Mok, K. M., Fong, D. T.-P., Krosshaug, T., Engebretsen, L., Hung, A. S.-L., Yung, P. S.-H., Chan, K.-M. (2011). Kinematics analysis of ankle inversion ligamentous sprain injuries in sports : 2 cases during the 2008 Beijing Olympics. American Journal of Sports Medicine, 39, 1548-1552.

Title	Kinematics analysis of ankle inversion ligamentous sprain injuries in sports - two cases during the 2008 Beijing Olympics		
Article type	Scientific Article		
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Keywords	video analysis, injury biomechanics, injury mechanism, ankle supination sprain		

What is known about the subject

Analyzing the injury video recordings provides valuable information such as joint kinematics of specific sport injury. It contributes to the study of injury mechanism. Previous study reported the kinematics of ankle sprain happened in laboratory. However, difference exists between injury case in laboratory and injury case in real game situation. Fong DTP, Hong Y, Yung PSH, Shima Y, Krosshaug T, Chan KM

(2009). Biomechanics of supination ankle sprain - a case report of an accidental injury event in laboratory. American Journal of Sports Medicine, 37(4), 822-827.

Adds to existing knowledge

This paper reveals the kinematics of ankle inversion ligamentous sprain of the two analyzed cases. The maximum joint angles and velocities are reported. It would be an implication for further quantitative description of ankle inversion ligamentous sprain injury mechanism.

INTRODUCTION

Ankle inversion ligamentous sprain is one of the most common injuries encountered in sports (Fong et al., 2007; Fong et al., 2009a). A precise description of the injury situation is a key component to understanding the aetiology and injury mechanism (Bahr and Krosshaug, 2005). However, quantitative analyses on injury cases are available only under rare circumstances due to coincidental calibrated video recording (Zernicke et al., 1977). Previously, qualitative analysis of joint biomechanics was reported on ankle injuries based on visual inspection (Andersen et al., 2004, Giza et al., 2003). Fong and co-workers (2009b) reported the first ever kinematics analysis of ankle inversion liagmentous sprain injury which accidentally happened in their laboratory.

However, the occurrence of recording ankle inversion liagmentous sprain injury in the laboratory is rare. Instead, injuries in sports are occasionally shown on TV with multiple camera views, and those video recordings could be further analyzed to explain the cause of injury. In order to develop a novel biomechanical analysis to produce continuous measurement of joint kinematics from video recordings, Krosshaug and Bahr (2005) introduced a Model-Based Image-Matching (MBIM) motion analysis technique for investigating human motion from uncalibrated video sequences, and employed the technique to determine the injury mechanism of anterior cruciate ligament ruptures (Krosshaug et al., 2007).

In 2008, the International Olympic Committee (IOC) suggested an injury surveillance system for multi-sports tournaments (Junge et al., 2008). The injury surveillance system provides important epidemiological information. Junge et al. (2009) reported the frequency, characteristics, and causes of injuries during the Beijing Olympics Games in 2008. Based on the information from the injury surveillance system, the injury incidents could be matched with the televised video recordings. Using the MBIM motion analysis technique, the ankle joint kinematics of two ankle liagmentous sprain injury cases could be reconstructed.

The purpose of this paper was to present the three-dimensional ankle joint kinematics of two ankle sprain cases detected by the injury surveillance system in Beijing

Olympics Games 2008.

METHOD

Injury records from the Beijing games were published in 2009 by the IOC Medical Commission (Junge et al 2009) In the IOC surveillance program, detailed information of each injury included injury time, place, sports event and part of body injured. Video recordings of some of the injury cases were obtained from the Olympic Broadcasting System (OBS). The inclusion criteria selection of videos were that the athlete was unable to continue the match or competition after the ankle inversion sprain motion, and the injury motion was clearly shown by at least two camera views. Two ankle inversion sprain cases were screened out for analysis. The first case was recorded from high jump event; the athlete sprained her left ankle during the take-off. The second case was captured in male field hockey match; the player sprained his left ankle during running under an opponent's pressure.

Model-Based Image-Matching motion analysis

The video recordings were 1280x720 pixels in resolution, deinterlaced to 50Hz in effective frame rate. The high jump case was captured by three video cameras, the relative angle between cameras 1 and 2 was 31°, between 2 and 3 was 17°. The relative surface area of the left below hip body part to the total video frame size was

2.1% (camera 1), 3.0% (camera 2) and 1.5% (camera 3). The field hockey case was captured by two video cameras, the relative angle between cameras 1 and 2 was 43°. The relative surface area of the left below hip body part to the total video frame size was 1.1% (camera 1), 4.4% (camera 2). The video recordings were transformed from their original format into uncompressed AVI image sequences using Adobe Premiere Pro (version CS4, Adobe Systems Inc., San Jose, California, US). Then the sequences were de-interlaced using Adobe Photoshop (version CS4, Adobe Systems Inc., San Jose, California, US), and the image sequences were synchronized and rendered into 1 Hz video sequences by Adobe AfterEffects (version CS4, Adobe Systems Inc., San Jose, California, US). The matchings were performed using 3D animation software Poser® 4 and Poser® Pro Pack (Curious Labs Inc., Santa Cruz, California, US). The surroundings were built in the virtual environment according to the real dimension of the sport field. The models of surroundings were manually matched to the background for the each frame in every camera view. The skeleton model from Zygote Media Group Inc. (Prove, Utah, US) was used for the skeleton matching. No anthropometrical measurements were available except subject's height. The segment dimensions were therefore iteratively adjusted during matching process until finally, a fixed set of scaling parameters was determined. The skeleton matching started with the shank segment and then distally matched the foot, and toe segments frame by frame. The joint angle time histories were read into Matlab (MathWorks, USA) with a customized script for data processing. Joint kinematics was deduced by the Joint Coordinate System (JCS) method (Grood and Suntay, 1983). The ankle joint measurement standard was according to the recommendation of International Society of Biomechanics (ISB) (Wu et al., 2002). The point of initial contact was defined as the foot touchdown observed from multi-views synchronized video. The ankle joint kinematics results from MBIM technique were filtered and interpolated by Woltring's Generalized Cross Validation Spline package (Woltring, 1986) with 15Hz cut-off frequency.

RESULTS

High Jump Injury

The injury occurred when the player performed the take-off stepping in the high jump qualification. At the point of initial contact, the heel contacted the ground with the ankle joint 30° inverted, 28° internally rotated and 5° plantarflexed, shown in Figure 1. At that time, the athlete was twisting her torso for jumping over the bar. Her left ankle was internally rotated because of the shank external rotation. At 0.08s after initial contact, the inversion angle reached maximum, shown in Figure 2. At that time, the ankle joint was 142° inverted, 37° internally rotated and 7° dorsiflexied. The maximum inversion velocity was 1752°/s.

Field Hockey Injury

The injury occurred when the player was chasing the opponent with body contact. At the point of initial contact, the ankle joint was 7° inverted, 4° internally rotated and 41° dorsiflexied, shown in Figure 1. After 0.02s, his forefoot slightly stepped on the opponent's foot and the ankle inversion motion was triggered. At 0.08s after initial contact, the inversion angle reached maximum, shown in Figure 4. At that time, the ankle joint was 78° inverted, 27° internally rotated and 13° dorsiflexed. The maximum inversion velocity was 1397°/s.

DISCUSSION

For the high jump case, the ankle joint was internally rotated by the twisting motion of the torso at initial contact. This ankle joint orientation would favour the ankle joint to perform a supination motion. In this case, the athlete failed to keep the ankle joint under control. At 0.04s after the initial contact, the ankle joint changed from an increase to a decrease in its plantarflexion angle. As shown in Figure 3, the ankle joint was inverted until the lateral malleolus touched the ground. Plantarflexion could not be performed in that joint orientation. Finally, the ankle joint sprain injury occurred at

0.08s after the initial contact. For the hockey injury, the ankle joint was in normal orientation at initial contact. Immediately after the initial contact, the medial forefoot contacted the opponent's foot and ankle joint inversion was triggered. The frame sequence of the injury is shown in Figure 5. Similar to the high jump injury case, the ankle joint was not plantarflexed at the point that maximum inversion angle was obtained (0.08s after initial contact).

In summary, the kinematics of two injury cases and the injury mechanism were different than those suggested by previous studies. Garrick et al. (1977) indicated that the typical mechanism of ankle liagmentous sprain was a combination motion with inversion, internal rotation and plantarflexion. Previous studies further suggested that the injury motion was composed of inversion plus an internal twisting of the foot (Safran et al., 1999), and plantarflexion with the subtalar joint adducting and inverting (Vitale and Fallat, 1988). However, in the present two cases, plantartflexion was found not to be involved in the ankle sprain injury motion. It implies that the subtalar joint was less involved in the ankle inversion sprain injury. The maximum inversion angle was reached at 0.08s after the initial contact. Konradsen et al. (1991) indicated that the reaction time of the peroneal muscles in healthy male subjects with stable ankles was 0.05 to 0.08s, and Fong et al. (2009b) suggested that inactive peroneus tendons may be the reason the sprain occurred. Lastly, the maximum inversion velocity of the two injury cases were 1752°/s for high jump injury and 1397°/s for hockey injury, as shown in table 1. It is much larger than 632°/s which has been reported by a previous study (Fong et al, 2009b). This suggests that the ankle joint experienced an explosive inversion torque and subsequent abrupt kinematic changes. In summary, the findings suggest that plantarflexion may not be as necessary a component of ankle supination sprain motion as previously believed. Instead, inversion and internal rotation should be considered when designing preventive measures. Furthermore, short injury duration and high inversion velocity implies that preventive measures should be able to resist a large ankle torque in a very short period of time. From the aspect of computer modelling, the kinematics can be further analyzed by to calculate the internal stress and liagmentous tension (Chao et al., 2007).

This study is limited to two cases screened out for MBIM motion analysis. Before generalizing the results to the injury mechanism of ankle inversion sprain, more injury cases are needed to be analyzed and reported. At this point, the results of this study can merely point out the research gap and spark further discussion on the injury mechanism. The IOC Medical Commission is working on an improvement allowing better connection between the injury surveillance system and videos. In addition, information on subject anthropometric data would increase the accuracy of the analysis (Krosshaug et al., 2007). In the present study, the subject anthropometric data other than height were not available because those measurements were not included in the injury surveillance system.

CONCLUSION

This study reported the ankle joint kinematics of ankle inversion liagmentous sprain. The ankle liagmentous injury resulted from a motion combining internal rotation and inversion on the ankle joint, instead of plantarflexion and inversion which was traditionally regarded as the typical injury mechanism. Furthermore, the maximum inversion angle occurred at 0.08s after initial contact. The inversion velocities measured were 1752°/s for high jump injury and 1397°/s for hockey injury. The results from the MBIM technique could contribute to the understanding of the injury mechanism of ankle supination sprain injury.

Acknowledgement

This research project was made possible by equipment and resources donated by The Hong Kong Jockey Club Charities Trust. It is a research project of The Hong Kong Research Institute of Textiles and Apparel and is financially supported by the Innovation and Technology Fund from Innovation and Technology Commission, Hong Kong Special Administrative Region Government, Project number: ITF/017/10TP. The research group wishes to acknowledge sincere gratefulness to the President of the IOC Medical Commission, Professor Arne Ljungqvist, the IOC Medical Director, Patrick Schamasch for their support for this study and to the Olympic Broadcasting System (OBS) for providing videos of the injuries.

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FIGURES LEGEND

Figure 1. Ankle joint kinematics of the player during the ankle supination sprain injury. Time zero represented the point of initial contact

Figure 2. Captures at the point of maximum inversion angle for high-jump injury

Figure 3. Frame sequence of high-jump injury. Time zero represented the point of initial contact

Figure 4. Captures at the point of maximum inversion angle for field hockey injury

Figure 5. Frame sequence of field hockey injury. Time zero represented the point of

initial contact

TABLE

Table 1. The descriptive data of ankle joint kinematics of the injury cases

	High Jump Case	Field Hockey Case	Fong et al. (2009)
Max. Inversion angle	142°	78°	48°
Max. Inversion velocity	1752°/s	1397°/s	632°/s