



Original Article

# Gender-related differences in lower limb alignment, range of joint motion, and the incidence of sports injuries in Japanese university athletes

YASUHIRO MITANI, RPT, PhD<sup>1)</sup>

<sup>1)</sup> Department of Rehabilitation Sciences, Faculty of Allied Health, Kansai University of Welfare Sciences: 3-11-1 Asahigaoka, Kashiwara, Osaka 582-0026, Japan

**Abstract.** [Purpose] To investigate the gender-related differences in lower limb alignment, range of joint motion, and history of lower limb sports injuries in Japanese university athletes. [Subjects and Methods] The subjects were 224 Japanese university athletes (154 males and 70 females). The quadriceps angle (Q-angle), arch height index, and ranges of internal and external rotation of the hip joints were measured. History of lower limb sports injury was surveyed using a questionnaire. [Results] Females had a significantly higher Q-angle and hip joint internal rotation angle and a significantly lower arch height index than males. The survey revealed that a significantly higher proportion of females had a history of lower limb sports injuries, and that the proportion of those with a history of foot/ankle injuries was particularly high. [Conclusion] These results suggested that females experience more lower limb sports injuries than males, and that a large proportion of these injuries involve the foot/ankle. Reduced lower limb alignment and increased range of joint motion in females may be risk factors for injury because they lead to increased physical stress being exerted on the lower legs during sporting activities.

**Key words:** Alignment, Range of joint motion, Sports injury

(This article was submitted Jul. 15, 2016, and was accepted Sep. 14, 2016)

## INTRODUCTION

An epidemiological survey of sports injuries in 51,047 males and females in Japan revealed a significantly higher incidence of knee joint, lower leg, and foot injuries in females than in males<sup>1)</sup>. In addition, it has been reported that the frequency of anterior cruciate ligament (ACL) injuries among basketball and soccer players is significantly higher in females<sup>2, 3)</sup>. As these findings suggest that females are more prone to lower limb sports injuries than males, it is important to understand the causes of these injuries in order to improve the prevention strategies available.

It is possible that muscle strength, muscle contraction rate, and joint flaccidity affect sports performance. In general, muscle strength is lower, the muscle contraction rate is slower, and joint flaccidity is higher in females than those in males<sup>4-6)</sup>, suggesting gender-related differences in the incidence of sports injuries. Furthermore, lower limb alignment and the range of joint motion are believed to affect the occurrence of sports injuries; for example, increased knee valgus and increased internal rotation of the hip are known risk factors for ACL injury<sup>7)</sup>. Thus, the characteristics of the alignment and range of joint motion of the lower limbs in males and females are possible factors that may confirm the gender-related difference in the frequency of lower limb sports injuries.

Nguyen performed a survey of gender-related differences in lower limb alignment, and reported that the quadriceps angle (Q-angle), tibiofemoral angle, and genu recurvatum deformity are more pronounced in females<sup>8)</sup>. However, the gender-

---

Corresponding author. Yasuhiro Mitani (E-mail: mitani@tamateyama.ac.jp)

©2017 The Society of Physical Therapy Science. Published by IPEC Inc.

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License <<http://creativecommons.org/licenses/by-nc-nd/4.0/>>.

**Table 1.** The competitive areas of the subjects

	Males (n=154)	Females (n=70)
Rugby	35	0
Track and field	23	10
Handball	13	13
Kendo	14	7
Gymnastics artistic	11	5
Volleyball	10	6
Basketball	7	8
Judo	8	6
Swimming	8	6
Soccer	10	2
Baseball	10	0
Tennis	2	4
Creative dance	2	2
Nippon kempo	1	0
Naginata	0	1

related differences in lower limb alignment and range of joint motion in university athletes have not been extensively assessed. Therefore, we measured lower limb alignment and the range of joint motion in Japanese university athletes, surveyed their history of lower limb sports injuries, and investigated the presence or absence of potential gender-related differences in these athletes. We also considered the relationship between gender-related differences related lower limb sports injuries and those related to lower limb alignment and range of joint motion.

## SUBJECTS AND METHODS

The subjects were 224 Japanese university athletes (154 males; mean height:  $174.8 \pm 8.6$  cm; mean weight:  $76.0 \pm 16.0$  kg; and 70 females; mean height:  $163.4 \pm 6.8$  cm; mean weight:  $59.7 \pm 9.2$  kg). All of the subjects were first-year university students with a high level of competitive sports skill. The competitive areas of the subjects are indicated in Table 1.

The objectives and methods of this study were explained to the subjects, and their consent to participate was obtained. This study was conducted with the approval of the Ethics Committee of Shijonawate Gakuen University (Approval Number 23-1).

To assess lower limb alignment, the Q-angle and arch height index were measured in the standing position. To assess the range of joint motion of the lower limbs, the ranges of internal and external rotation of both hip joints were measured (308 male legs, 140 female legs). The Q-angle and arch height index were measured in the standing position, with the soles contacting the ground in a manner such that the center of the heel and the second toe passed over parallel lines 20 cm apart on the floor. The subjects looked straight ahead at a mark positioned at eye level, and were instructed not to shift their center of mass. To assess the Q-angle, the angle formed by a line linking the superior anterior iliac spine and the center of the patella and a line linking the center of the patella and the tibial tuberosity was measured using a goniometer. The arch height index was calculated by dividing the height of the navicular bone by the length of the foot. The height of the navicular bone was measured using a ruler as the distance from the floor to its most protruding portion. Foot length was measured using a measuring tape as the distance from the rear end of the heel to the tip of the longest toe. The ranges of internal and external rotation of the hip joints were measured using a goniometer in the prone position with the knee joint bent at  $90^\circ$ . The history of lower limb sports injury was surveyed by questionnaire, and the presence or absence of a history of lower limb injury and the proportions of each type of injury were calculated. For subjects with a history of lower limb injury, the proportions of subjects with foot/ankle, lower leg, knee, and thigh injuries were calculated.

The Mann-Whitney *U*-test was used to compare values between the genders. The  $\chi^2$  test was used to compare the proportion of subjects with a history of injury between the genders. The significance threshold was 5%. IBM SPSS Statistics 20 for Windows was used for all statistical analyses.

## RESULTS

Females had a significantly higher Q-angle and hip joint internal rotation angle, and a significantly lower arch height index than males (Table 2). In total, a significantly higher proportion of females (64.3%,  $n=45$ ) than males (46.1%,  $n=71$ ) had a history of lower limb sports injury ( $p<0.05$ ). Furthermore, a significantly higher proportion of females (34.3%,  $n=24$ ) than

**Table 2.** The values of alignment and range of joint motion of the lower limb

	Males	Females
Q-angle (degrees)	11.3 ± 4.8	15.0 ± 5.1**
Arch height index	0.183 ± 0.030	0.168 ± 0.025**
Hip joint internal rotation angle (degrees)	27.1 ± 9.6	40.3 ± 9.8**
Hip joint external rotation angle (degrees)	40.3 ± 8.0	40.6 ± 8.6

Mean ± SD, \*\*p<0.01

males (20.8%, n=32) had a history of foot/ankle injuries (p<0.05). A history of lower leg injuries was found in 4.5% (n=7) of males and in 11.4% (n=8) of females, a history of knee injuries was found in 24.7% (n=38) of males and in 32.9% (n=23) of females, and a history of thigh injuries was found in 9.1% (n=14) of males and in 11.4% (n=8) of females, with none of these differences showing statistical significance. However, as three males and five females had a history of ACL injury, a tendency for more injuries was seen in females.

## DISCUSSION

The Q-angle in females was significantly higher than that in males in this study and was correlated with the tibia-femur angle<sup>9)</sup>, implying that females have a greater knee valgus than males. An increase in knee valgus increases the tensile stress experienced by the medial knee and compressive stress by the lateral knee, and is thus considered to be associated with medial collateral ligament and meniscus damage. Furthermore, an increase in the Q-angle increases the compressive stress on the patellofemoral joint<sup>10)</sup>, causing patellofemoral joint inflammation. The knee joint at ACL injury onset is often in the valgus position<sup>11)</sup>; therefore, an increase in knee valgus is thought to increase the risk of physical stress on the knee and as a consequence ACL injury<sup>12)</sup>. Consequently, it is inferred that females, who have a greater Q-angle than males, have a higher incidence of sports-related knee injuries. In particular, the incidence of ACL injuries is considered to be greater in females<sup>2,3)</sup>, and the present results also reflected a tendency toward more females having a history of ACL injuries than males. Therefore, an increased Q-angle (i.e., increased knee valgus) seems to predispose individuals to ACL injuries. However, Pantano et al. reported that there was no relationship between the Q-angle and knee valgus during one-legged squats<sup>13)</sup>, so there is not necessarily a definite relationship between the Q-angle measured when standing still and the physical stress imparted on the knees during sporting activities. In addition, as the present results revealed no gender-related differences in subjects with a history of knee injury, further investigation of the relationship between the Q-angle and the incidence of knee injury is necessary.

In the present study, females had a significantly lower arch height index than males. The arch of the foot acts to cushion shocks when loaded, and so it is possible that a decreased arch height index is associated with insufficient cushioning of shocks, thereby increasing the physical stress exerted on the legs during sporting activities. Furthermore, a decrease in the arch height index is associated with pronation of the foot when loaded. Tensile stress on the medial ankle joint and compressive stress on the lateral ankle joint increase as a result of greater pronation of the foot. Consequently, it is possible that a smaller arch height index is associated with increased physical stress exerted on the foot and ankle joint during sporting activity, and these factors can therefore be regarded as injury-causing factors. Similarly, since the present results revealed that a greater proportion of females had a history of foot/ankle injury than males, the reduced arch height index in females might be associated with the incidence of foot/ankle injuries. Pronation of the foot induces knee valgus and internal rotation of the lower leg<sup>14)</sup>, suggesting that a low arch height index is associated with increased physical stress on the knee joint. However, as stated earlier, no gender-related differences were found in the subjects with a history of knee injury; therefore, further study of the relationship between a decreased arch height index and the incidence of knee injury is necessary. A significantly higher angle of internal rotation of the hip joint was noted in females compared to that in males. Because the position of internal rotation of the hip joint is thought to determine the risk for ACL injury<sup>7)</sup>, the incidence of ACL injury is higher in females, because they have a greater angle of internal rotation of the hip joint than males.

The survey revealed that a significantly higher proportion of females had a history of lower limb sports injuries than males, and that those with a history of foot/ankle injuries were particularly common. Furthermore, the history of ACL injury tended to be higher in females. Lower limb alignment and the increased range of joint motion in females might then be risk factors for injury because of the increased physical stress they exert on the lower legs during sporting activities. Thus, to develop preventive strategies for such injuries, it is necessary to thoroughly understand the characteristics of lower limb alignment and range of joint motion in both genders.

In this study, no gender-related differences were seen between those with a history of sports injuries other than for injuries involving the feet/ankles. The site of sports injury onset is related to the characteristics of the sport in question, so each sport as well as the frequency of onset per unit time of competition will need to be assessed individually in the future.

## REFERENCES

- 1) Takahashi S, Suzukawa M, Kawamura M, et al.: An epidemiological study of sports injuries in a sports medical center rehabilitation department: —The first report—all sports injuries. *The Journal of Japanese Society of Clinical Sports Medicine*, 2010, 18: 518–525. (in Japanese).
- 2) Agel J, Arendt EA, Bershadsky B: Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer: a 13-year review. *Am J Sports Med*, 2005, 33: 524–530. [[Medline](#)] [[CrossRef](#)]
- 3) Jenkins WL, Killian CB, Williams DS 3rd, et al.: Anterior cruciate ligament injury in female and male athletes: the relationship between foot structure and injury. *J Am Podiatr Med Assoc*, 2007, 97: 371–376. [[Medline](#)] [[CrossRef](#)]
- 4) Häkkinen K: Force production characteristics of leg extensor, trunk flexor and extensor muscles in male and female basketball players. *J Sports Med Phys Fitness*, 1991, 31: 325–331. [[Medline](#)]
- 5) Bell DG, Jacobs I: Electro-mechanical response times and rate of force development in males and females. *Med Sci Sports Exerc*, 1986, 18: 31–36. [[Medline](#)] [[CrossRef](#)]
- 6) Beighton P, Solomon L, Soskolne CL: Articular mobility in an African population. *Ann Rheum Dis*, 1973, 32: 413–418. [[Medline](#)] [[CrossRef](#)]
- 7) Ireland ML: Anterior cruciate ligament injury in female athletes: epidemiology. *J Athl Train*, 1999, 34: 150–154. [[Medline](#)]
- 8) Nguyen AD, Shultz SJ: Sex differences in clinical measures of lower extremity alignment. *J Orthop Sports Phys Ther*, 2007, 37: 389–398. [[Medline](#)] [[Cross-Ref](#)]
- 9) Nguyen AD, Shultz SJ: Identifying relationships among lower extremity alignment characteristics. *J Athl Train*, 2009, 44: 511–518. [[Medline](#)] [[CrossRef](#)]
- 10) Huberti HH, Hayes WC: Patellofemoral contact pressures. The influence of q-angle and tendofemoral contact. *J Bone Joint Surg Am*, 1984, 66: 715–724. [[Medline](#)]
- 11) Olsen OE, Myklebust G, Engebretsen L, et al.: Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sports Med*, 2004, 32: 1002–1012. [[Medline](#)] [[CrossRef](#)]
- 12) Hewett TE, Myer GD, Ford KR, et al.: Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. *Am J Sports Med*, 2005, 33: 492–501. [[Medline](#)] [[CrossRef](#)]
- 13) Pantano KJ, White SC, Gilchrist LA, et al.: Differences in peak knee valgus angles between individuals with high and low Q-angles during a single limb squat. *Clin Biomech (Bristol, Avon)*, 2005, 20: 966–972. [[Medline](#)] [[CrossRef](#)]
- 14) Khamis S, Yizhar Z: Effect of feet hyperpronation on pelvic alignment in a standing position. *Gait Posture*, 2007, 25: 127–134. [[Medline](#)] [[CrossRef](#)]