RELATIONSHIP BETWEEN ANTERIOR TIBIAL TRANSLATION AND ISOMETRIC STRENGTH IN FEMALE ATHLETES

Yasuyuki Ueda, Yukio Urabe, Rieko Sasaki, Miyuki Miyazato, and Orie Yamaguchi

Department of Sport Rehabilitation, Graduate School of Health Sciences, Hiroshima University, Hiroshima, Japan

The purpose of this study was to determine whether the isometric strength of the muscles around the knee and hip is associated with anterior tibial translation. Forty-four female high school basketball players participated in this study. Anterior tibial translation was measured with a Kneelax 3 arthrometer. The isometric strengths of knee flexion, knee extension, and hip abduction were determined with a hand-held dynamometer. In the case of both the legs, significant correlations were found between the anterior tibial translation, knee extension strength, and hamstring/quadriceps strength (H/Q) ratio. No significant correlations were found between the anterior tibial translation and the knee flexion and hip abduction strengths. Muscle imbalance between the quadriceps and hamstring muscles may lead to greater anterior tibial translation.

KEY WORDS: anterior tibial translation, isometric strength, ACL

INTRODUCTION:

Anterior cruciate ligament (ACL) tear is the most common severe ligament injury of the knee. Approximately 70% of all ACL injuries sustained by athletes are due to a non-contact mechanism (Boden et al. 2000). Female athletes appear to be at a greater risk of sustaining this injury than male athletes. Although establishment of the cause of such a gender discrepancy with regards to non-contact ACL injuries has received substantial attention, the exact cause remains unknown. Rosene and Fogarty (1999) reported that female athletes had higher mean anterior tibial translation than their male counterparts. The implications of this greater absolute increase in the anterior tibial translation in ACL injury are relatively unknown. Uhorchak et al. (2003) reported that women with higher values of anterior tibial translation had a 2.7 times higher relative risk of injury than women with lower values of anterior tibial translation; however, the mechanism underlying this observation was not clear. Some studies have indicated that anterior tibial translation can be modulated by the quadriceps and hamstring muscles. The quadriceps muscles exert anteriorly directed shear forces from the tibia to the femur, and the hamstring muscles exert less posterior shear force on the tibia. In addition, Myer et al. (2005) demonstrated that the hip abductor muscles may play an important role in controlling the excessive occurrence of valgus knee. Physiologic dynamic valgus torque on the knee can substantially increase the anterior tibial translation and the load on the ACL (Fukuda et al. 2003). Our initial hypothesis was that the possible cause of the greater anterior tibial translation was muscle weakness and imbalance around the knee and hip. Strong quadriceps muscles lead to higher anterior tibial translation, and strong hamstring and hip abductor muscles create lower anterior tibial translation. The purpose of this study was to determine whether the strength of the muscles around the knee and hip is associated with the anterior tibial translation.

METHOD:

This study recruited 44 female high school basketball players without ACL injury (mean age, 16.3 ± 0.7 y; height, 161.1 ± 5.7 cm; mass, 52.3 ± 5.2 kg; years of basketball experience, 6.0 ± 1.9 y). The dominant leg was determined based on the foot that was used by the athlete to kick a ball. All subjects granted written informed consents for participation in the study, and the study protocol was approved by the review board of the author's institution.

Procedures: Anterior tibial translation in each subject was measured with a Kneelax 3 arthrometer (Monitered rehab systems, Netherlands). Instrumented examination was performed with the subject in the supine position. Both legs were placed in a thigh support,

with 30° of knee flexion. Measurements were performed during internal and external rotation of the knee, with a footrest and a strap around the thighs keeping the legs in a neutral position. The arms were placed along the body, and subject was asked to relax. The Kneelax 3 arthrometer measures the displacement of the tibia relative to the femur and emits distinct tones when a force of 132 N is applied. The anterior tibial translation was measured in millimeters. The maximal isometric strengths of knee flexion, knee extension, and hip abduction were tested with a hand-held dynamometer (μTas F1, ANIMA, Japan). Knee flexor strength was tested with each subject in the prone position and the knee at 60° of flexion. The hand-held dynamometer was placed just proximal to the ankle behind the lower leg, and a belt was used to fix it in position. Knee extensor strength was tested with the subject in the sitting position with the hip and knee at 90° flexion; the device was placed on the front of the lower leg and fixed in position using a belt. Hip abductor strength was tested with the subject in the supine position and 0° of hip abduction; the device was placed just proximal to the knee on the lateral side of the femur and fixed in position with a belt. Each test was performed 3 times and the mean values of the isometric strengths determined in the 3 tests were calculated. The isometric strengths were normalized to the subject's body weight, and the hamstring to quadriceps muscles ratio (H/Q ratio) was calculated.

Statistical Analysis: Stat View version 5.0 (SAS Institute Inc. USA) was used for the analysis. The average values of the strengths of knee flexion, knee extension, and hip abduction from the 3 rounds of measurement were used. The correlation of anterior tibial translation with the strengths of knee flexion, knee extension, hip abduction, and the H/Q ratio was calculated by using Peason's correlation coefficients. A significance level of 0.05 was applied for all statistical analyses.

RESULTS:

In the case of the dominant leg, significant correlations were found between anterior tibial translation and knee extension strength ($r = 0.35$, $p = 0.01$) and the H/Q ratio ($r = –0.38$, $p = 0.01$). No significant correlations were observed between the anterior tibial translation and the strengths of knee flexion and hip abduction (Figure 1). In the case of the non-dominant leg, significant correlations were observed between anterior tibial translation and the knee extension strength ($r = 0.35$, $p = 0.01$) and the H/Q ratio ($r = –0.40$, $p = 0.01$). No significant correlations were found between the anterior tibial translation and the strengths of knee flexion and the hip abduction (Figure 2).

DISCUSSION:

This study was conducted to determine whether the isometric strengths of the muscles around the knee and hip are associated with the anterior tibial translation in female athletes. Analysis of the results indicated that the knee extension strength and H/Q ratio were significantly correlated with the anterior tibial translation on both the sides: right and left. This finding supported the hypothesis to some extent. Ergun et al. (2004) found that competitive soccer players demonstrated significantly lower sagittal knee laxity and had stronger knee flexors and extensors than sedentary controls. They found no relationship between the muscle strength and sagittal knee laxity. The results of this study did not support these previous results. The noted discrepancies could be attributed to the fact that the gender of the subjects and method of muscle strength measurement differed in the 2 studies. Rosene and Fogarty (1999) reported that there was a difference in the anterior tibial translation between female and male subjects; therefore, the results of studies with subjects of different genders differ. Several studies have suggested that anterior tibial translation is influenced by certain factors. Steiner et al. (1986) demonstrated that the anterior knee laxity increased by 18% to 20% in the normal knees of collegiate basketball players after 90 min of practice and in recreational runners after a 10-km race. However, after a series of squats by power-lifters, no significant change in laxity was noted, suggesting that ligamentous laxity does not increase when a few high stresses are exerted at lower rates. Wojtys et al. (1996) measured the effect of quadriceps and hamstring muscle fatigue on the anterior tibial translation in 10

normal knees. At the point at which the muscles reached fatigue, the average increase in the anterior tibial translation was 32.5%. By performing an in vitro study using cadaver knees, Markolf et al. (1981) determined the effect of joint load on the anterior-posterior knee laxity at 20° of knee flexion. They found a change of approximately 1 mm in the anterior-posterior knee laxity corresponding to a change of 100 N in the joint load. This 100 N decrease in the joint load due to post-exercise muscle fatigue may have led to the increased knee laxity. Additionally, regular training has an eventual effect on the anterior tibial translation, although this effect probably depends on the type of the sport. Kettunen et al. (1997) studied elite male athletes and reported a lower knee laxity in runners and soccer players than in shooters and weight lifters. Anterior tibial translation may also be lower in runners and soccer players. Based on this knowledge, it can be inferred that the anterior tibial translation may be controlled by exercise. In the present study, a significant relationship was demonstrated between the anterior tibial translation and the isometric strength of the knee extensor and the H/Q ratio. Sell et al. (2007) reported that an increase in the 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. This concept supports the results of the present study. Therefore, a decrease in the quadriceps activity during a stop-jump may contribute to a decrease in the proximal tibia anterior shear force. However, the quadriceps have to contract to control knee flexion, and a decrease in the activity of the quadriceps may lead to ligamentous injury. The question to be addressed is whether decreased knee laxity necessarily reduces the risk of ligamentous injury or whether increased laxity predisposes athletes to a higher risk of injury. Among several factors, the contribution of anterior tibial translation, among several factors, to ligamentous injury cannot be proved with certainty. Prospective studies are necessary for investigating the existence of a direct relationship between anterior tibial translation and ligamentous injury.

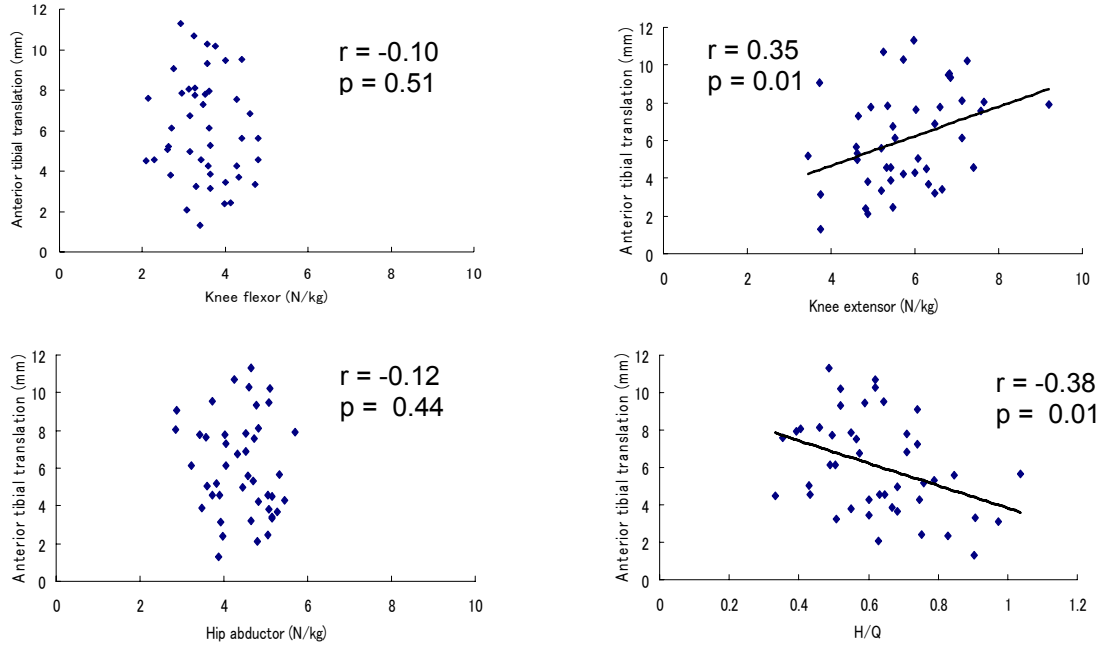

Figure 1: Correlation between anterior tibial translation and knee flexor, knee extensor, hip abductor and H/Q ratio in the dominant leg

CONCLUSION:

This study established that anterior tibial translation was associated with the quadriceps strength and H/Q ratio. Therefore, training for building muscle strength may decrease the anterior tibial translation in female athletes. Further studies are required to determine whether decreased anterior tibial translation necessarily reduces the risk of ligamentous

injury or whether increased anterior tibial translation predisposes athletes to a higher risk of injury.

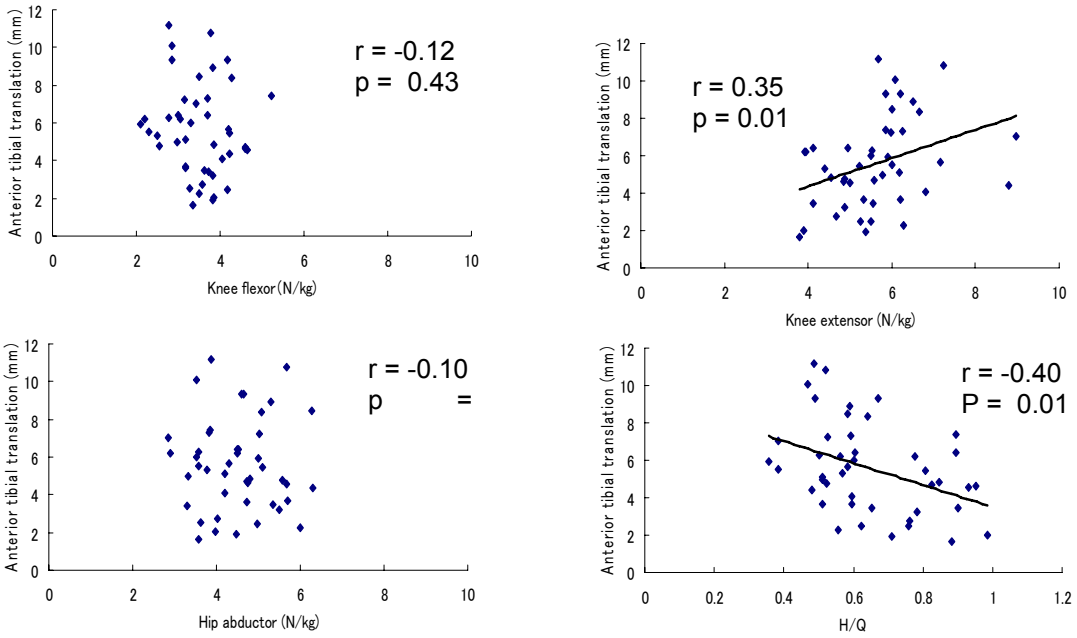

Figure 2: Correlation between anterior tibial translation and knee flexor, knee extensor, hip abductor and H/Q ratio in the non-dominant leg

REFERENCES:

Boden BP, Griffin LY, Garrett Jr. WE. (2000). Etiology and prevention of noncontact ACL injury. *Physicians Sports Med*. 28, 53-60.

Ergun M, Islegen C, Taskiran E (2004). A cross-sectional analysis of sagittal knee laxity and isokinetic muscle strength in soccer players. *Int J Sport Med*. 25, 594-8.

Fukuda Y, Woo SL, Loh JC, et al. (2003). A quantitative analysis of valgus torque on the ACL: a human study. *J Orthop Res.* 21, 1107-12.

Kettunen JA, Kujala UM, Raety H, et al. (1997). Determinants of sagittal knee laxity in former elite athletes. *Sports Exerc and Injury*. 3, 164-7.

Markolf KL, Barrgar WL, Shoemaker SC, et al. (1981). The role of joint load in knee stability. *J Bone Joint Surg (Am)*, 63, 570-85.

Myer GD, Ford KR, Hewett TE (2005). The effect of gender on quadriceps muscle activation strategies during a maneuver that mimics a high ACL injury risk position. *J Electromyogr Kinesiol.* 15, 181-9.

Rosene JM, Fogarty TD (1999). Anterior tibial translation in collegiate athletes with normal anterior cruciate ligament integrity. *J Athl Train*. 34 (2), 93-8.

Sell TC, Ferris CM, Tsai YS, et al. (2007). Predictors of proximal tibia anterior shear force during a vertical stop-jump. *J Orthop Res.* 25 (12), 1589-97.

Steiner ME, Grana WA, Chillag K, et al. (1986). The effect of exercise on anterior-posterior knee laxity. *Am J Sports Med*. 14, 24-9.

Uhorchak JM, Scoville CR, Williams GN, et al. (2003). Risk factors associated with noncontact injury of the anterior cruciate ligament. *Am J Sports Med*. 31 (6), 831-42.

Wojtys EM, Wylie BB, Huston LJ (1996). The effects of muscle fatigue on neuromuscular function and anterior tibial translation in healthy knees. *Am J Sports Med*. 24, 615-21.