

Kristianslund, E., Bahr, R., Krosshaug, T. (2011). Kinematics and kinetics of an accidental lateral ankle sprain. *Journal of Biomechanics*, 44, 2576-2578.

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Kinematics and kinetics of an accidental lateral ankle sprain

Short communication

Word count: 1603 including Acknowledgments

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KEYWORDS: Ankle, sprain, 3D motion analysis

Abstract

Ankle sprains are common during sporting activities and can have serious consequences. Understanding of injury mechanisms is essential to prevent injuries, but only two previous studies have provided detailed descriptions of the kinematics of lateral ankle sprains, and measures of kinetics are missing. In the present study a female handball player accidentally sprained her ankle during sidestep cutting in a motion analysis laboratory. Kinematics and kinetics were calculated from 240 Hz recordings with a full-body marker setup. The injury trial was compared with two previous (non-injury) trials. The injury trial showed a sudden increase in inversion and internal rotation that peaked between 130 and 180 ms after initial contact. We observed an attempted unloading of the foot from 80 ms after initial contact. As the inversion and internal rotation progressed, the loads were likely to exceed injury threshold between 130 and 180 ms. There was a considerable amount of dorsiflexion in the injury trial compared to neutral flexion in the control trials, similar to the previously published kinematical descriptions of lateral ankle sprains. The present study also adds valuable kinetic information that improves understanding of the injury mechanism.

Introduction

Ankle sprains are among the most frequent sports injuries and represent a significant contribution to time lost from sports participation (Fong et al., 2007). The injured athlete may suffer long-term sequelae such as an unstable joint and reduced proprioception (Wikstrom et al., 2010), increasing the risk of subsequent ankle injuries. Various preventive measures have been shown to be effective in reducing the incidence of ankle sprains (McKeon and Mattacola,

2008), but these may be refined with an improved understanding of the injury mechanism (Bahr and Krosshaug, 2005).

Lateral ankle ligament injury is traditionally described as an inversion trauma (Andersen et al., 2004), but a detailed description of joint kinetics is lacking. There are several ways to study sports injury biomechanics. One of the most valuable methods is analyzing the rare injuries occurring during biomechanical testing (Krosshaug et al., 2005). With a high number of test subjects, an injury may occur even when the injury risk is lower than during normal training. Two previous reports describe the kinematics of accidental ankle sprains using video analysis, but kinetic descriptions are lacking (Fong et al., 2009; Mok et al., 2011). A more precise description of moments acting on the ankle at the time of injury would improve understanding of the injury mechanisms. This case report provides a description of the kinematics and kinetics of an ankle sprain in a motion analysis laboratory.

Methods

The injured athlete participated in baseline testing for a cohort study initiated to study risk factors for ACL injury. The study protocol was approved by the Regional Committee for Medical and Health Research Ethics.

An elite female team handball player (173 cm, 63.7 kg, 22 years) suffered an accidental ankle lateral ligament sprain during testing. The injury was confirmed by clinical examination of an orthopaedic surgeon.

The player wore running shoes, shorts and a sports bra, and 34 reflective markers were attached to the legs, arms and torso. Eight 240 Hz infrared cameras (ProReflex , Qualisys Inc., Gothenburg, Sweden) captured the motion, while ground reaction forces were measured by a 120 x 60 cm force platform (AMTI LG6-4-1, Watertown, MA, USA) collecting at 960 Hz. Prior to the sidestep cutting we performed a static calibration trial. The player was instructed

to focus entirely on faking and moving around a static defender (height 178 cm) using her usual right-left sidestep cutting technique. The defender adjusted her position between trials to ensure that the player stepped onto the force platform with her right foot. For a trial to be accepted, the cut had to be performed with match-like intensity as perceived by the investigators, the stance foot had to hit the force platform and all markers had to stay firmly attached to the player's skin. The injury occurred during the player's third accepted trial. Prior to this the player had completed 19 trials which were discarded because markers fell off or the player did not hit the force plate.

The kinematics were obtained using custom Matlab scripts (MathWorks Inc., Natick, MA, USA), as described by Krosshaug & Bahr (2005). Kinetics were calculated with standard inverse dynamics, with joint moments projected onto the joint rotational axes. Marker trajectories and force data were processed with a smoothing spline with 15 Hz cut-off frequency (Woltring, 1986). The motion of the foot segment was calculated from the ankle joint center and markers at the heel and at the head of the fifth metatarsal. Ankle flexion was defined as rotation about the medio-lateral axis of the tibia, internal rotation around the vertical axis of the foot and inversion about the floating axis, the cross product between the two others (Wu et al., 2002). The axis cross of the foot is aligned with the global axis cross in the standing trial. Inversion velocity was found by differentiating a polynomial spline fitted to the inversion angle time course.

Results

The sidestep cutting angle was 38° for the injury trial vs. 39° and 41° for the control trials, while the approach speed was 4.6 m/s vs. 4.5 m/s and 4.4 m/s. Three phases were defined in the injury trial, based on the observed joint kinematics time histories (Fig. 1): 0-50 ms of the contact phase (phase I), 50-80 ms (phase II) and 80-170 ms (phase III). In phase I we

observed a sudden increase in inversion (16° vs. 6° and 5° in the two previous trials without injury) and internal rotation (8° vs. 4° and -1°). The center of pressure was located apx. 2 cm more laterally on the foot sole during this time period. In phase II and III, an increased lateral excursion of the center of pressure was observed (8.4 cm vs. 3.3 and 3.0 cm). In phase III, from apx. 80 ms onwards, the inversion moment increased, reaching a peak of 79 Nm at 138 ms after initial contact. At this time the inversion angle had reached 23° , the internal rotation angle was 46° and dorsiflexion was 22° . The inversion moment was followed by an internal rotation moment, reaching a peak of 64 Nm at 167 ms. In the same period there appeared to be an unloading of the foot, with a dorsiflexion of the ankle and reduced ground reaction force (figure 2) and knee flexion moment (figure 3). The control trials displayed mainly eversion moments of the ankle throughout the stance phase, and joint angular deflections of less than 6° . Maximum inversion velocity was $559^\circ/\text{s}$ in the sprain trial and $166^\circ/\text{s}$ and $221^\circ/\text{s}$ in the two control trials.

[Figure 1 around here] [Figure 2 around here] [Figure 3 around here]

Discussion

This study provides a detailed description of lateral ankle sprain dynamics occurring accidentally during testing in a motion analysis lab. The injury involved dorsiflexion and excessive inversion and internal rotation. An unloading of the foot was initiated after apx 80 ms. Unphysiological inversion and internal rotation ankle moments resulting in high joint deflections likely caused the injury in the time period between 130 and 180 ms (Parenteau et al., 1998).

The primary ligamentous restraint to an inversion moment in a plantarflexed position is the anterior talofibular ligament (Bahr et al., 1998). In line with this, inversion sprains have

traditionally been described as resulting from a combination of inversion and plantar flexion (Andersen et al., 2004). In this injury case, ankle flexion patterns are similar between injury and control trials until about 80 ms after initial ground contact, when the athlete in the injury trial goes into dorsiflexion. This is in line with a previous case study describing kinematics of an ankle sprain that reported markedly lower plantar flexion in the injury trial compared with the normal trials for the first 200 ms of the stance (Fong et al., 2009). A low plantar flexion was also seen in a recent study investigating ankle sprain biomechanics for two cases using a model-based motion analysis technique (Mok et al., 2011). This implies that plantar flexion is not required for injury to occur. Taping the foot to avoid plantar flexion seems less relevant to prevent this injury mechanism. We see a marked increase in plantar flexion during the late stance phase, after the assumed time of ligament rupture. This is also seen in one of the video-based cases.

For this injury case there was a substantial difference in inversion velocity between control and injury trials. This has been suggested to be useful for differentiating between sprains and normal sporting motions, and intelligent sprain-protecting footwear based on this is under development (Chu et al., 2010). Trap-doors or tilting platforms allowing sudden inversion movement have been used to simulate ankle sprains, but important information such as inversion velocity is often not stated (Menacho et al., 2010). This study provides real-life data of kinetics and kinematics to ensure validity of these laboratory simulations.

The injured subject in this study performed a match-like sidestep cut past a static defender, with cutting angle similar to those seen in previous studies, but a somewhat lower approach speed (Benjaminse et al., 2011). As we attempted to recreate a playing situation as close as possible to real play, it seems reasonable to assume that the injury mechanism is representative for what might occur during actual handball play. Fatigue from performing a

high number of cuts may have occurred, similar to that experienced during training or match play.

Joint moments have been calculated treating the foot as a rigid segment and are expressed about virtual ankle axes (Wu et al., 2002). Using a multi-segment foot model would have been better to be able to assess the motion of talocrural and subtalar joint, as well as ligament loading. Unfortunately, due to the limited number of markers this was not possible in this case. Nevertheless, the joint moments accurately describe the timing of events and joint loads within the constraint of the method and increase our understanding of ankle sprain injury mechanisms.

Understanding injury mechanisms is crucial in preventing injuries, and the current case may be helpful in refining methods to prevent the most common sports injury.

Acknowledgements

The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture, the South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport, and Norsk Tipping AS. The research of Eirik Kristianslund has been partly funded by the Medical Student Research Program at the University of Oslo. No sponsor had any role in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; and in the decision to submit the manuscript for publication. We thank Andrew McIntosh and Antonie van den Bogert for valuable discussion.

Conflict of interest statement

No author has any financial and personal relationships with other people or organisations that could inappropriately influence their work.

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Figure 1: Time course of ankle joint angles and moments. Initial contact at 0 ms, toe off at 242 ms, 279 ms and 254 ms

Figure 2: Vertical ground reaction force (N)

Figure 3: Knee flexion moments (Nm)





