MODEL-BASED IMAGE-MATCHING KINEMATICS ANALYSIS OF THREE ANKLE SUPINATION SPRAIN INJURY CASES IN SPORTS

Kam-Ming Mok[1,2], Aaron See-Long Hung[1,2] ,Daniel Tik-Pui Fong[1,2], Tron Krosshaug[3], Kai-Ming Chan[1,2]

Department of Orthopaedics and Traumatology, Prince of Wales Hospital, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, China [1]
The Hong Kong Jockey Club Sports Medicine and Health Sciences Centre, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, China [2]
Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Ullevaal Stadion, Oslo, Norway [3]

Ankle sprain is one of the most common injuries encountered at sport events. Three ankle supination sprain cases from high jump, tennis and hockey were chosen for analysis. Model-Based Image-Matching (MBIM) technique was implemented for reconstructing 3D ankle joint kinematics. The profiles of ankle joint kinematics were outputted from the selected sprain cases. The maximum inversion angle ranged from 78° to 142°. Plantarflexion was again found to be not necessary in ankle supination sprain injury. The results from the MBIM technique would contribute to the understanding of biomechanical injury mechanism of ankle supination sprain injury in sports. The future direction is to analyze more cases to consolidate the findings.

KEYWORDS: ankle sprain, injury biomechanics, video analysis

INTRODUCTION: Ankle sprain is one of the most common injuries encountered at sport events. 20% of the sports injuries are ankle sprains (Fong, 2007). A precise description of the injury situation is a key component to understanding the aetiology and injury mechanism (Bahr, 2005).

Injury incidents are occasionally recorded unintentionally during television broadcasting. Those video recordings provide valuable information for deducing joint kinematics of specific sport injury, as well as, contributing to the study of injury mechanism. From the previous studies, qualitative analysis of joint biomechanics was reported on ankle injuries based on visual inspection (Andersen, 2004). Quantitative analyses on injury cases were available under rare circumstances due to coincidental calibrated video setting (Zernicke, 1977; Fong, 2009). However, body marker tracking system or calibrated video setting are normally not available in all situations. Quantitative description on ankle joint biomechanics was not reported in those studies because no validated method to deduce the three dimensional (3D) joint kinematics from uncalibrated video recordings. In order to develop a novel biomechanical analysis to produce continuous estimates of joint kinematics from video recordings, Krosshaug and Bahr (2005) introduced a Model-Based Image-Matching (MBIM) technique for investigating human motion from uncalibrated video sequences.

The purpose of this paper was to investigate the ankle joint kinematics of three typical ankle sprain cases from take-off stepping, cutting and running motion.

METHOD: Three ankle supination sprain cases from high jump, tennis and hockey were chosen for analysis because of their difference in injury motions and circumstances. The first case was recorded from high jump event in Beijing Olympics Games 2008. The player sprained her left ankle during the take-off stepping. The second case was recorded from male tennis match in Vienna 1995. The player sprained his left ankle during a cutting step with back-hand volley. The third case was captured in male hockey match in Beijing Olympics Games 2008. The player sprained his left ankle during body contact with an opponent. The inclusion criteria were that the player was unable to continue the match or competition after the ankle supination motion, and the injury motion was captured by at least two video cameras. The injury situation and the video information were tabulated in Table 1. 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. The skeleton was scaled with respect to the height. The skeleton was further scaled with reference to the proportions of body segment which were defined from the standing post image of the player obtained from the internet site. 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, 1983).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.

The accuracy of MBIM technique on measuring ankle joint kinematics was well-validated (Mok, 2009). The ankle kinematics profile was divided to two phases, pre-sprain and post-sprain, based on the inversion angle.

Table 1. Description of the injury situation and the video sequences

Case no.	Sport event	Gender	Motion	No. of views	Sampling frequency	Video Resolution
1	High Jump (Olympic 08)	Female	Take-off stepping	3	50Hz	1280x720
2	Tennis (Vienna 95)	Male	Cutting	2	50Hz	320x240
3	Hockey (Olympic 08)	Male	Running	2	50Hz	1280x720

RESULT: Figure 1 presents the curve of the ankle joint kinematics of players during the ankle supination sprain injury. Table 2 tabulated the maximum inversion angle, the maximum inversion velocity and the duration from touchdown to maximum sprain. Maximum sprain was defined as the time point of maximum inversion angle reached. The photo captures at the point of maximum inversion angle were shown in Figure 2.

Table 2. The descriptive data of ankle joint kinematics of three injury cases

	Case 1	Case 2	Case 3	Fong et al. (2009)
Max. Inversion angle	142°	94°	78°	48°
Max. Inversion velocity	1752°/s	1488°/s	1397°/s	632°/s
Duration (TD to Max.Sprain)	0.08s	0.12s	0.08s	0.08s

For case one, the player was performing take-off stepping in high jump trial and the injury happened. The maximum inversion angle reached 142° at the point. She twisted her torso for overcoming the bar, leading to her ankle was internal rotated with larger degrees comparing with the other two cases. For case two, the player was performing cutting motion with backhand volley in the tennis match. Sudden plantarflexion was observed at the point of heel touch down. After the full plantar foot contact, increase in inversion and internal rotation were observed until the inversion reach the peak value, 94°. After the peak inversion, the ankle kept internal rotated and plantarflexed. For case three, the player was chasing the opponent with body contact. His left foot slightly stepped on the opponent's foot and the ankle supination motion was triggered. The maximum inversion reached 78°. Internal rotation was observed at the point of peak inversion.

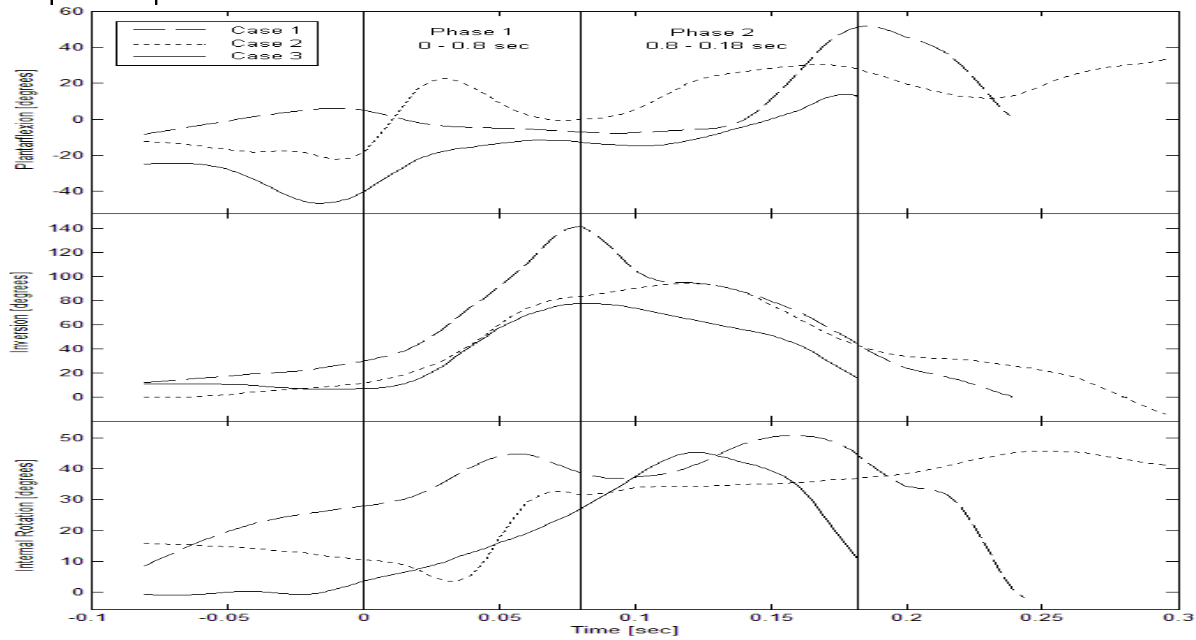

Figure 1. Ankle joint kinematics of the player during the ankle supination sprain injury. Time zero represented the point of heel touchdown. Positive values are Plantarflexion/Inversion/Internal Rotation.

DISCUSSION: Concluding the three selected cases, the ankle kinematics profile were divided into two parts according the phase division approach reported by Fong (2009), shown in Figure 1. Phase 1 was the pre-sprain phase, from 0 sec to 0.8 sec. In this phase, the ankle internal rotation inversion angles were increasing. Phase 2 was the post-sprain phase, the inversion angle decreased and the ankle kept internal rotated.

Compared with the previous biomechanical ankle sprain case report (Fong, 2009), the three analyzed cases were higher in severity. The maximum inversion angle and maximum inversion velocity were higher. The duration from heel touchdown to maximum sprain was similar. Increase in inversion and internal rotation appeared in pre-sprain phase (phase 1).

Large plantarflexion was not found in the analyzed ankle supination sprain injury. There is variation among cases by visual inspection. For instance, vigorous eversion was recorded right after the peak inversion only in case one, however, not in the other two cases.

Figure 2. Captures at the point of maximum inversion angle for Case 1-3 respectively.

CONCLUSION: This study reported the ankle joint kinematics of ankle supination sprain. The results from the MBIM technique could contribute to the understanding of biomechanical injury mechanism of ankle supination sprain injury. Due to variation among cases, the future direction is to analyze more cases to consolidate the findings.

REFERENCE:

Andersen, T.E., Floerenes, T.W., Arnason, A. & Bahr, R. (2004) Video analysis of the mechanisms for ankle injuries in football. *American Journal of Sports Medicine*. 32(Suppl): S69-S79.

Bahr, R. & Krosshaug, T. (2005) Understanding injury mechanisms: A key component of preventing injuries in sports. *British Journal of Sports Medicine*. 39(6): 324-329.

Fong, D.T.P., Hong, Y., Shima, Y., Krosshuag, T., Yung, P.S.H. & Chan, K.M. (2009) Biomechanics of supination ankle sprain: a case report of an accidental injury event in the laboratory. *American Journal of Sports Medicine*. 37(4): 822-827.

Fong, D.T.P., Hong, Y., Chan, L.K., Yung, P.S.H. & Chan, K.M. (2007) A systematic review on ankle injury and ankle sprain in sports. *Sports Medicine*. 37(1): 73-94.

Grood, E.S. & Suntay, W.J. (1983). A joint coordinate system for the clinical description of three-dimensional motions: application to the knee. *Journal of Biomechanical Engineering,* 105, 136-144.

Krosshaug, T. & Bahr, R. (2005) A model-based image-matching technique for three-dimensional reconstruction of human motion from uncalibrated video sequences. *Journal of Biomechanics*. 38(4): 919-29.

Mok, K.M., Fong, D.T.P., Krosshaug, T., Yung, P.S.H. & Chan, K.M. (2009) Validation of Model-Based Image-Matching Technqiue with bone-pin marker based motion analysis on ankle kinematics: A cadaver study. *Proceedings of XXVII International Symposium on Biomechanics in Sports* (pp. 197). Limerick, Ireland

Woltring, H.J. (1986) A Fortran package for generalized, cross-validatory spline smoothing and differentiation. *Advances in Engineering Software,* 8(2): 104-113

Zernicke, R.F., Garhammer, J., Jobe, F.W. (1977) Human patellar-tendon rupture. *Journal of Bone and Joint Surgery - American Volume*. 59(2): 179-83.

Acknowledgement

This research project was made possible by equipment and resources donated by The Hong Kong Jockey Club Charities Trust