Kinematic analysis of a televised medial ankle sprain

This item was submitted to Loughborough University's Institutional Repository by the/an author.


Additional Information:

- This is an Open Access Article. It is published by Elsevier under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International Licence (CC BY-NC-ND). Full details of this licence are available at: (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Metadata Record: [https://dspace.lboro.ac.uk/2134/32348](https://dspace.lboro.ac.uk/2134/32348)

Version: Published

Publisher: Elsevier © Asia Pacific Knee, Arthroscopy and Sports Medicine Society

Rights: This work is made available according to the conditions of the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) licence. Full details of this licence are available at: https://creativecommons.org/licenses/by-nc-nd/4.0/

Please cite the published version.
Kinematic analysis of a televised medial ankle sprain

Francesca E. Wade a, 1, Kam-Ming Mok b, Daniel Tik-Pui Fong a, *

© 2018 Asia Pacific Knee, Arthroscopy and Sports Medicine Society. Published by Elsevier (Singapore) Pte Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

A recent consensus statement from the International Ankle Consortium highlights the need for preventative programs to reduce the prevalence of ankle sprains. Ankle injuries are commonly seen in both athletic and general populations. American Football players are at high risk, with 72% reporting a foot or ankle injury during their athletic career. These injuries are not insignificant, as over half the incidences reported in a ten-year period in National Football League athletes caused a time loss from play greater than one week.

In order to develop effective preventative strategies, the injury mechanism must be understood. To date, prior work investigating ankle sprain injury mechanisms has focused on inversion sprains, but recent research has focused on objectively quantifying how injury occurs; unbiased injury mechanisms are necessary for successful injury prevention work. However, investigating injury mechanisms quantitatively is challenging. Traditional motion analysis techniques can be used when accidental incidents occur in a laboratory setting, although these events are rare. At the ankle, there are currently three documented cases of an accidental lateral ankle sprain injury analyzed using three-dimensional motion analysis.

The problem of obtaining exact injury biomechanics has been approached in many ways. Often, retrospective analyses that identify pathologies in the musculoskeletal system are used, but it is impossible to tell whether the observed pathological symptoms are caused by the injury or were the reason for its occurrence. Other investigative approaches include a simulation of the event within the laboratory setting in healthy participants, and using cadaver limbs or computer simulations to replicate the injurious motion.

A markerless motion analysis technique was suggested as an alternative approach to investigate injury mechanisms. The researchers developed a model-based image matching (MBIM) technique using uncalibrated video images to reconstruct the motion of a subject in three dimensions, applying the method to anterior cruciate ligament injury investigations. The MBIM method was adapted to investigate ankle sprain injuries by Fong and...
colleagues.\textsuperscript{10} As the majority of injuries occur outside of a laboratory setting, MBIM allows for investigations of many injuries occurring in their natural settings.

The velocity of ankle inversion is a key mechanism of lateral ankle sprains with high inversion velocities, up to 1752/s, being reported.\textsuperscript{14–18} Eversion is a component of ankle pronation and is commonly seen in running.\textsuperscript{23} During running, healthy ankle eversion velocities have been reported between 115/s\textsuperscript{-2} to 207/s\textsuperscript{-2}; we chose an eversion velocity of 250/s as an injurious threshold for the current case study. This study will use MBIM to identify potential injury mechanisms for a single ankle eversion sprain case that occurred in an American Football athlete. We hypothesize that an eversion velocity greater than the injury threshold of 250/s might be observed.

**Methods**

A search for appropriate video footage (used for analysis under fair use agreement) of ankle eversion injuries that met key criteria was conducted on the official National Football League (NFL) website, using keywords such as ‘ankle sprain’, ‘ankle injury’ and ‘lower leg injury’. Key criteria included multiple views of the injury, with at least one view occurring in real time, clear and visible boundary lines that are ideally perpendicular to each other (such as field markings), adequate resolution for visual identification of knee orientation, the relative size ratio of the foot and shank to overall video, and no more than one consecutive frames where the injured limb is obscured. For an evasion injury event to be considered, the unwanted motion had to cause excessive evasion during landing or cutting, the athlete had to be unable to continue play following injury, and post-match reports must have described the injury as an ankle sprain.

A single non-contact evasion ankle sprain case study was selected for analysis. The 23 year old quarterback landed on his right leg awkwardly on a rollout run in the third quarter of a 2013 season. Due to limited access to medical history, neither medical play following injury, and post-match reports must have described the injury as an ankle sprain.

A virtual environment of the American Football field was reconstructed using the dimensions outlined in the NFL rule book,\textsuperscript{26} with one meter equal to 0.41 Poser units, or a 410% scale. For each injury view, the reconstructed field was manually aligned with the recorded field by adjusting the camera orientation, position and focal length. Once focal length was identified in the first frame, it remained constant throughout matching.

A male skeleton model (Zygote Media Group Inc., USA) was matched to a still image of the injured athlete to identify body proportions — specifically the shank and the foot. Segment dimensions were adjusted iteratively during matching in order to identify the appropriate scaling parameters. The model used comprised of four segments (pelvis, thigh, shank and foot) with three degrees of freedom at the ankle joint, and two degrees of freedom at the knee and the hip (flexion/extension and abduction for both joints). The default skeleton model ankle joint center was adjusted as previously reported\textsuperscript{17} to lie at the midpoint between the malleoli.

The skeleton model was matched to the synchronized video footage of the athlete, starting at the pelvis and continued distally in each frame. Once matched, the skeleton was replaced with a ‘nude man’ model to determine longitudinal rotation for each segment using surface anatomy. Tibial rotation was assumed to be fully distributed at the ankle. An example matched frame sequence is illustrated in Fig. 1.

The overall motion of the skeletal model was assessed and adjusted by two additional researchers to ensure a smooth motion. Individual segment parameters, such as foot segment bend, twist and turn, were evaluated by the same researcher who conducted the initial matching to manually smooth each parameter’s angle curve, minimizing the noise in the computed velocities.

The time histories of ankle joint angle from the skeletal model were imported into Matlab (MathWorks Inc., USA), and joint angles were computed using a custom-written script, following the ISB-recommended joint coordinate system.\textsuperscript{28} Initial foot ground contact, as observed from the multi-view video, was considered the start of the injury, and all kinematics are reported using this event as time zero. Foot orientations are reported relative to the shank segment.

**Results**

At the point of initial ground contact, time zero, the ankle joint was 11° plantarflexed, 32° externally rotated and 12° everted. At the moment of peak eversion, occurring 0.2 seconds after initial contact, the ankle joint was 39° dorsiflexed, 30° externally rotated and 50° everted. At this time, there was minimal eversion velocity (78/s) and high dorsiflexion velocity (569/s), while internal rotation did not change (Fig. 2). The maximum eversion velocity (426/s) occurred immediately following ground contact. Peak dorsiflexion occurred at 0.27 seconds following ground contact (Fig. 2), later than that of peak eversion, although peak dorsiflexion velocity is observed with peak eversion. Internal rotation remains constant throughout the contact phase.

**Discussion**

Using MBIM on a non-contact evasion ankle sprain case identified an injury mechanism that is a combination of dorsiflexion and eversion, accompanied by high eversion and dorsiflexion velocities that occur just prior to peak eversion. At initial contact, the ankle joint was externally rotated, with slight plantarflexion and a moderate level of eversion. This position is a vulnerable one, characterized by peak eversion occurring rapidly after.

The clinical qualitative eversion sprain injury mechanism is
talocrural joint dorsiflexion combined with subtalar joint abduction and eversion. In other words, eversion sprains occur through a combination of pronation, abduction and dorsiflexion, and the results from this study support this.

Prior work reported injury mechanisms for two eversion ankle sprains in soccer players. The sprains occurred through trampling, with maximum eversion of 25.2° and 20.0°, and associated velocities of 210°/s and 320°/s for each case. The average plantarflexion/dorsiflexion displacement in the current study was 64°, double the 30° reported in the soccer player cases. The discrepancies between the three cases can be explained due to the nature of the injury, those previously reported are contact injuries, while this case study is of a non-contact medial ankle sprain.

Curiously, peak eversion occurred at almost identical timepoints following ground contact - 0.20s and 0.22s for each case reported by Li et al. and 0.20s in the present report. This consistent timing reinforces that ankle eversion sprains occur explosively. The rapid time to peak eversion combined with the large range of motion (RoM) we observed implies that medial ligaments are strained first, followed by the talofibular ligaments. The medial ligaments are stronger, but rapid changes in orientation strain ligaments to the point of failure. The peak eversion velocity reported in this case suggests the ankle joint was acted upon by an excessive torque, leading to rapid changes in kinematics.

The eversion velocity observed in the current study is higher than that found by Li et al., but the three eversion sprain cases have considerably lower eversion/inversion velocity values than those reported in inversion sprains (Table 1), suggesting different injury mechanisms. In this case, the ankle did not fully roll over its medial edge, instead the shank moved laterally while the foot remained planted, causing the eversion motion to come from tibial displacement rather than a medial shift of pressure. However, there appears to be a similar time-scale of injury between inversion and eversion ankle sprains, thus research on inversion ankle sprain can be used to guide explorations into eversion ankle sprain mechanisms.

Large eversion and dorsiflexion RoM in this case and those reported by Li et al. is implicated in the injury mechanism. The injury mechanism for inversion ankle sprains has a larger average plantarflexion RoM than that of eversion sprains (Table 1), although this planar motion appears to be critical to the development of both lateral and medial ankle sprains. This is cogent considering the differences in lateral and medial structures of the ankle anatomy.

The tibialis anterior and posterior, flexor digitorum longus and flexor hallucis longus insert on the medial ankle, along with a strong lattice of ligaments, restricting the eversion range of motion.
The large RoM over the dorsiflexion and eversion ranges observed is sufficient to injure the deltoid ligament, the posterior talofibular ligament, and, to a lesser extent, the anterior talofibular ligament, provided the fibula doesn't restrict the movement. It is this fibular restriction that could explain the lower, but still injurious, frontal plane velocities observed in both the present study and past work, when compared with lateral sprain studies, which could be double - the reason for the reduction in likelihood of missing key events of the injury. Further improvements to the MBIM method involve obtaining subject-specific anthropometric data, where athletes consent to researchers to access their information or are available to take direct measurements. It should also be emphasized that the proposed injury mechanism is only speculated from observations — it cannot be said with certainty whether the reported kinematics are a cause or consequence of the eversion ankle sprain.

### Conclusion

The present study used quantitative analysis to analyze ankle joint kinematics in an ankle eversion sprain case that occurred in an American football quarterback. The results suggest a case-specific injury mechanism comprising of sudden eversion and dorsiflexion, with constant internal rotation, agreeing with the clinical qualitative pathology. It is hoped this MBIM analysis starts the discussion for further research into the injury mechanism of medial ankle sprain injuries.

### Conflicts of interest

The author(s) have no conflicts of interest relevant to this article.

### Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

### Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.asmart.2018.02.001.

### References


