LOWER EXTREMITY BIOMECHANICS OF AN ANKLE 'GIVING WAY' CASE DURING THE DROP LANDING

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The purpose of our study was to present an accidental ankle 'giving way' case of a participant with chronic ankle instability (CAI) during drop landing test and compare lower extremity biomechanics with that of the participant's normal landing trials. A 7-camera Vicon system was used to capture motions of the participant drop landing from a 30-cm high box. Ground reaction forces were collected using two force plates. Lower extremity joint angles and moments were generated. Subjective comparisons were made between the giving way trial and normal trials. For the giving way trial, the participant exhibited greater ankle inversion, internal rotation and less hip abduction angle in pre-landing phase compared to the normal trials. In addition, the ankle exhibited greater eversion moment and external rotation moment in the landing phase. Center of pressure was more lateral in the giving way trial. We suggest that a more inverted and internally rotated ankle position before landing may place ankle at a high risk of giving way and sprain for CAI individuals.

KEYWORDS: ankle sprain, landing technique, inverse dynamic.

INTRODUCTION: Lateral ankle sprain is one of the most common musculoskeletal injuries during physical activity (Doherty et al., 2014). An initial ankle sprain often causes repeated sprains and results in chronic ankle instability (CAI) (Hertel, 2002). The most common mechanism of a lateral ankle sprain has been attributed to excessive ankle inversion with plantarflexion angle (Hertel, 2002). However, direct biomechanical evidence behind the mechanism is still limited. A previous case study reported biomechanics of a lateral ankle sprain incidence for an individual without CAI during a cutting maneuver (Fong et al., 2009). Greater ankle internal rotation at initial contact has been observed for the injury trial. However, without joint kinetics information, the detailed mechanism of ankle sprain is still unrevealed.

During an ongoing research study on CAI landing mechanics, one participant experienced an accidental episode of the ankle 'giving way' (peak angles: inversion = 58°; internal rotation = 50°) on the 10th and last landing trial of drop landings. Giving way has been described as 'a temporary uncontrollable sensation of instability or rolling over of one's ankle (Simon, Donahue, & Docherty, 2012, p763). The participant's forefoot was contacting the ground while the rearfoot drifted laterally during the giving way. The participant quickly returned and controlled ankle without sprain, losing balance or fall. No injury, pain or other symptoms occurred after the incident. The participant returned to full sports activities the next day. This provided us the opportunity to investigate the mechanics that occurred during an actual giving way landing exhibited by a CAI individual. Therefore, the purpose of our study was to compare lower extremity mechanics exhibited during this giving way landing to the normal landings for this CAI individual.

METHODS: The participant (19 years old, female, 166 cm, 63 kg) completed the previously validated ankle instability questionnaires; the right ankle was classified as CAI (IdFAI = 19, CAIT = 24) and chosen as the test limb. For a given drop-landing trial, the participant stood on a box 30 cm high from the force plates, then stepped forward with the test limb followed by the other limb and landed with test foot on the tilted force plate (25°) and the other foot on the flat force plate (Fig.1). Locations of 29 reflective markers placed on the trunk, pelvis and lower extremity were captured by a 7-camera Vicon system (120 Hz). Two force plates (2040 Hz) were used to collect the ground reaction force (GRF) and center of pressure (COP). Nine normal landing trials and one accidental giving way trial was collected. The

phase of interest included pre-landing (-100 ms to 0 ms) and landing phase (0 ms to +200 ms). Ankle joint angles were calculated using Cardan (XYZ) sequence. The ankle joint center was determined as the midpoint between the markers placed on the medial and lateral malleolus. Ankle joint moments were calculated using an inverse dynamic method. Medial-lateral location of COP was calculated in the foot coordinate system with ankle joint center as the origin. Hip joint angles were also generated, because they may relate to the leg orientation and foot placement during landing. Joint angle, moment and COP data were averaged respectively across the nine normal trials to generate the ensemble average curve. Qualitative comparisons were made between the giving way trial and normal trials. The significant difference was defined as that the difference was greater than one SD (shaded area in Fig.2, about 1.5 times of 95% CI) of normal trials.

RESULTS: For joint angles in the pre-landing phase, no obvious difference in ankle dorsiflexion/plantarflexion angles or hip flexion/extension angles was found between the giving way trial and normal trials. However, the participant displayed greater ankle inversion, internal rotation and less hip abduction throughout the pre-landing phase in the giving way compared to the normal trials. In addition, greater hip external rotation angle was observed just before the initial contact (-25 ms) in the giving way trial. During the landing phase, the participant rolled over the ankle with drastically greater plantarflexion, inversion and internal rotation angle.
For ankle joint moments in the pre-landing phase, no obvious difference was observed except for an earlier external rotation moment. During the landing phase, in general, greater ankle external rotation moments and eversion moments with a more lateral COP location were observed in the giving way trial.

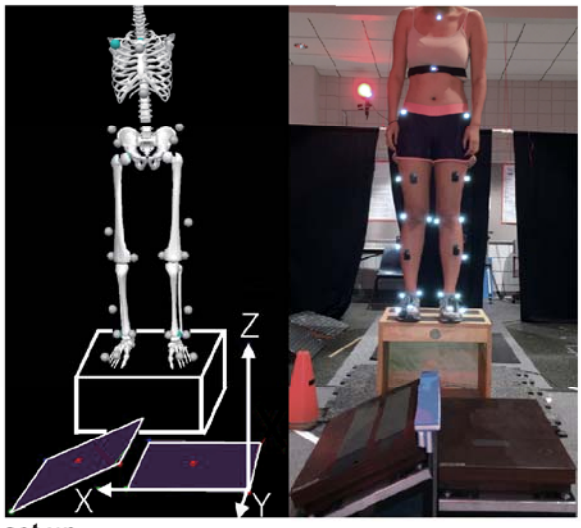

Figure 1: Experimental set up.

DISCUSSION: Landing in a more inverted and internally rotated ankle position may be a typical mechanism resulting in giving way, because the ankle was in a less stable position (Delahunt, Monaghan, & Caulfield, 2006) especially for CAI individuals with reduced ankle muscle co-contraction and strength (Lin, Chen, & Lin, 2011; Tine Willems, Witvrouw, Verstuyft, Vaes, & De Clercq, 2002). Reduced or delayed onset of ankle evertor activity could contribute to the increased ankle inversion (Shima, Maeda, & Hirohashi, 2005) and further leads to a greater subtalar tilt angle and reduced stability (Yamamoto et al., 1998). A previous study also found greater ankle internal rotation and inversion angles in pre-landing phase during a sprain incident (Fong et al., 2009), which agreed with our findings. Moreover, though hip kinematics may not associate with mechanisms of CAI (De Ridder, Willems, Vanrenterghem, Robinson, & Roosen, 2014), the external hip rotation motion from -75 ms to initial contact may be used to compensate excessive ankle internal rotation and control foot

orientation in the pre-landing phase. In the giving way landing phase, the participant displayed greater ankle plantarflexion, inversion and internal rotation indicating the episode of giving way occurred, similar to that of Fong et al. (2009) case study.

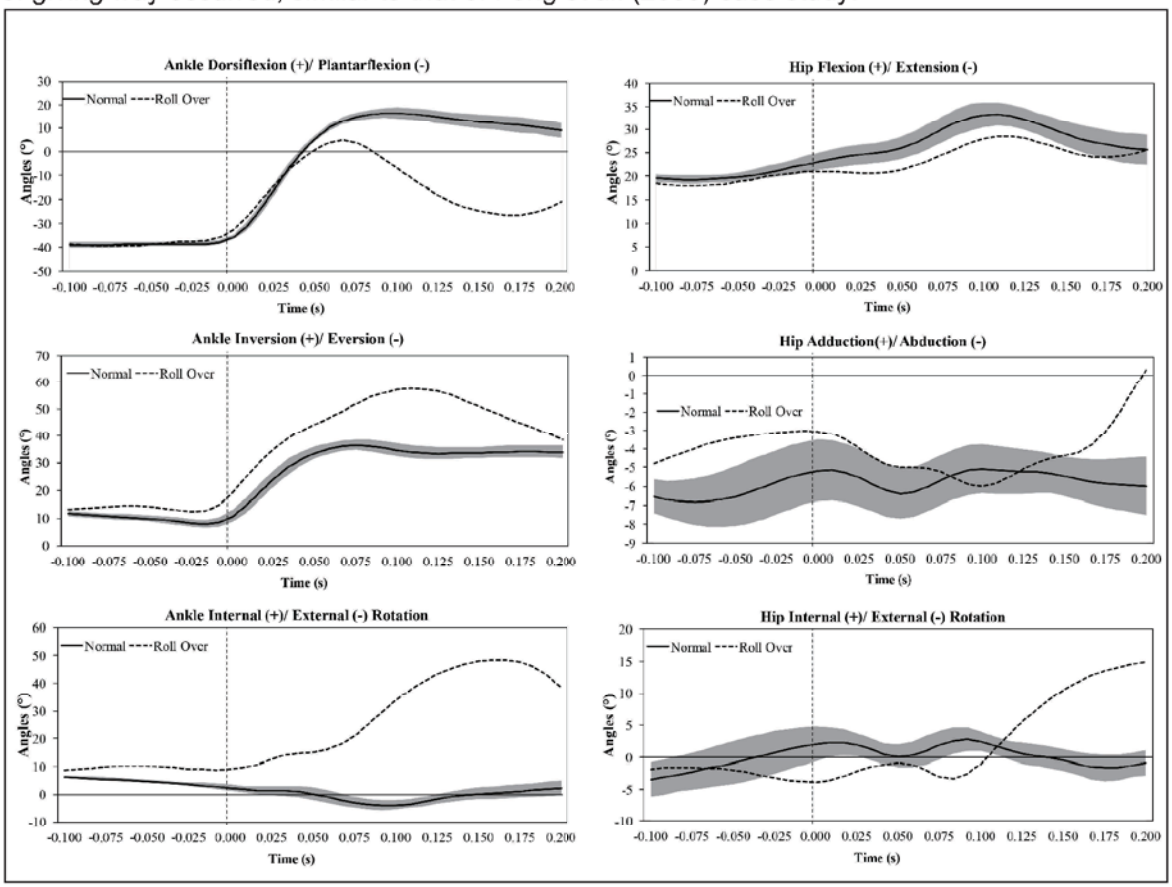

Figure 2: Ankle and hip joint angles in the giving way trial and mean and SD of normal trials during pre-landing and landing phase. Note: the vertical dash line indicates initial contact; the vertical axes are not on the same scale.

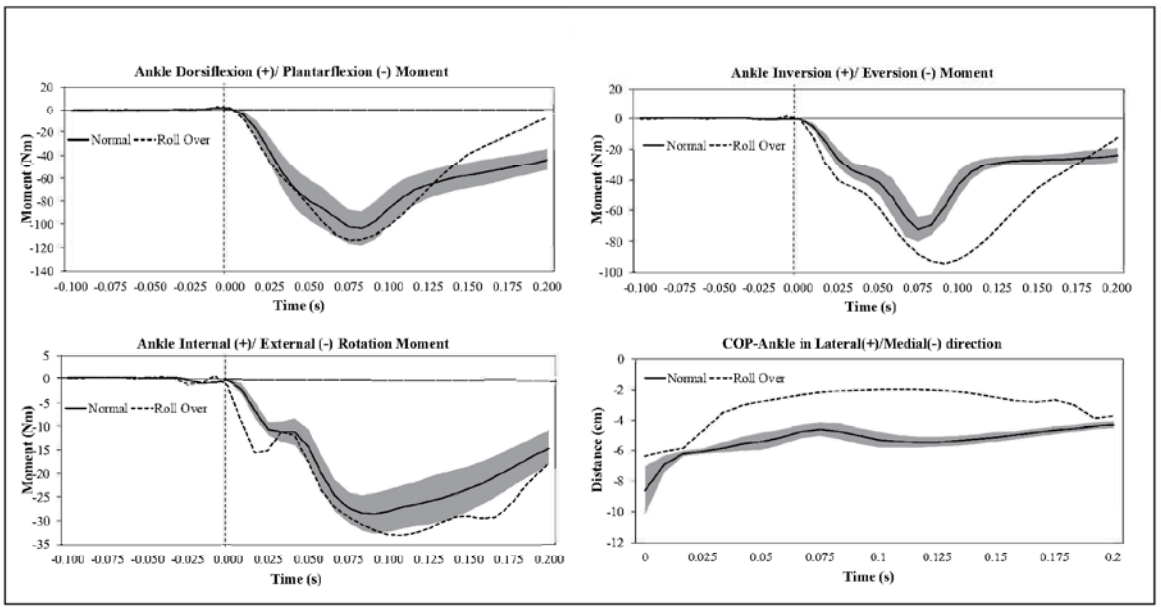

Figure 3: Ankle joint moments and center of pressure (COP) in the medial-lateral direction relative to the ankle joint center.

The ankle joint moments were comparable among all trials except for an earlier exhibited ankle external rotation moment in the giving way pre-landing phase. This external rotation moment may be used to control and prevent the excessive ankle internal rotation similar to the hip external rotation described earlier. COP shifted laterally for all trials in the landing phase; however, COP was more lateral in the giving way, which corresponded with the results during the ankle sprain (Fong et al., 2009). The more lateral COP may be due to the increased ankle inversion when the lateral border of the foot was contacting the ground.

CONCLUSION: For this participant with CAI, when landing on a laterally tilted surface, a more inverted and internally rotated ankle position before landing led to the episode of giving way. Therefore, to prevent ankle giving way or sprain during landing for individuals with CAI, we recommend that training for improving ankle proprioception and evertor strength may be helpful to allow proper ankle position before landing.

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