The Knee 20 (2013) 85–89

Contents lists available at SciVerse ScienceDirect

The Knee

Sidestep cutting maneuvers in female basketball players: Stop phase poses greater risk for anterior cruciate ligament injury

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ARTICLE INFO

Article history:
Received 24 October 2011
Received in revised form 25 June 2012
Accepted 8 July 2012

Keywords:
Anterior cruciate ligament injury
Basketball
Electromyographic
Kinematics
Sidestep cutting maneuver

ABSTRACT

Background: Many non-contact anterior cruciate ligament (ACL) injuries in female basketball players occur during sidestep cutting. The objective of this study was to identify the phases of a sidestep cutting maneuver that place athletes at a greater risk for ACL injuries.
Methods: Ten healthy female collegiate basketball athletes were asked to perform sidestep cutting movements; the knee flexion and valgus angles as well as the electromyographic activity of the vastus lateral, vastus medial, biceps femoris, and semimembranosus muscles of the non-dominant leg were analyzed during the maneuver.
Results: The mean knee valgus angle peak tended to be greater during the stop phase than during the side-movement phase. The quadriceps activation during the stop phase was significantly higher than that during the side-movement phase. Moreover, the ratio of hamstring to quadriceps muscle activation during the stop phase was significantly lower than that during the side-movement phase, as assessed by surface electromyography.
Conclusion: Female basketball athletes have a higher risk for ACL injury during the stop phase than during the side-movement phase of the sidestep cutting maneuver.
Level of evidence: Level III.

1. Introduction

Non-contact anterior cruciate ligament (ACL) injuries commonly occur during stopping, landing, and cutting maneuvers during basketball drills and competitions [1]. Boden et al. [2] reviewed videotapes of ACL disruptions and noted that most non-contact injuries occur with the knee close to extension during a sharp deceleration or landing maneuver. However, anterior drawer load in isolation was insufficient to rupture the ACL without additional valgus load [3]. In addition, knee joint valgus is often implicated as a hazardous position for the ACL [4,5] and has been linked to ACL injury risk [6].

Urabe et al. [7] performed electromyographic (EMG) analysis during jump landing and demonstrated that the ratio of hamstring to quadriceps muscle activation (H/Q ratio) was significantly lower in female athletes even though the knee flexion angle was increased compared to that in the early phase of landing. Anterior tibial translation and ACL strain are increased among female athletes with a low H/Q ratio [8]. The low H/Q ratio could be one of the reasons female athletes have a higher incidence of non-contact ACL injury during jump landing [7]. Colby et al. [9] analyzed quadriceps and hamstring muscle activity during sidestep cutting and demonstrated that the H/Q ratio was the lowest when the knee flexion angle was 33°. Their study suggested that the risk of ACL injury is higher at this angle.

Ireland [10] reported an example of an ACL injury to the left knee as seen from the back and left side of a basketball athlete. In that particular case, the subject had just rebounded and stopped to change direction to avoid the defending player. However, in this situation, the injury is not detected until the athlete takes his or her weight off the injured leg [11]. The body's center of mass moves laterally after one-legged jump landing or stopping during sidestep cutting maneuvers. Therefore, knee valgus and flexion during these three maneuvers favor ACL injury. Based on the potential mechanism of ACL injuries during sidestep cutting maneuvers, the phases at greater risk for ACL injury may be clarified by analyzing the knee flexion angle on the sagittal plane, the knee valgus angle on the frontal plane, and EMG activation of quadriceps and hamstring muscles. Thus far, however, few studies have been conducted from the viewpoint of kinematics and EMG variables during sidestep cutting.

The objective of this study was to identify the phases of a sidestep cutting maneuver that put basketball athletes at a greater risk for ACL injuries by analyzing knee valgus and flexion angles as well as the quadriceps and hamstring activity. We hypothesized that larger knee valgus angles, smaller knee flexion angles, and lower H/Q ratios will appear during deceleration phases of sidestep cutting with greater risk of ACL injury.

2. Methods

Ten healthy female collegiate basketball athletes who reported no orthopedic disease in their lower extremities provided written consent to participate in this study. The subjects' average age, height,

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doi:10.1016/j.knee.2012.07.003

weight, and history of playing basketball were 20.9 ± 2.0 years, 158.4 ± 7.0 cm, 52.8 ± 5.9 kg, and 5.1 ± 0.7 years, respectively. The power for each analysis of variance was not less than 0.65 if the effect size was more than 0.80 [12]. A priori power analysis by G*power revealed that obtaining a static power of 0.75 at an effect size of 0.80 with an alpha level of 0.05 required a sample size of at least 10 subjects. Approval for this study was obtained from the institutional review board of the Graduate School of Health Sciences, Hiroshima University (ID number, 1027).

Four markers were placed on the floor 1 m away from each other. An electric metronome was set at 180 beats/min, and the participant was instructed to begin running on the first beep. The participant ran two steps forward, planted the non-dominant leg on her third step, and then the dominant leg stepped at an angle of approximately 90°. The dominant leg was defined as the leg usually used for kicking a soccer ball [13]. In this study, all of the participants indicated the right leg as their dominant leg. The non-dominant leg was adopted as plant leg based on the fact that the majority of surgical limbs in ACL reconstruction are non-dominant [14]. A cutting trial was deemed successful if the participant performed the maneuver at a speed of 2–3 m/s. Five trials were performed after sufficient practice runs. Fig. 1 shows the protocol used for sidestep cutting. The stop phase was defined as the period from initial foot strike to the maximum knee flexion. The side-movement phase was defined as the period from maximum knee flexion to toeing off. To simulate the actual basketball movements, participants were asked to place their upper limbs in front of their chests as if they were receiving a pass.

Sixteen retro-reflective adhesive backbone markers (10 mm in diameter) were placed over the anterior superior iliac spine, posterior superior iliac spine, lateral and medial condyles of the femur, lateral and medial condyles of the tibia, and lateral and medial malleoli before measurement. Three high-speed (200 frames/s) CCD cameras (Has-200R; Ditect, Tokyo, Japan) were placed at the front and lateral sides of the subjects to measure the knee flexion angle from the sagittal plane and the valgus and varus angles from the frontal plane during sidestep cutting.

The raw kinematic data were filtered using a General Cross Validatory quintic-order spline [15] and analyzed using Dipp-Motion XD software (Ditect, Tokyo, Japan). For quantification of knee joint angles during the cutting cycle, a kinematic model was defined from a standing static trial and from lower limb anthropometric measurement. The hip joint center was estimated from the markers of anterior superior iliac spine and posterior superior iliac spine according to Vaughan's method [16]. Joint centers for the knee and ankle were determined in the standing trial [17]. The femur center was defined as the midpoint between the lateral and medial condyles of the femur. The tibia center was defined as the midpoint between the lateral and medial condyles of the tibia. The talocrural joint center was defined as the midpoint between the lateral and medial malleoli. Knee flexion angles and valgus angles were calculated in the order *xyz* axes according to Grood's method [18] after two skeletal segments (thigh and tibia) were built.

Bipolar superficial EMG sensors (Blue Sensor; MEDICOTEST, Olstykke, Denmark) were placed over the vastus lateral (VL), vastus medial (VM), biceps femoris (BF), and semimembranosus (SM) muscles on each subject's non-dominant leg, following Perotto's method [19] before EMG measurements. Maximal muscle activity was measured during a maximum voluntary isometric contraction (MVIC) against a manual resistance for 5 s [20]. The MVIC tests for the VL and VM oblique muscles were performed while the subject was in a sitting position with the knee flexed at 90°. The MVIC tests for the BF and SM oblique muscles were performed while the subject was in a prone position with the knee flexed at 30°. Raw dynamic EMG and EMG gathered during MVIC were amplified (Bio-amp ML132; AD Instruments, Colorado, USA), subjected to A/D conversion at 1 kHz, and rectified with a high-pass filter at 500 Hz and low-pass filter at 20 Hz (Mac Lab/8s; AD Instruments, Colorado, USA). Then, the data were stored on a personal computer. Kinematic and EMG data were synchronized using a digital timing signal counter (custom-made) and recorded using CCD camera software (Ditect).

To allow for comparison of EMG intensity between phases, EMG obtained during the sidestep cutting maneuver was normalized to

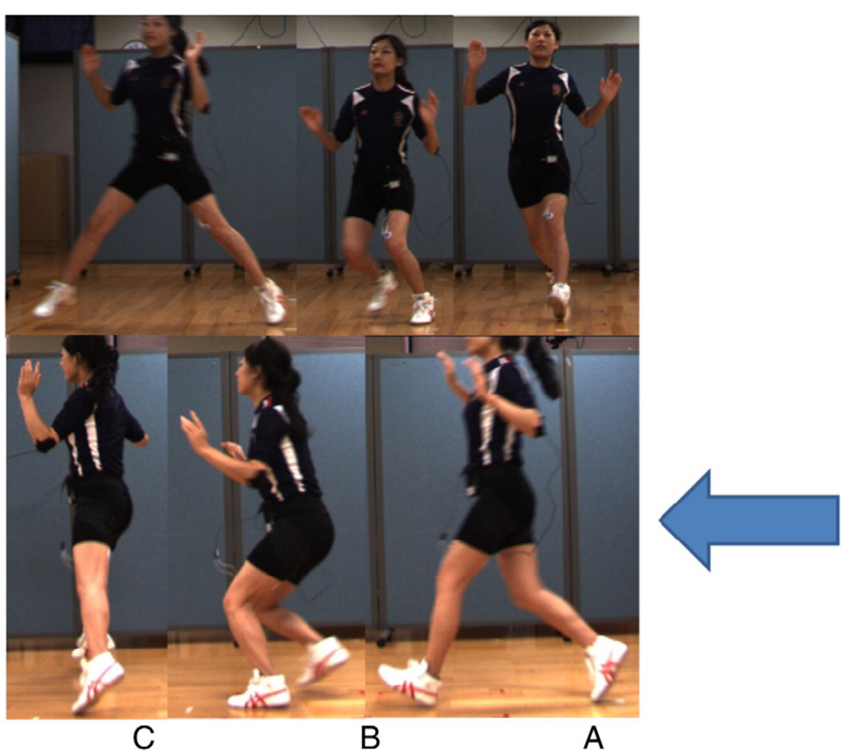

Fig. 1. Sidestep cutting with up to two approach steps and one leg stopping followed by sidestepping. This movement is observed from the anterior (above) and lateral aspects (below). A: Initial contact of the left foot. B: Maximum flexion of the left knee. C: Left foot toeing off while right foot sidesteps. The stop phase is from A to B, and the side-movement phase is from B to C.