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KINEMATICS ANALYSIS OF AN ANKLE INVERSION LIGAMENTOUS SPRAIN INJURY CASE IN BASKETBALL

Sophia Chui-Wai Ha, Lili Tao, Daniel Tik-Pui Fong

Department of Orthopaedics and Traumatology, Prince of Wales Hospital, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, China

Ankle inversion ligamentous sprain is one of the most common sports injuries. Model-Based Image Matching (MBIM) motion analysis technique allows us to understand the injury mechanism quantitatively by analyzing the three-dimensional human motion. In this study, the basketball player had performed an unwanted excessive ankle inversion by landing on the foot of the opponent. The ankle joint kinematics was presented within 0.1 second after footstrike. Result had further conformed that plantarflexion is not necessarily a criterion to sprain an ankle. Internal rotation associated with a sudden inversion would be the main phenomenon. An acceleration of inversion velocity is being suggested to be another important phenomenon of ankle inversion sprain injury. The quantified data in this study can serve as a base of development to investigate ankle joint motion.

KEY WORDS: video analysis, injury mechanism, injury biomechanics, ankle supination sprain

INTRODUCTION: Ankle ligamentous sprain is one of the most common injuries encountered in sports (Fong, Hong, Chan, Yung & Chan, 2007). A precise description of the injury situation is a key component to understanding the injury mechanism (Krosshaug & Bahr, 2005). The injury mechanism is still unclear (Fong et al., 2009). Previous study had described ankle ligamentous sprain as a combination of inversion and internal rotation of the ankle joint (Safran, Benedetti, Bartolozzi, & Mandelbaum, 1991), or plantarflexion with the subtalar joint adducting and inverting (Vitale & Fallat, 1988). A recent study reported a dorsiflexion instead of plantarflexion occurred in a laboratory accidental ankle supination sprain injury (Fong et al., 2009). These studies only gave a picture of ankle sprain injury in a qualitative way.

In order to analyze the injury mechanism quantitatively in biomechanical methods, a Model-Based Image-Matching (MBIM) technique was introduced to study anterior cruciate ligament injuries (Krosshaug & Bahr, 2005). This developed technique was further used to analyze ankle sprain injury after validation (Mok et al., 2011a). The MBIM technique was being used to investigate 2 ankle inversion injuries occurred in 2008 Beijing Olympics (Mok et al., 2011b).

There are several reasons to analyze the injury by MBIM technique even with numerous approaches emerged to understand the injury mechanism quantitatively (Krosshaug, Andersen, Olsen, Myklebust, & Bahr, 2005). It is unethical and practically not feasible to carry out real injury in experiments while real injury cases happen in controlled biomechanics laboratory are rare. To date, there were only 3 laboratory incident reports (Fong et al., 2009; Kristianslund, Bahr, & Krosshaug, 2011; Gehring, Wissler, Mornieux, & Gollhofer, 2013). The injured subjects in each report were performed a run-and-cut movement in the test and had accidentally sprained their ankle. The number of real injury cases is very limited and researchers could not passively wait for a real incident to happen in a controlled environment. It is more proactive and aggressive to use unexpected real injury captured by broadcasting companies in order to do analyze more cases. The very first real injury analysis was published in 1997. Zernicke, Garhammer and Jobe (1977) reported a human patellar tendon rupture captured unintentionally during a weight-lifting competition. Further improvement in video analysis was introduced in 2005 by using the MBIM technique. A 3-dimensional human motion from un-calibrated video sequences was done successfully in anterior cruciate ligament injury (Krosshaug & Bahr, 2005). In this study, a case is analyzed by using the same method to understand the ankle inversion sprain injury mechanism.

METHODS: An online video search was performed. A video is being chosen to analyze must have at least 2 camera views showing the shank, the ankle joint, and the foot segment during the injury motion. An injury is being recognized when 1) the athlete performed an unwanted excessive ankle inversion during a landing and sideward cutting motion, with the foot segment rolling over the lateral edge of the foot; 2) being forced to withdraw from the game or to continue after a brief rest with treatment to the ankle joint; and 3) was reported to have sustained an ankle sprain injury in the post-match report.
MBIM motion analysis had been reported before (Mok et al., 2011a). The videos were transformed from the original format into uncompressed AVI image sequence by using Adobe Premiere Pro (CS4, Adobe Ststems Inc, San Jose, California). The image sequences were then de-interlaced using the same software, and the image sequences were synchronized and rendered into 1-Hz video sequences by Adobe After-Effects (CS4, Adobe Systems Inc). The matching was being done by using 3-dimension animation software Poser 4 and Poser Pro Pack (Curious Labs Inc, Santa Cruz, California). The virtual environment is built according to the real dimensions of a basketball court. The models of surroundings were matched manually to the background for each frame in every single camera view. The skeleton model from Zygote Media Group Inc (Provo, Utah) was used to match with the athlete. No anthropometrical measurements were available except the subject's height. The segment dimensions were therefore iteratively adjusted during the matching process until finally a fixed set of scaling parameters was determined. The skeleton matching started with the hip, thigh, shank segment and then distally matched the foot and toe segments frame by frame.
The profile of the ankle joint orientation was then read into a self-compiled script (Matlab, MathWords Inc, Natick, Massachusetts) with a customized script for data processing. Joint kinematics was deduced by the joint coordinate system (JCS) method (Grood & Suntay, 1983). The ankle joint measurement standard was according to the recommendation of the International Society of Biomechanics (ISB) (Wu et al., 2002). The foot strike was determined visually from the video sequence. The ankle joint kinematics results from the MBIM technique were filtered and interpolated by Woltring's generalized cross-validation spline package with 15-Hz cut-off frequency (Woltring, 1986).

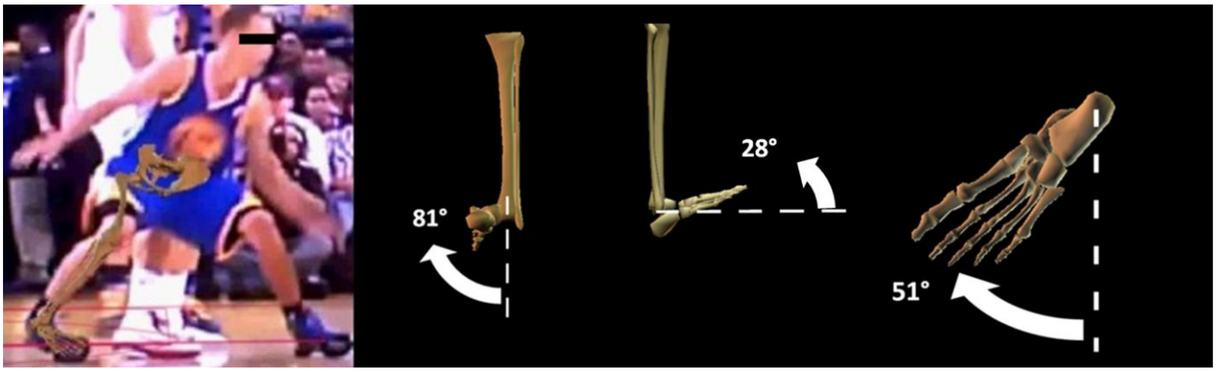

Figure 1: (a) Screenshot from 1 view showing the moment with the greatest ankle inversion; (b) The right ankle joint orientation presented in the inversion (back view), dorsiflexion (lateral view) and internal rotation (bottom view) planes.

RESULTS: Figure 2 shows the profile of ankle kinematics whereas Table 1 shows the peak angle, velocity, time to peak angle, and the comparison with the cases reported in 4 previous studies (Fong et al., 2009; Kristianslund et al., 2011; Mok et al., 2011; Gehring et al., 2013). The peak inversion in this case is 81° which lies within the range of 48°-142°. This case had shown a dorsiflexion trend throughout the whole injury process. The ankle rotation has a fluctuation from external rotation to internal rotation after footstrike. The result has shown a pattern of sudden inversion with a peak internal rotation at 0.04 second. The peak inversion velocity has reached 2687 deg/s.

			Mok et al. (2011)			Fong et al. (2012)					
	This study	Fong et al. (2009)	case 1	case 2	Kristianslund et al. (2011)	case 1	case 2	case 3	case 4	case 5	Gehring et al. (2013)
Peak inversion, deg	81	48	142	78	~35	94	48	59	67	126	~45
Peak inversion velocity, deg/sec	2687	632	1752	1397	559	1488	509	837	724	800	1290
Time of peak inversion, sec	0.04	0.2	0.08	0.08	~0.18	0.12	0.08	0.12	0.17	0.44	N/A
Peak plantarflexion, deg	-28	1	~52	~16	~20	30	28	31	37	-8	~50
Peak plantarflexion velocity, deg/sec	637	370	N/A	N/A	N/A	1748	381	561	571	325	1240
Time of peak plantarflexion, sec	0.06	0.04	0.18	0.17	0.3	0.16	0.1	0.03	0.46	0.07	N/A
Peak internal rotation, deg	51	10	~50	~45	~55	46	26	99	84	75	~13
Peak internal rotation velocity, deg/sec	3419	271	N/A	N/A	N/A	1170	412	2124	1312	530	580
Time of peak internal rotation, sec	0.04	0.2	0.15	0.12	0.16	0.26	0.06	0.12	0.26	0.41	N/A

Table 1: Peak value of the ankle angles and velocities in each injury incident reported.

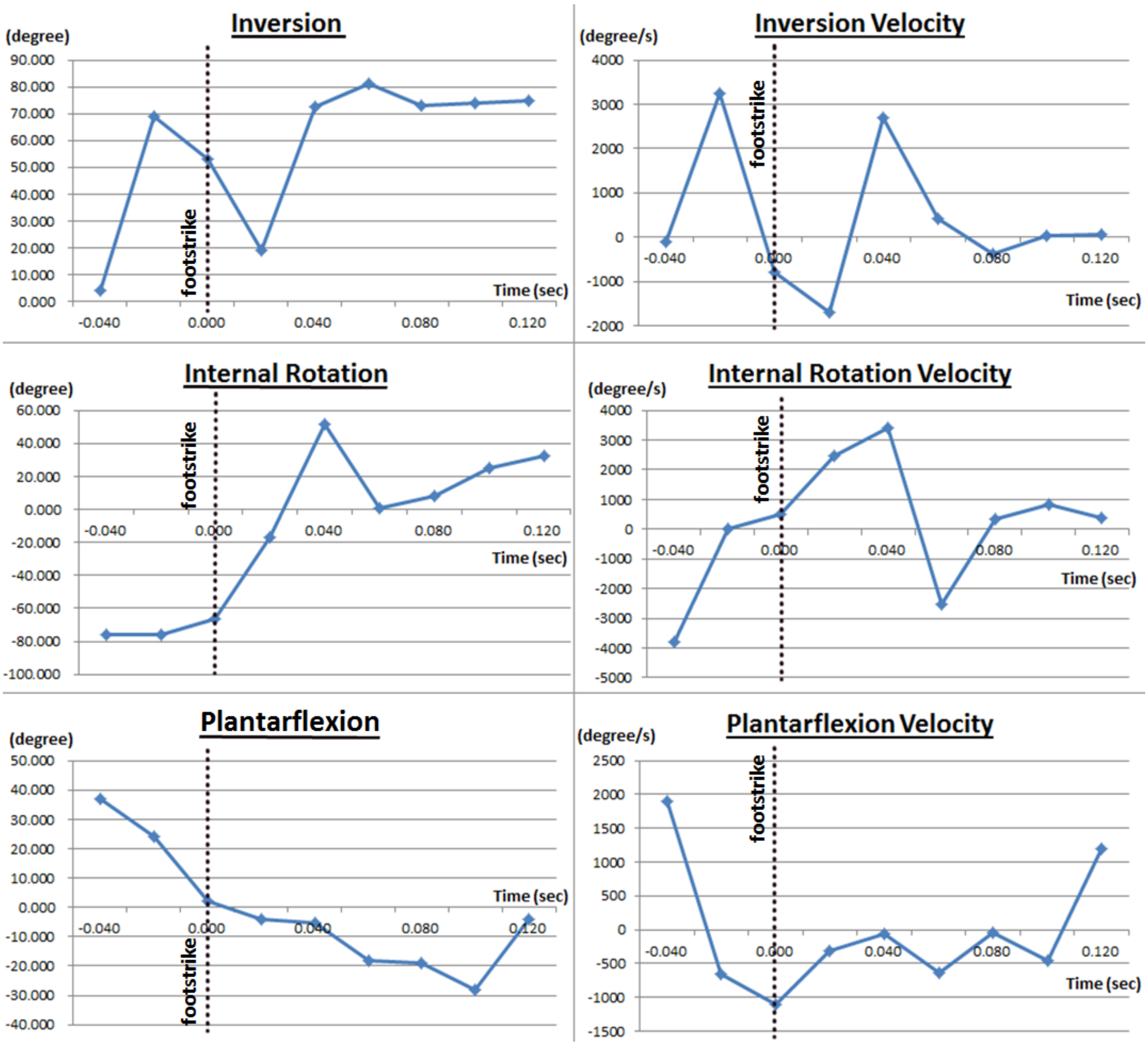

Figure 2: Profile of joint orientation and angular velocity of ankle inversion, internal rotation, and plantar flexion.

DISCUSSION: The result obtained is associated with the previous suggestion of our study. Plantarflexion is completely absent in the ankle inversion injury mechanism, instead, there was a trend of dorsiflexion (Fong et al., 2009). The inversion happens at the same time with internal rotation. The peak degree of internal rotation 51° happens with a sudden increase in inversion degree of 54° from approximately 19° to 73°. The peak inversion in this case lies within the range (48°-142°) obtained in previous studies while the peak inversion velocity 2687deg/s was the highest among all (Fong et al., 2009; Fong, Ha, Mok, Chan, & Chan, 2012; Gehring et al., 2013; Kristianslund et al., 2011; Mok et al., 2011). The high velocity suggested when the injury happens with a heel contact with an opponent, the velocity would increase.

The player expected to step on the flat surface but he had stepped on a round surface which caused the sudden acceleration.

CONCLUSION: This is the first analysis of basketball ankle inversion ligamentous sprain case. It further agrees on our previous finding on the injury mechanism as sudden inversion associated with internal rotation might happen with a dorsiflexed ankle joint. Internal rotation could be one of the causes of inversion. However, the inversion speed does play an important role to the injury.

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