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Short communication

How to sprain your ankle – a biomechanical case report of an inversion trauma

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ABSTRACT

In order to develop preventive measures against lateral ankle sprains, it is essential to have a detailed understanding of the injury mechanism. Under laboratory experimental conditions the examination of the joint load has to be restricted with clear margins of safety. However, in the present case one athlete sprained his ankle while performing a run-and-cut movement during a biomechanical research experiment. 3D kinematics, kinetics, and muscle activity of the lower limb were recorded and compared to 16 previously performed trials. Motion patterns of global pelvis orientation, hip flexion, and knee flexion in the sprain trail deviated from the reference trials already early in the preparatory phase before ground contact. During ground contact, the ankle was rapidly plantar flexed (up to 1240°/s), inverted (up to 1290°/s) and internally rotated (up to 580°/s) reaching its maximum displacement within the first 150 ms after heel strike. Rapid neuromuscular activation bursts of the m. tibialis anterior and the m. peroneus longus started 40–45 ms after ground contact and overshot the activation profile of the reference trials with peak activation at 62 ms and 74 ms respectively. Therefore, it may be suggested that neuromuscular reflexes played an important role in joint control during the critical phase of excessive ankle displacement.

The results of this case report clearly indicate that (a) upper leg mechanics, (b) pre-landing adjustments, and (c) neuromuscular contribution have to be considered in the mechanism of lateral ankle sprains.

1. Introduction

Lateral ankle sprains rank among the most frequent injuries in sports (Fong et al., 2007). For successful development of preventive measures, it is essential to have a sound understanding of the injury mechanism (Bahr and Krosshaug, 2005). While several methodological approaches are available to study etiological details about sprain occurrences (e.g., athlete interviews or simulation of non-injury situations), one valuable approach is the analysis of the undesired situation in which an athlete is injured during a biomechanical measurement (Krosshaug et al., 2005).

Few case reports of lateral ankle sprains are available containing biomechanical data about ankle joint kinematics and kinetics during the phase of ground contact (Kristianslund et al., 2011; Mok et al., 2011; Fong et al., 2009). The present case report enlarges this current information as additional measurement methods were applied. This report is able to describe the entire lower limb kinematics, the neuromuscular activation profile and the preparatory adjustments during an ankle sprain. Based on this additional knowledge the injury mechanism of lateral ankle sprains may be understood more comprehensively.

2. Methods

2.1. Experimental setup

One male soccer player (23 years; 1.83 m; 75 kg) participated in biomechanical measurements in a cross sectional study. He reported no orthopedic problems in the preceding six months; however he stated previous ankle sprains and self-reported functional deficits during sporting activities (FAAM-G sport subscale: 84%; Nauck and Lohrer, 2011). Before participation the subject gave written informed consent according to the local ethics committee. The protocol of the experimental setup required the athlete to perform three types of run-and-cut movements (45° and 180° sidestep cuts; -20° crossover cut) with an approach speed of 5 m/s. The type of movement offered was randomized and indicated by a light signal shortly before changing the direction. Due to the purpose of the cross sectional study the measurement was conducted on artificial soccer turf (Ecofill®, Mondo S.p.A., Alba, Italy) wearing four different pairs of cleated soccer shoes (prototypes, adidas AG, Herzogenaurach, Germany). Accidentally, the athlete twisted his left ankle during the 17th trial performing a turn movement (180° sidestep cut). Fortunately, the athlete did not need to seek medical attention. He reported mild pain and swelling for two days but was immediately able to fully load the affected joint. He stated complete recovery after 7–10 days.

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2.2. Data acquisition and analysis

Three-dimensional human motion analysis was performed with a motion analysis system at 200 Hz (Vicon Motion Systems, Oxford, UK). For this purpose, 17 retro reflective markers were placed on the pelvis and on the left leg, which enabled us to calculate hip, knee and ankle joint angles. Specifically for the ankle joint, the joint center was defined as midway between the medial and lateral malleolli. The foot was modeled as a single rigid segment based on rearfoot markers and one marker at the first metatarsal head. All joint angles were derived using a joint coordinate system approach (Wu et al., 2002; Grood and Suntay, 1983) resulting in plantar/dorsiflexion, inversion/eversion and internal/external rotations for the ankle joint complex. The first derivative of a polynomial spline fitting of the angle data was used to determine angular velocities. The global orientation of the pelvis and the foot segment were determined according to Wu and Cavanagh (1995). Marker trajectories and ground reaction forces (BP600900, AMTI, Watertown, USA) were low-pass filtered with a 4th order Butterworth filter at 15 Hz. Joint kinetics were calculated with a standard inverse dynamics approach and are reported as external joint moments. All calculations were done with a custom written script (Bodybuilder, Vicon Motion Systems, Oxford, UK).

In addition, the activities of the m. peroneus longus, m. tibialis anterior, m. soleus, m. gastrocnemius lateralis, m. vastus lateralis, and m. biceps femoris were measured using wireless bipolar surface electromyography at 1000 Hz (myon RFTD-E08; myon AG, Baar, Schweiz). The raw data were band-pass filtered (10–500 Hz, Butterworth 4th order), rectified, and smoothed with a 30 Hz low-pass filter (Butterworth 4th order).

We were able to analyze all trials in a time window from 200 ms before until 300 ms after heel strike. For a descriptive analysis, the range of the 16 reference trials at each time point is compared to the trial with the ankle sprain.

3. Results

3.1. Ankle mechanics

The injury trial was characterized by a rapid increase in plantarflexion (up to 50°), in inversion (up to 45°), and in internal rotation (up to 13°) during the first 60 ms of ground contact (Phase 1; see Fig. 1). The peak angular velocities were: 1240°/s for plantarflexion, 1290°/s for inversion, and 580°/s for internal rotation. After a subsequent reduction of plantarflexion and inversion (Phase 2: 60–105 ms) the forefoot served as a pivot point and both the inversion and especially the internal rotation raised again up to 42° and 24°, respectively (Phase 3: 105–160 ms).

In contrast to the reference trials, the injury trial displayed an initial plantarflexion moment (Fig. 1). The inversion and internal rotation moments were characterized by a slightly increased first peak component and a clearly enhanced second peak component compared to the reference conditions.

3.2. Leg mechanics

Already in the phase before ground contact, the orientation of the pelvis, hip flexion, and knee flexion deviated remarkably from the reference trials (Fig. 2). The pelvis was generally less internally rotated in the push-off direction; the hip flexion was approximately 35 ms delayed, leading to a more flexed hip position at touchdown. The knee flexion was initially delayed but was overcompensated during the 100 ms before ground contact, leading to a fully extended knee at touchdown, which in combination with the more flexed hip resulted in a steep heel strike (see Fig. 2: foot extension).

3.3. Muscle activity

The pre-activation patterns of the injury trial were comparable to the reference trials despite a considerable shift in timing of the m. vastus lateralis. However, the post-landing activation in the injury trial was characterized by an initial suppression of the m. tibialis anterior (up to 40 ms) and the m. peroneus longus (up to 44 ms). The subsequent phase of activation bursts overshot the muscle activity of the reference trials (Fig. 3). Distinct peaks were observed after 62 ms and 109 ms for the m. tibialis anterior and after 74 ms and 108 ms for the m. peroneus longus.

4. Discussion

4.1. Preparatory adjustments

This case report adds the following information to current knowledge: the angular excursions of the pelvis, hip and knee joint had already deviated considerably from the non-injury trials

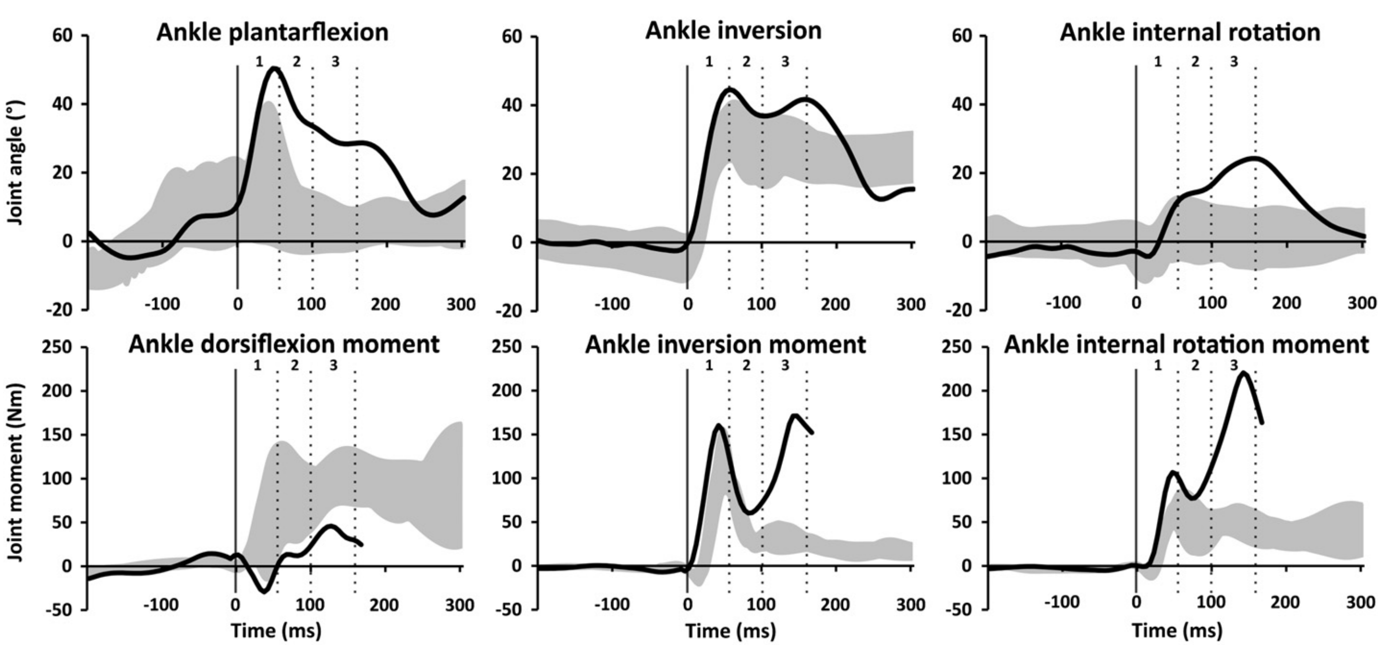

Fig. 1. Ankle kinematics and kinetics of the injury trial (black line) and of the 16 reference trials (grey band represents the range). Joint moments of the injury trial are presented until 175 ms after heel strike because the athlete subsequently touched the force plate with his second leg. Phases (1, 2, 3) are defined according to the excursion profile of the ankle inversion.