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Comparison of The Hamstring-to-Quadriceps Strength Ratios of Collegiate Soccer Players and Age-Matched Healthy Students

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ABSTRACT

B. D. SEO, H. S. SHIN, and D. W. HAN, Comparison of The Hamstring-to-Quadriceps Strength Ratios of Collegiate Soccer Players and Age-Matched Healthy Students. Korean Journal of Sport Biomechanics, Vol. 19, No. 4, pp. 617-625, 2009. The primary purpose of this study was to compare the hamstring-to-quadriceps strength(H/Q) ratios in collegiate soccer players and normal age-matched healthy students, and the secondary purpose was to investigate the changes in the H/Q ratio according to the degree of knee flexion. Twenty-five subjects volunteered to participate in this study. The study group comprised 12 healthy male collegiate soccer players, and the control group, 13 healthy age-matched male collegiate students. The modified N-K table was used for isometric strength measurement(unit: N). Mann-Whitney tests were performed to determine the differences in the H/Q ratios of soccer players and age-matched students at different knee flexion angles of the dominant leg. The strength of the hamstring muscle in the study group was significantly lower than that observed in the control group at knee flexion angles of 60° (p<.001), 90° (p<.01), and 120° (p<.05). The strength of the quadriceps muscle in the study group was significantly higher than that observed in the control group at flexion angles of 30° (p<.001) and 60° (p<.05). The H/Q ratios in the study and control groups differed significantly at all angles (60°, p<.001 90°, p<.001 and 120°, p<.001).

KEYWORDS : HAMSTRING TO QUADRICEPS STRENGTH RATIO(H/Q RATIO), ISOMETRIC MUSCLE STRENGTH, SOCCER PLAYERS

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Ⅰ. Introduction

Soccer, one of world's most popular team sport, is a game characterized by running and jogging interspersed with high-intensity sprints. Several studies have shown that the majority of the most soccer injuries(from 50 % to 80 %) involve the lower extremities(Alentorn-Geli et al., 2009; Rochcongar, Laboute & Carling, 2009, Wong & Hong, 2005). Most of these injuries are ligament injuries to the knee (such as anterior cruciate ligament) and the ankles, and muscle strain to the hamstrings and the groin. The anterior cruciate ligament(ACL) strain-shielding effect provided by the hamstring muscles has been well documented(Greig & Siegler, 2009). Because the quadriceps can generate force that exceeds the ACL failure load, the co-activation of the hamstrings is believed to be essential for the maintenance of knee stability(Hagood, Solomonow, Baratta Zhou & Ambrosia, 1990; Osternig, Caster & James, 1995). The strength relationship between the hamstrings and quadriceps has been related to hamstrings co-activation. If this co-activation is imbalanced or not coordinated, the ACL must endure the entire strain, increasing the risk of rupture(Heidt, Sweeterman, Carlonas, Traub & Tekulve, 2000). Therefore, it is important to achieve a balance between the hamstrings and quadriceps in order to provide the necessary stabilization during specific sports activities.

Many underlying problems may have contributing roles in non-contact ACL injuries, in addition to the stresses experienced by soccer players, including muscular imbalances of the hip, poor foot mechanics, poor deceleration and plyometric(energy-storing) function, inefficient hamstring to quadriceps strength ratio(H/Q ratio), and poor acclimation to playing surface(Rahanma, Reilly & Lees, 2002). The H/Q ratio of these factors has been recognized as an indicator of the ability to dynamically stabilize the knee and to prevent ACL injury of the knee(Hiemstra, Webber, MacDonald & Kriellaars, 2004). The H/Q ratios have been studied with growing interest since the isokinetic concept of exercise was introduced by Hislop and Perrine in 1967. This parameter was used to indicate normal balance between the extensor and flexor function in the knee, by measuring in unilateral ratio. It used peak torque value of hamstring and quadriceps in unilateral side to calculate the ratio, by dividing the maximal hamstrings peak torque by the maximal quadriceps peak torque. Controversy exists, however, regarding the optimal H/Q ratio for the knee. The literature on isometric tests and slow speed isokinetic tests shows that a normal H/Q ratio ranges from 31 percent to 80 percent, and the recommended optimum H/Q ratio is between 50 percent and 80 percent(Arvidsson, Eriksson, Haggmark & Johnson, 1981; Stafford & Grana, 1984). The H/Q ratio cited in several recent research reports was calculated from peak torque values observed at 60°/s using isokinetic equipment(Anderson, Dome, Gautam, Awh & Rennirt, 2001).

As mentioned previously, despite the high rates of ACL injuries seen in contact sports(as such soccer), the majority of injuries occur as a result of a non-contact mechanism. The mechanism causing this injury usually falls into one of three categories: planting and cutting, straight knee landing, and one-step stop landing with the knee in hyper-extension(Davis, Ireland & Hanaki, 2007; White, Lee & Cutuk, 2003). These cause an incredible amount of stress, which the lower extremity of the body can normally endure. If the positioning of the body is altered in the landing, however, injury can occur. These movements include rather better isometric factors than isokinetic factors, although they take place over very short periods of time. In landing after jumping, our body weight comes down to earth by the action of gravity. As soon as we land on the earth, the reactive ground force acts. Decker, Torry and Wyland(2003) reported that males reached a peak extensor moment .038 seconds after contact with the ground was made. Therefore, the two forces maintain equilibrium at any point where there isometric movement of the lower extremity. At this point, a muscle imbalance of the lower extremity will result, which will increase stress on the ACL in soccer players.

The hypothesis of our study is that the H/Q ratio of collegiate soccer players should be lower than normal age-matched subjects. Furthermore, there should be a difference in the H/Q ratio according to the degrees of the knee joint. It is because most of their activities are forced on quadriceps muscle, such as kicking. Also, when they perform a landing task after jumping, according to the angle of their knee joint, their H/Q ratio should appear different for soccer players. Accordingly, The primary purpose of this study was to investigate the H/Q ratio in collegiate soccer players to compare it to that of normal age-matched subjects, and the secondary purpose was to investigate the change aspects of the H/Q ratio according to each of the degrees of the knee in the isometric method.

Ⅱ. Methods

1. Subjects

Twelve healthy male collegiate soccer players in a study group and thirteen healthy age-matched male collegiate healthy students in a control group volunteered for this study. All subjects had no history of ACL injury, knee pain, or tenderness, and no history of any lower extremity injury during the preceding 6 months. The general characteristics of the subject were recorded(Table 1). The dominant leg reported by the subject was used in assessing the strength. The dominant leg was defined as the leg identified by subjects as the one that would be used to kick a ball. Prior to participation, all subjects read and signed the informed consent agreement.

Table 1. The general characteristics of the subjects

(unit: N)

Items	Soccer players group(n1=13)	ge-matched students group (n2=12)
Age (year)	21.30±0.48a	21.25±0.45
Weight(kg)	70.34±12.10	63.42±2.86*
Height (cm)	176.58±5.46	172.41±4.37
Dominant leg (number)	Right (13)	Right (12)
Career (years)	5 year ~ 7year(9), 10 year over(4)	

a Mean±SD

* $p<.05$

2. Instrumentation and Measurement Protocol

In 1954, Noland and Kuckhoff(1954) introduced an innovative isotonic resistance device known as the N-K table which still is used widely today. It was designed to make progressive resistance exercises for the quadriceps and hamstring muscle groups more convenient and efficient. The unique aspect of the N-K table is the adjustable lever arm that holds the weight and is, thus, termed the "resistance arm." This is separate from the "exercise arm," which is the arm that contacts the user(Daniel, Douglas, Kristinn and David, 1998).

Our study was used modified N-K table which was attached digital muscular strength meter(Power Track Ⅱ TM Commander, USA) to measure the maximum voluntary contraction(MVC) of dominant

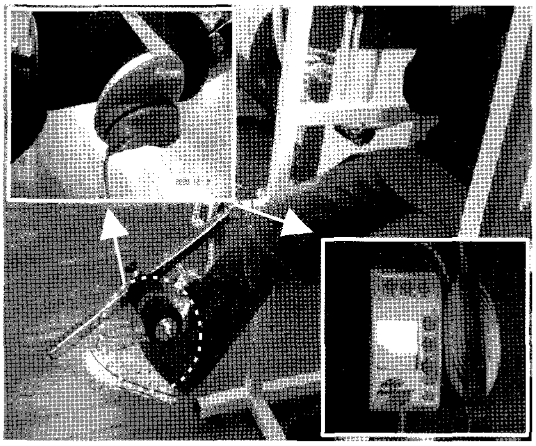

Figure 1. The modified N-K table and digital muscular strength meter(Power Track Ⅱ TM Commander, USA)

leg(figure 1). The digital muscular strength meter which was in contacted with the ankle joint of dominant leg was fixed the exercise arm of N-K table. The Goniometer(Professional 6 Piece Goniometer Set, Indus International, USA) was used to set the angle of exercise arm of N-K table and then was fixed at each 30°, 60°, 90°, 120°.

The measurement was performed in a seated position on a modified N-K table, with the hips maintained at approximately 90° of flexion, with both hands crossed on the chest. Stabilization straps were used to minimize movement of the thigh segment of the measured extremity. The axis of rotation of the modified N-K table was aligned with the lateral femoral condyle of the knee. Each subject performed three maximal isometric contractions at each angle (30°, 60°, 90° and 120°) for knee flexion and extension (with a three-minute rest between measurements). All test was measured by identical reacher who was blind to the purpose of this study. Subjects were given verbal encouragement to help to ensure that a maximal effort was being put forth. Verbal encouragement consisted of loudly exhorting a subject ("Kick hard! Go! Go! Go! Kick!") for the entire duration of the contraction. The MVC value were expressed on the panel of the isometric measurement device and was recorded. Each measurement was performed three times, and the mean values were used to calculate the H/Q ratio.

3. MVC to Quadriceps and Hamstring muscle

The MVC is the most commonly used for defining the strength in isometic measured in Newton(N). The MVC is a measure of strength and can be a maximal exertion of force.

4. Hamstring to Quadriceps Strength Ratio

The H/Q ratio was used to indicate normal balance between the extensor and flexor function in the knee, by measuring in a unilateral ratio(Rosene, Fogarty & Mahaffey, 2001). Our study was used to calculate the ratio, by dividing the MVC of hamstring muscle by the MVC of quadriceps muscle(Equation 1). The low of H/Q ratio means imbalance between the hamstrings and quadriceps in order to provide the necessary stabilization during specific sports activities.

$$H/Q\ ratio = \frac{MVC\ of\ hamstring\ m\mu scle}{MVC\ of\ quadreceps\ m\mu scle} \times 100 \cdots Equation\,1$$

H/Q ratio : The hamstring to quadriceps strength ratio, MVC: maximum voluntary contraction

5. Data Analysis

SPSS ver. 12.0 program was used for data analysis. Mann-Whitney were conducted to determine differences in H/Q ratios between soccer player and age-matched students at each angle of dominance leg. The mean values of MVC were used for data analysis. A significance level of .05 was applied for all statistical analyses.

Table 2. MVC of the hamstring and the quadriceps muscle

(unit: N)

degree (°)	Hamstring muscle			Quadriceps muscle		
	Soccer players group (n1=13)	Age-matched students group (n2=12)	Z-value	Soccer players group (n1=13)	Age-matched students group (n2=12)	Z-value
30	235.72±111.74a	185.92±29.49	-.925	310.50±43.27	213.67±64.46	-3.29***
60	130.81±34.10	248.08±23.60	-4.24***	381.92±48.30	336.50±61.60	-2.37*
90	158.06±30.93	216.25±56.66	-2.44*	447.83±35.74	400.58±64.85	-1.96
120	117.94±29.53	165.50±52.40	-2.61**	385.00±76.35	370.50±56.30	-.30

a M±SD
* *p*<.05, ** *p*<.01, *** *p*<.001

Table 3. The hamstring to quadriceps strength ratio

(unit: N)

degree (°)	Soccer players group (n1=13)	Age-matched students group (n2=12)	Z-value
30	71.96±29.64a	96.22±44.44	-1.63
60	34.31±8.39	75.30±21.87	-4.24***
90	35.40±8.12	53.97±11.69	-3.75***
120	31.03±6.13	44.42±11.47	-3.2***

a M±SD
* *p*<.05, ** *p*<.01, *** *p*<.001

Ⅲ. Result

1. MVC of the Hamstring and the Quadriceps muscle

The inter-group comparisons of MVC value of quadriceps and hamstring muscle in the soccer players group and the age-matched students group are shown in Table 2. In the hamstring muscle of the soccer players group, MVC value was lower than in the age-matched students group at 60°(p=.000), 90°(p=.014) and 120°(p=.008), showing significant differences (p<.05). In the quadriceps muscle of soccer players group, MVC value was higher than in the age-matched students group at 30°(p=.000), and 60°(p=.016), again showing significant differences (p<.05).

2. The Hamstring to Quadriceps Strength Ratio

This study revealed a significant difference between the soccer players group and age-matched students group at 60°(p=.000), 90°(p=.000), and 120°(p=.001) in H/Q ratio. It appears that the soccer players group had lower H/Q ratio compared to the age-matched students group(Table 3).

Ⅳ. Discussion

In discussing their findings, White et al.(2003) emphasized the importance of the relationship between the quadriceps and hamstring, and in the interaction of this musculature with the knee. They suggested that the success of co-activation plays a large role in providing stability to the knee and supporting the ACL in counteraction of anterior tibial translation. In this study, therefore, H/Q ratios are used to describe the strength surrounding the knee joint. Previous studies have reported hamstring to quadriceps peak torque ratios from 50 to 62 percent for healthy individuals(Hamill & Knntzen, 2003), and from 50 percent to 60 percent in soccer players (Aagaard, Simonese, Trolle, Bangsbo & Klausen, 1996). Coplin(1971) recommended a ratio of 60 percent in an attempt to maintain a normal balance for the torque stress applied to the normal knee joint for college-age athlete. Oberg, Moller, Gillquist and Ekstrand(1987), Stafford and Grana(1984) reported that soccer players had a higher H/Q ratio than non-players. Consequently, the optimum concession value for the knee joint recommended by several researchers was 60 percent for college-age athletes, in an attempt to maintain a normal balance for the torque stress of the knee.

However, previous studies used isokinetic dynamometer for measuring H/Q ratio. We suggest that isokinetic methods are actually not useful for expressing the H/Q ratio of soccer players, because most of the low extremity injury in soccer players happen in non-contact situations, such as planting and cutting, and straight knee landing(White et al, 2003, Davis et al, 2007). Most of these non-contact situations provided rather better results when analyzed using isometric rather than isokinetic methods. In addition, because the isokinetic methods depend on the velocity of flexion and extension, the results of previous studies show wide differences of H/Q ratio according to angle velocity. In isometric and slower-speed isokinetic tests, the normal H/Q ratio has been found to be about 50 percent, whereas in the isokinetic test speed of 300°/sec or more, the H/Q ratio exceeds 100 percent(Wyatt & Edwards, 1981). Therefore we undertook this study to determine whether soccer players have higher quadriceps isometric muscle strength, as well as to determine whether soccer players have a lower hamstring to quadriceps strength ratio than age-matched students in the isometric method.

The Hamstring to Quadriceps Strength Ratio

The results of this study were different than the results of previous isokinetic studies. Yeefun, Hirunrat, Chentanez and Gaogasigam(2002) found that the soccer players had greater H/Q ratio in dominant and non-dominant limbs than those of the control group in 60° per second. The average hamstring to quadriceps ratios in dominant limbs of the soccer players and the control group was 67 percent and 61 percent, respectively. Chin, So, Yuan, Li and Wong (1994) reported that the only ration measured at 60 °/sec in dominant limb was only 56 percent in Asian soccer players and may result from subject aged, body composition and training activity. The finding were consistent with the those of previous studies reporting H/Q peak torque ratios between 50 percent to 60 percent for healthy individual, and 50 percent to 60 percent in soccer players(Hamill & Knntzen, 2003).

Our results indicated a reduced H/Q ratio in soccer players group, and only at 30° revealed H/Q ratio value of over 60 percent in soccer players. Age-matched students on the other hand revealed this at 30° and 60°. In inter-group comparison, the results of this study revealed that there was significant difference between soccer players and age-matched students at knee angle of 60°, 90°, and 120° (p<.05). The reason for the difference in H/Q ratio levels may be due to the fact that soccer players were frequently involved in high-speed running and impact and perform kicking exercises on a daily basis, whereas the age-matched students take part in typically daily life activities, which were less active than the soccer players. In addition, soccer players had more fast twitch muscle than age-matched students. Accordingly, H/Q ratio will reveal lower in soccer players than age-matched students.

The MVC of the Hamstring and the Quadriceps Muscle

The strength of the thigh muscles is a critical component in knee stabilization. Elite athletes in sports such as soccer, volleyball, and basketball are more likely to have hypertrophy of their quadriceps. This strengthening may cause the quadriceps to produce a force larger than can be tolerated by the ligament, thus injuring it. Furthermore, adequate hamstring strength to counteract the increased quadriceps activity is important to stabilize the knee joint(Greig & Siegler, 2009). If the hamstring muscle has insufficient muscle strength, it will lead to shear force by the larger muscle strength of the quadriceps. The factors responsible for the increased shear force acting on the tibia are suggested to be increased quadriceps force, decreased hamstring force, a decreased knee flexion angle, or a combination thereof (Rosene, et al., 2001). The result of this study revealed that a significant difference of MVC of hamstring muscle(60°, 90°, and 120°, $p<.05$) and quadriceps muscle(30°, 60°, $p<.05$) compared with age-matched students. Sell, Ferris, Abt, Tsai, Myers, Fu, and Lephart(2004) reported that an increase in the values obtained in the electromyography(EMG) test of the quadriceps predicts a greater proximal tibia anterior shear force during vertical stop-jumps, and the repeated exertion of this force increases the extent of anterior tibial translation. Therefore, we guess that soccer players have insufficient muscle balance of lower extremity and soccer players was exposed to low extremity injury.

V. Conclusion

We compared H/Q ratio of soccer players with age-matched healthy students. The soccer players showed the more larger quadriceps muscle strength. And there was revealed the lower of H/Q ratio than age-matched healthy students. In conclusion, soccer players who participated in this study require training for the balance of low extremity muscles(quadriceps and hamstring). In particular, hamstring training should be encouraged for functional stability of knee joint. The limit of this study was to have no consideration for effect weight on the muscle strength. In future study, it need to consider the weight and muscle strength.

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