Knee and Trunk Kinematics during anticipated and unanticipated side step and crossover cutting tasks

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Introduction:
In a sports setting, non-contact anterior cruciate ligament (ACL) injuries often occur during sidestep cutting tasks. The knee abduction and tibial internal rotation angle during sidestep cut would increase than during straight running. Non-contact ACL injuries often occur during an unanticipated sidestep cut, which has been produced to higher knee loads than those that occur during an anticipated maneuver. During sidestep cut, the movement trunk center of mass (CoM) changes laterally. Therefore, trunk orientation would be changed between anticipated and unanticipated cutting task. The aim of this study was to compare knee flexion/extension, knee abduction/adduction, external/internal tibial rotation, trunk orientation (trunk forward orientation and trunk lateral orientation).

METHODS:
Seven healthy athletes (mean age 22.5, range 21-27) performed three anticipated tasks, including running straight, side step cutting (ANS) and crossover cutting (ANC), and three unanticipated tasks, running straight, side step cutting (UNS) and crossover cutting (UNC). Subjects were excluded from the study if they had history of serious musculoskeletal injury, any musculoskeletal injury within the past 6 months. Before participation, all subjects provided written informed consent in accordance with approved by the ethics committee of Waseda University. All subjects were right-leg dominant. The dominant leg was determined as the leg used kick a ball.

An eight-camera high speed motion analysis system (Hawk; Motion Analysis Corp., Santa Rosa, CA) was used to record the lower limb and trunk movements three dimensionally. Ground reaction forces were recorded using a force plate (9287A; Kistler Japan Co., Ltd., Tokyo, Japan) to determine the foot contact. The motion and force data were recorded at 200 Hz.

To each subject, 25 and reflective markers were secured to the lower limb and 12 markers were to the trunk. A three segment model was created including trunk, thigh and shank of the left lower extremity using the point Cluster Technique (PCT). We calculated knee kinematics using the joint coordinate system proposed by Grood and Suntay. For PCT, the skin markers are classified into two groups: a cluster of points representing a segment and points representing bony landmarks. For the cluster of points 10 and 6 markers were attached respectively to the thigh and shank segment. The bony landmarks of these segments were the great trochanter, the lateral and medial epicondyles of the femur, the lateral and medial edges of the tibia plateau, the lateral and medial malleol, calcaneal, and the fifth metatarsophalangeal joint. For the trunk, the bony landmarks were right and left shoulders, clavicles, sternum, the 3rd thoracic vertebrae.

The subjects were required to perform at least 3 successful trials of 3 maneuvers, a straight run, a sidestep cutting, and a crossover cutting, under two different conditions, anticipated and unanticipated. Colored tape placed at 45° angles from the force plate was used to provide visual feed back. For this study, only the sidestep cut and crossover cut trials were analyzed. Using a target board with three LED, subjects were given cues for 1 of the 3 tasks in both the anticipated and unanticipated conditions. Subjects received the cue before the trial, for the anticipated trials. During unanticipated trials, subjects received visual cue approximately 400 msec before reaching the force plate. Subject performed the sidestep cut at 5.0 ± 0.5 m · s⁻¹ and achieved a cut angle of 45 ± 5° based on marks the floor.

In each trial, we calculated the angular displacements of flexion/extension, abduction/adduction, and external/internal tibial rotation using PCT. The trunk orientation (trunk forward orientation and trunk lateral orientation) was also calculated. The trunk orientation was aligned with respect to global axes. The reference position for these movements was obtained during the static trial. We analyzed each variable at the time of 100msec before foot contact, the time of foot contact, and the peak value at stance phase. All independent variables were calculated for each trial, then averaged across three trials.

A paired t-test was performed to determine differences between anticipated and unanticipated condition during side step and crossover cutting tasks respectively at 100msec before foot contact, the foot contact and the peak value at stance phase. Significance was set at p<0.05.

RESULTS:
The UNC task result in greater knee abduction angle at 100 msec before foot contact and foot contact compare to ANS (p<0.05). There was no significant knee abduction difference between ANS and UNC at peak value during stance phase. Neither knee abduction at each point was significantly different between ANS and UNC, and ANC and UNC at each point were not significantly different respectively.

Trunk forward orientation was not significantly different between anticipated and unanticipated tasks (Figure.1). During anticipated task, trunk lateral orientation tilted toward step direction than unanticipated task both sidestep cut and crossover cut (Figure.1).

DISCUSSION:
The primary purpose of this study was to compare the biomechanical characteristics of the knee and trunk during anticipated and unanticipated cutting maneuvers. Neither the knee abduction nor external tibial rotation angle at peak value was different between anticipated and unanticipated condition. But the trunk lateral orientation shifted toward opposite to the stepping direction during sidestep cut. Therefore, the trunk CoM would be shifted to same direction and this would increase the knee abduction moment. Therefore unanticipated sidestep cut would be risk factor of non-contact ACL injuries.

This study has several limitations. Influences of the hip and ankle have recently been suggested. However, this present study analyzed only the kinematics of the knee and trunk. Although joint kinetics holds importance for analyzes of athletic tasks and for examination of the mechanism of injuries, we only analyzed knee and trunk kinematics because we have not developed a joint-moment calculation system corresponding to PCT. Future studies should be examine the relation between kinematics and kinetics data to assess the ACL injury mechanism.

REFERENCES: