee and ankle joint, Isokinetic strength, Athletic performance level

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INTRODUCTION

One of the most popular athletic games, soccer, requires a basic element of strong physical power almost at the threshold level[1], through which successful athletic performance is marked by technical and tactical activities[2]. Physical power is based on muscle strength and durability, quick reaction and agility, and flexibility, and it involves complex components, such as the relationship between the strength of the quadriceps femoris and anaerobic power[3]. To maintain balance and allow for quick reactions and agility during soccer, the iterative interaction among the joints of the lower limb has a significant effect on the players' athletic performance[4].

The muscle strength of the knee joint plays a role in supporting the body's weight. During a game, however, it also supports the center of body mass while performing such dynamic movements as kicking the ball, jumping, and changing direction, which all rely on quick reaction, agility, and coordination[5]. Functional abnormalities of the knee joint can include overuse, repetitive injuries, or unstable proprioception due to repetition of limited movements within the joint's mobility range[6]. To maintain the stability of the knee, it is important to evaluate the level of the muscle strength balance, to assess

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endurance using isokinetic exercises, and then to facilitate muscle development accordingly[7)].

In soccer, the foot and ankle joints have the highest rates of injury, and functional movement impairment can be a cause of instability through insufficient muscle strength and lack of proprioception[8)]. Even when structural instability is excluded, functional instability can cause the weakening of the ankle joint when movement patterns are repetitive, direction is abruptly changed[9)], or active movement is carried out intensely[10)]. In competitive elite sports like soccer, these problems can manifest themselves as chronic issues such as a higher risk of injury or functional abnormalities[11)]. The coordinated activity of the joints and muscles involved in movements of the ankle joint further enhances the functional stability by improving stable weight support as well as motor control function[12)].

Through the measurement of isokinetic variables, the aim of this study was to assess the impacts of functional and chronic asymmetry on the muscle strength of the left and right knee and ankle joints in soccer players at a range of athletic performance levels, and to generate useful data for the development of effective functional exercise programs for symmetrical muscle strength.

SUBJECTS AND METHODS

The 49 study subjects were recruited from 3 different levels of athletic performance: professional soccer players (K league, n=15), amateur players (K3 league, n=16), and college soccer players (U league, n=18). All of the participants provided written consent to participate in the study, after the study procedure and methods were explained to them. Table 1 shows the general characteristics of the subjects. All the subjects understood the purpose of this study and provided their written informed consent prior to participation, in accordance with the ethical standards of the Declaration of Helsinki.

The isokinetic muscle functions of the knee and ankle joints were the main experimental variables of the study, and they were measured using the Humac Norm Testing and Rehabilitation system (CSMi Medical & Solution, USA). Subjects were seated in the measurement chair, and the torque of the knee joint was aligned with the rotating axis of the dynamometer by adjusting the position with a table-tube cross clamp and a pedestal column clamp. The thigh area and the upper body were tightly fixed using a strap and a belt so that the quadriceps exercise would not be affected by external force during the flexion and extension exercises of the knee joint. Additionally, to isolate the muscle strength of the area of interest, the ankle was fixed with a strap by adjusting the length of the lower leg and the adjustment axis with an adapter, after which the flexion and extension exercises of the knee were performed. The range of motion was determined by measuring the maximum flexion from the position in which the joint was extended (0°) in a sitting position. Care was taken so that the joint would not be either hyperextended more than 0° or hyperflexed more than 135°. Measurements were taken by group. As a warm-up exercise, the subjects performed flexion and extension exercises of the lower limb 3 times below maximum and 1 time at maximum, at angle speeds of 60°/sec and 180°/sec. Then, the measurements were collected 5 times at the angle speed of 60°/sec and 15 times at the angle speed of 180°/sec. After the measurements were obtained at each speed, the subjects were told to repeat the flexion and extension of the knee joint, while resting for approximately 2 minutes in a sitting position.

Next, the subjects were seated in the measurement chair in the same manner described above for the knee joint, and the strength of the plantar flexion and dorsiflexion muscles in the ankle were measured at angle speeds of 30°/sec and 120°/sec. After completion of a warm-up exercise of plantar flexion and dorsiflexion 3 times below maximum and 1 time at maximum, at the angle speed of 30°/sec and 120°/sec, measurements were taken 5 times at 30°/sec and 15 times at 120°/sec. After the performance was measured at each speed, the subjects repeated the flexion and extension exercises, while resting for approximately 2 minutes in a sitting position. For each measurement, the researcher verbally encouraged the subjects to perform at their maximum.

All of the data analysis was conducted using SPSS for Windows version 20.0 (SPSS Inc., USA). Means and standard deviations were computed for all the measurement items. To test group differences, one-way ANOVA was performed, and when significant differences were found, post-hoc comparisons were performed using the *Scheffe* method. Statistical significance was set to $p < 0.05$.

RESULTS

Tables 2 and 3 show the results of the one-way ANOVA on peak isokinetic strength and differences in muscle strength of the knee and ankle joints, and the level of muscle strength on the left and the right, according to level of athletic performance. Peak extensor strength of the knee joint was significantly higher in the university players (UP) than the professional players (PP) or amateur players (AP), both in the right and left knee at the angle speed of 60°/sec (both $p<0.001$) and the angle speed of 180°/sec (both $p<0.01$). The peak flexor strength of the knee joint was significantly higher in AP than PP or UP, at the angle speed of 180°/sec in the right knee ($p<0.05$).

Tables 4 and 5 show the results of the one-way ANOVA on the peak strength of the isokinetic function in the ankle joint, as well as the ratio of muscle strength on the left and right, according to participant's level of athletic performance. The peak plantar flexor strength of the ankle joint was higher in AP than PP or UP at the angle speed of 120°/sec in the right ankle ($p<0.01$). The peak dorsiflexor strength was significantly lower in UP than PP or AP in the right ankle at the angle speed of 30°/sec, and at the angle speed of 120°/sec ($p<0.001$), and significantly higher in the left ankle at the angle speed of 30°/sec

Table 1. General characteristics of participants

Variables	n	PP (K league)	AP (K3 league)	UP (U league)
Age (yrs)	15	26.9±4.4	21.1±1.9	20.3±1.5
Height (cm)	16	179.4±7.3	175.5±4.1	180.9±4.6
Weight (kg)	18	77.5±8.0	70.4±4.6	76.6±6.1

Values are mean±SD
PP: professional players, AP: amateur players, UP: university players

Table 2. Comparison isokinetic peak torque of the knee joint

			PP	AP	UP
Extensor (Nm)	60°/sec	Right	207.8±23.2	205.3±18.8	254.1±34.0***
		Left	202.7±33.1	204.9±20.3	246.9±43.6***
	180°/sec	Right	123.0±21.1	118.6±29.3	148.1±21.3**
		Left	128.0±27.9	120.0±22.4	147.3±20.8**
Flexor (Nm)	60°/sec	Right	133.6±28.8	129.1±20.0	152.0±38.1
		Left	131.5±25.2	128.1±17.5	145.1±25.2
	180°/sec	Right	90.1±25.3	111.9±19.2	95.4±24.3*
		Left	91.9±22.5	104.4±11.9	97.6±21.2

Values are mean±SD, *p<0.05, **p<0.01, ***p<0.001
PP: professional players, AP: amateur players, UP: university players

Table 3. Comparison isokinetic ratio of the knee joint

		PP	AP	UP
60°/sec (%)	Right	64.1±10.9	64.1±11.5	60.0±13.2
	Left	64.9±7.0	64.9±10.5	59.2±7.6
180°/sec (%)	Right	72.6±13.5	64.1±11.5	66.2±20.3
	Left	71.8±10.7	64.9±10.5	66.7±13.9

Values are mean±SD
PP: professional players, AP: amateur players, UP: university players

Table 4. Comparison isokinetic peak torque of the ankle joint

			PP	AP	UP
Plantar flexion (Nm)	30°/sec	Right	106.8±28.3	125.0±25.8	109.1±28.1
		Left	101.8±20.9	109.2±21.2	105.4±23.9
	120°/sec	Right	51.7±18.8	80.8±23.4	62.9±20.8**
		Left	56.8±20.0	76.1±34.7	58.7±17.0
Dorsi flexion (Nm)	30°/sec	Right	30.3±8.7	34.9±5.8	22.3±5.1***
		Left	29.9±7.4	33.6±5.5	35.4±5.1*
	120°/sec	Right	16.2±7.0	19.6±4.2	9.9±2.2***
		Left	17.2±5.9	18.4±3.7	17.2±2.6

Values are mean±SD, *p<0.05, **p<0.01, ***p<0.001
PP: professional players, AP: amateur players, UP: university players

Table 5. Comparison isokinetic ratio of the ankle joint

		PP	AP	UP
30°/sec (%)	Right	28.5±4.0	28.7±7.0	21.1±4.6***
	Left	30.1±8.3	31.7±7.8	35.6±10.3
120°/sec (%)	Right	32.6±9.7	26.2±9.4	17.7±6.3***
	Left	32.3±11.6	27.0±9.5	30.2±9.1

Values are mean±SD, ***p<0.001
PP: professional players, AP: amateur players, UP: university players

(p<0.05). UP showed a significant asymmetry in muscle strength between the left and right sides compared to PP and AP at the angle speeds of 30°/sec and 120°/sec (p<0.001). The ratio of the muscle strength of the ankle joint in the left and the right was significantly lower for UP than PP or AP in the right ankle at the angle speed of 30°/sec and at the angle speed of 120°/sec (p<0.001).

DISCUSSION

Reinforcing muscle strength to maintain the stability of the knee joint is essential for soccer players[13)]. Deficiencies in quadriceps muscle strength have a direct link to the risk of injury and can cause osteoarthritis in the knee joint[14)]. It has been reported that injury frequency increases in athletes when there is a difference of 10% or more between the strength of the left and the right quadriceps femoris[15, 16)]. One cause of instability of the main joints in the lower limbs is instability of flexion and extension movements, accompanied by loss of muscle strength; this instability can be manifested in a variety of forms[17)].

In the present study, UP had significantly higher isokinetic strength of the quadriceps femoris than PP or AP, and no asymmetry was observed in the left and the right muscle strength. However, a previous study on the isokinetic strength of elite players and AP demonstrated that the muscle strength rate of the hamstring was higher in elite players[18)]. Although in that study it was observed, as in this study, that UP had significantly higher quadriceps femoris strength, PP showed balance between the quadriceps femoris and the hamstring and a higher muscle strength rate of the hamstring. It is thought that the muscle strength rate of the hamstring is higher because it enhances the stability of the knee joint to increase speed over short distances and to allow for precise foot techniques.

The muscle strength in the ankles of soccer players also differs depending on players' athletic performance level. A study that compared the isokinetic muscle strength in the ankle joint of UP and PP found that it was greater in PP, who were at a higher level of athletic performance than UP[19)]. In this study, the plantar flexor strength was higher in AP compared to PP and UP, and no asymmetry in muscle strength in the left and the right was observed, whereas the dorsiflexor strength was significantly lower in UP compared to PP and AP. Our finding is similar to that of a previous study that reported that muscle strength imbalance in the foot joints, deficiencies in proprioception, mechanical instability, and weakening of the peroneal tendon, which can all be caused by repetitive training, overuse, and damaged soft tissue, are interrelated[20)]. Thus, it is believed that the tibialis anterior, which is involved in dorsiflexion and inversion, is relatively weak in muscle strength expression, in comparison to the strength of the soleus, gastrocnemius, and peroneal tendon that are involved in plantar flexion and eversion.

Muscle balance is an indicator employed to judge the level of athletic performance, and the extent of muscle imbalance due to exercise and incorrect positioning is one factor that influences performance[21–23)]. Soccer is a sport in which a variety of connecting movements, including running, abrupt stopping, changing direction, jumping and landing, kicking and passing, repeatedly occur and these movements require complex functioning of the knee and ankle joints. The hamstring and the calf muscle work to maintain the stabilized center of body mass or to push the ground surface using reaction force, and the quadriceps femoris and dorsiflexors are used when moving forward, kicking, or adjusting a ball by flexion of the hip joint, extension of the knee, and dorsiflexion of the ankle. It is not only the balance between the agonist and antagonist muscles, but also the balance between the left and the right, and between the proximal joint and distal joint in a weight-bearing position that are involved during exercise[24, 25)]. As seen in the UP in this study, the weakening of dorsiflexors due to muscle strength asymmetry in the right ankle joint is thought to cause the strengthening of the extension muscles of the knee joint in order to maintain the center of body movement and stability.

To maintain stability and balance in lower limb movement, it is essential to maintain muscle activation[26)]. When a movement is made by a soccer the player, the muscles in the foot are already activated to function before the foot touches the ground[27)], and when the knee joint sustains a large shock like landing or when the center of mass moves, the contraction greatly increases in the quadriceps femoris[28)]. It is thought that muscle strength asymmetry in the ankle joint may strengthen the muscles of the knee joint as a counterbalance in order to maintain the center of body mass. In the future, to investigate the extent of muscle activation due to asymmetry between left and right, studies must be conducted on muscle contraction as the center moves with the use of kinetic variables.

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