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Knee rotation associated with dynamic knee valgus and toe direction

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ABSTRACT

Background: Dynamic knee valgus contributes to injuries of the anterior cruciate ligament (ACL). However, it is unclear how the knee rotates during dynamic knee valgus. Knee rotation significantly affects ACL strain. To understand knee rotation during dynamic knee valgus should help the clinician evaluate dynamic alignment. The purpose of this study was to determine how the knee rotates during dynamic knee valgus and whether the knee rotation is affected by toe direction (foot rotation).
Methods: Sixteen females performed dynamic knee valgus in three toe directions (neutral, toe-out, and toe-in) while maintaining the knee flexion angle at 30°. The knee rotation angle was evaluated using a 7-camera motion analysis system. Knee rotation was compared between the start position and the dynamic knee valgus position, as well as among the three toe directions, using repeated measures ANOVA models.
Results: The knee significantly rotated externally in the dynamic knee valgus position compared with the start position in two toe directions (neutral and toe-out). A similar tendency was observed with the toe-in condition. Toe direction significantly affected the knee rotation angle. For toe-out and toe-in conditions, external and internal shifts of knee rotation compared with neutral were observed.
Conclusions: The knee rotates externally during dynamic knee valgus, and the knee rotation is affected by toe direction.
Clinical Relevance: Because of knee abduction and external rotation, the ACL may impinge on the femoral condyle in the case of dynamic valgus, especially in the toe-out position.

1. Introduction

Anterior cruciate ligament (ACL) injury is one of the most common sports injuries, with about 100,000 such injuries occurring each year in the United States (US) [1]. Approximately 50,000 ACL reconstructions are performed each year in the US [2], and if an ACL reconstruction costs $17,000 [3], the economic cost is almost $850,000,000 per year in the US. However, ACL injury not only causes economic loss, but also results in time lost from sports activity and work in the short term. In the long term, it causes osteoarthritic changes with or without ACL reconstruction [4]. These reports indicate that prevention of ACL injury is very important.

Various programs for the prevention of ACL injury have been suggested, and their efficacies have been validated [5–7]. Nevertheless, the rate of ACL injury remains constant over the decades [8]. The reason for this appears to be that prevention programs are not popular, and they are not provided in cooperation with athletes and therapists. If ACL injury prevention programs were to become effective and easy to implement, they may become widespread. To prepare simple programs, however, understanding the mechanisms and risk factors for ACL injury is important.

It has been reported that 70% of ACL injuries occur in noncontact situations, including cutting, landing, pivoting, and deceleration without contact with opponents [9]. Based on the reports of video analyses of ACL injuries, the knee is in slight flexion and abduction at the moment of ACL injury [10,11]. Bone bruises appear after ACL injury in the lateral knee compartment [12–14]. These studies suggest that knee abduction motion occurs at the time of ACL injuries. Hewett et al. [15], in their prospective report, examined the relationships among ACL injury, the knee abduction angle, and the external knee abduction moment during the landing maneuver. They noted that the subjects who demonstrate the dynamic posture called dynamic knee valgus had greater risk for ACL injury. Poor neuromuscular control may induce greater knee abduction, which is thought to be a risk factor for ACL injury.

The prevention programs have focused on dynamic posture, such as preventing knee abduction motion during athletic tasks [5–7,16]. Many researchers have reported that knee rotation is significantly related to ACL injury [17–22]. However, knee rotation has not been sufficiently investigated in vivo. Internal rotation of the knee combined with knee abduction significantly increases ACL strain, compared with knee

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abduction alone [18,21,22]. Furthermore, knee external rotation combined with knee abduction increases the risk of ACL injury, because the ACL impinges on the femoral condyle [17,19,20]. Therefore, it is very important to examine how the knee rotates during dynamic knee valgus.

Dynamic knee valgus is regarded not only as frontal plane motion (hip adduction, knee abduction, and ankle eversion), but also as horizontal plane motion (femoral internal rotation and tibial internal or external rotation) [15,23]. There is no consensus about the direction of tibial rotation during dynamic knee valgus. Tibial rotation should be significantly affected by ankle and foot kinematics. Ankle eversion causes tibial internal rotation [24,25], and foot internal and external rotations also theoretically cause tibial internal and external rotations through the ankle joint.

The purposes of this study were to reveal how the knee rotates during dynamic knee valgus and to determine whether knee rotation is affected by toe direction, including foot internal and external rotation. We hypothesized that the knee rotates externally during dynamic knee valgus and that knee rotation is affected by toe direction.

2. Materials and methods

2.1. Subject

Sixteen women (mean ± SD: age 21.5 ± 1.6 years; height 158.5 ± 5.8 cm; weight 53.1 ± 7.6 kg) participated in this study. Women were chosen as subjects because they have a greater risk of ACL injury [8]. Subjects were excluded if they reported any previous history of musculoskeletal injury (e.g., sprain, fracture, low back pain) or neurological or systemic disease. All subjects read and signed an informed consent form approved by the Institutional Review Board of Hokkaido University.

2.2. Procedures and instrumentations

The experimental trials were conducted in the laboratory of Hokkaido University. Forty retroreflective markers were placed on the sacrum, right iliac crest, and bilateral shoulders, anterior superior iliac spines, greater trochanters, hips, medial and lateral knees, medial and lateral ankles, heels, 2nd and 5th metatarsal heads, and right thigh and shank cluster markers (Fig. 1). In all subjects, the dominant leg (the side for kicking a ball) was the right leg. Throughout the experiment, the subjects were barefoot. First, the data of the static standing trial were collected for each subject. Then, the data for the dynamic knee valgus trials, in which the subjects stepped forward 40% of their height with their dominant leg and maintained the trunk upright were collected for each subject (Fig. 2). During the dynamic knee valgus trials, the subjects maintained the knee flexion angle at 30°, and the investigator checked the knee flexion angle with a traditional goniometer. The toe directions (from the heel to the 2nd metatarsal head) of the right foot were set in three directions, including 0° (neutral), 10° (toe-out), and −10° (toe-in) relative to the sagittal plane on the horizontal plane (Fig. 3). The toe direction of the left foot was always set at 0° (neutral). The subjects were asked to maintain the knee directed forward in the start position. The subjects performed maximum dynamic knee valgus for 5 s in each toe direction (Fig. 2). During the dynamic knee valgus position, the subjects maintained neutral rotation of their pelvis as

Fig. 1. Marker placement.

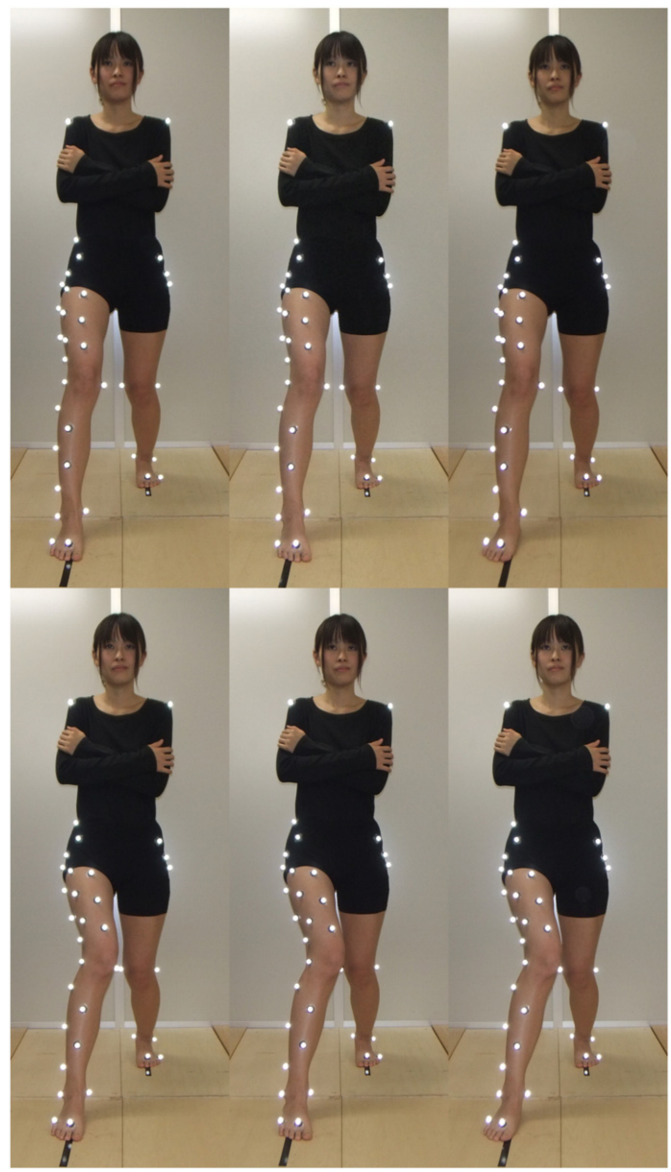

Fig. 2. Upper and lower panels demonstrate start position and dynamic knee valgus position respectively. Also, left, center and right panels show neutral, toe-in and toe-out toe directions. Neutral toe direction was set at 0° relative to the sagittal plane on the horizontal plane, and toe-in and toe-out was set −10° and 10°, respectively. During trials, the subjects were asked to step forward 40% of their height with dominant leg, and also maintain the trunk upright and the knee flexion angle at 30°. The subjects performed maximum dynamic knee valgus for 5 s on each toe directions (lower three panels).