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Gender differences in knee kinematics and muscle activity during single limb drop landing

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Abstract

The likelihood of sustaining an ACL injury in a noncontact situation is two to eight times greater for females than for males. However, the mechanism and risk factors of ACL injury are still unknown. We compared knee kinematics as well as electromyographic activity during landing between male and female athletes.

Eighteen male athletes and nineteen female athletes participated in the experiment. The angular displacements of flexion/extension, valgus/varus, and internal/external tibial rotation, as well as the translational displacements of anterior/posterior tibial translation during single limb drop landing were calculated. Simultaneous electromyographical activity of the rectus femoris (RF) and hamstrings (Ham) was taken.

During landing, internal tibial rotation of the females was significantly larger than that of the males, while differences were not observed in flexion, varus, valgus, and anterior tibial translation. Hamstrings/quadriceps ratio (HQR) for the 50 ms time period before foot contact was greater in males than in females.

The mechanism of noncontact ACL injury during a single limb drop landing would be internal tibial rotation combined with valgus rotation of the knee. Increased internal tibial rotation combined with greater quadriceps activity and a low HQR could be one reason female athletes have a higher incidence of noncontact ACL injuries.

Keywords: ACL injury; Risk factor; Tibial rotation; Hamstrings/quadriceps ratio

1. Introduction

In sports science, many researchers have studied the mechanism as well as the risk factors of anterior cruciate ligament (ACL) injury. ACL injury is one of the most common injuries in sports activities and often occurs in noncontact situations [1–3]. The likelihood of sustaining an ACL injury is two to eight times greater for females than for males [1,3–6].

According to questionnaire and video analyses [2,7–9], a large portion of ACL injuries occur in the noncontact situation at the time of foot strike during sudden stopping, cutting or landing. The position of the knee at the time of injury is in slight flexion and valgus with the tibia in internal or external rotation [9].

In biomechanical studies, increased knee valgus and high abduction loads increased the risk of ACL injury during athletic tasks [10–16]. The angle of knee flexion was also a factor during ACL injury [11,14,17–19]. Furthermore, Wojtys et al. reported that female athletes have greater internal tibial rotation during external loading. However, the relationship between rotation of the tibia and the risk of ACL

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injury during the high risk maneuver (i.e., landing, cutting) are still unknown.

The purpose of this study was to analyze the 3-D *in vivo* kinematics of the knee including tibial rotation during a single limb drop landing. Moreover, we compared knee kinematics as well as electromyographic activity of the quadriceps and hamstrings between male and female athletes to examine the risk factors of ACL injury. Our hypothesis was that female athletes have greater internal tibial rotation also during landing and therefore have greater risk for ACL injury.

2. Materials and methods

2.1. Subjects

Eighteen male athletes and nineteen female athletes who attend Waseda University and were free of musculoskeletal ailment participated in the experiment. The average age of the male subjects was 19.8 (4.6) yrs. (Mean (SD)), the average height was 1.77 (0.4) m, the average weight was 68.7 (16.2) kg and the average BMI was 21.9 (0.9). The average age of the female subjects was 19.4 (0.9) yrs., the average height was 1.66 (0.1) m, the average weight was 60.0 (7.5) kg and the average BMI was 21.6 (1.6). Ten male and eleven female subjects were basketball players, while the remaining eight male and eight female subjects were tennis players. Subjects who played different sports were recruited to examine the difference between genders that is not influenced by a particular sports activity. Subjects signed an informed consent document approved by Waseda University.

2.2. Experimental task

All subjects performed a single limb drop landing from a 30 cm platform (Fig. 1). The subjects were instructed to put their hands on their lower torso, stand on their right foot, and jump 30 cm away from the platform. The subjects were to land on their right foot with their foot in a neutral position (Fig. 2). Upon landing, each subject was instructed to place their center of mass as far forward as possible in an attempt to limit horizontal motion and land without jumping up. Throughout the experiment, the subjects were barefoot. The subjects were allowed several preparation trials. Measurement was continued until three successful trials were accomplished consecutively.

Fig. 1. Landing position and arrangement of makers. Subjects performed a single limb drop landing from a 30 cm platform. Twenty four reflective markers of 9 mm diameter were secured to the limb.

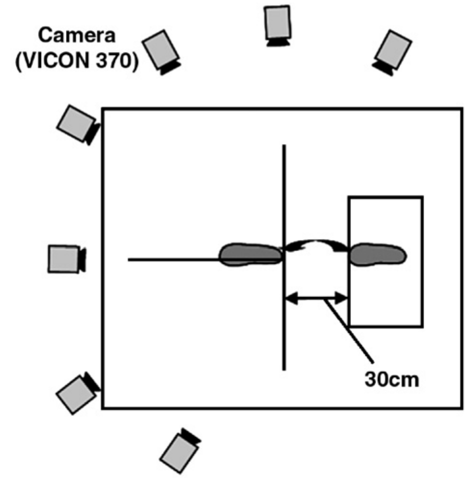

Fig. 2. Experiment setup and task. Subjects landed on their right foot 30 cm away from the platform. A seven camera VICON 370 motion analysis system was used.

2.3. Data collection

All experiments took place at the National Rehabilitation Center for Persons with Disabilities in Saitama, Japan. A seven camera VICON 370 motion analysis system (Oxford Metrics Ink., Oxford, UK) was used to record the 3-D movements of the lower limb (Fig. 2). The laboratory was equipped with six force plates (9287A, Kistler Japan Co., Ltd., Tokyo, Japan). The motion and force data were recorded at 200 Hz and 1000 Hz, respectively.

For each subject, twenty four reflective markers of 9 mm diameter were secured to the lower limb using double-sided adhesive tape (Fig. 1). The markers were used to implement the Point Cluster Technique (PCT) [20]. The PCT provides a minimally invasive estimation of the *in vivo* motion of the knee. By using a cluster system of skin markers on a limb segment, the PCT assumes to cancel out the noise resulted from skin deformation. We developed our algorithm of the PCT following the procedure described by Andriacchi et al. [20]. We calculated the knee kinematics using the Joint Coordinate System proposed by Grood and Suntay [21]. In the PCT, the skin markers are classified into two groups: a cluster of points representing a segment and points representing bony landmarks. For a cluster of points, ten and six markers were attached on the thigh and shank segment, respectively. The bony landmarks were the great trochanter, the lateral and medial epicondyles of the femur, the lateral and medial edges of the tibia plateau, the lateral (fibula) and medial malleoli and the fifth metatarsophalangeal joint.

Simultaneous electromyographical activity of the rectus femoris (RF), biceps femoris (BF) and semimembranosus (SM) were measured. Amplified surface electrodes (DelSys, Inc., Boston, USA) were used to detect muscular activity. Preamplification was equal to 1000, while the common mode rejection rate was 92 dB. Double-sided adhesive strips were used to adhere the electrodes to the subject's skin. Additionally, surgical tape (NICHIBAN Co., Ltd. Tokyo, Japan) was placed over the electrodes as well as around the thigh and shank to retard movement of the electrodes on the skin that would cause movement artifacts. Surface EMG electrodes were placed at the midpoint of the top of the patella to the posterior superior iliac spine over the muscle belly of the RF and distally one-third of the distance from the knee joint space to the ischial tuberosity over the muscle bellies of the BF and the SM. The reference electrode was placed on the head of the fibula. We recorded the EMG data at 1000 Hz.