ANALYSIS OF A LATERAL ANKLE SPRAIN INJURY IN BADMINTON WITH A MODEL-BASED IMAGE-MATCHING FORENSIC VIDEO ANALYSIS METHOD

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The purpose of this study was to examine the kinematics of an acute lateral ankle sprain sustained during a televised badminton match. A clip of an acute lateral ankle injury sustained during a match was edited and imported into Poser 4 and Poser Pro Pack to match the badminton court ground line and the player's skeletal model. Internal rotation rose with time and peaked at 57° at 0.28s, plantarflexion peaked at 22° at 0.08s and subsequently decreased, and inversion peaked at 92° at 0.2s. The maximal plantarflexion, internal rotation, and angular velocity of internal rotation were 492°/s, 921°/s, and 969°/s, respectively. After the strike, the ankle injury developed as a result of ankle inversion and internal rotation motions. To reduce ankle injuries in badminton, players should maintain a regulated landing posture while adjusting for environmental conditions and increase their strength and conditioning training on landing skills.

KEYWORDS: acute lateral ankle sprain; biomechanics; injury prevention

INTRODUCTION: Badminton is a sport that everyone can participate in, regardless of gender and age. From amateurs to professional athletes, about 200 million people worldwide participate in it (Phomsoupha and Laffaye,2015). Although badminton is good for health, it can also cause injuries. A 20-year epidemiological study conducted in the United States from 1997 to 2016 showed that the ankle joint is the most affected body part in badminton (Nhan et al. 2018), and a large number of epidemiological studies have shown that the majority of ankle injuries are lateral ankle sprains (Goh 2013; Yung et al. 2007). Successful injury prevention must aim to tackle the causal-type aetiology and mechanism. For lateral ankle sprain, a known aetiology is a tilted landing posture, causing rapid ankle inversion. Mimicking injury in the laboratory is unethical and practically very difficult. In 2009, Fong and colleagues carried out the first forensic video analysis of lateral ankle sprains with kinematic quantities. So far, there have been 10 similar reports, reporting 19 lateral ankle sprains or giving-way episodes have been published, including one in high jump, one in hockey, five in tennis, and four in basketball, also eight cases of cutting motion were captured in laboratory trials (Fong et al., 2021) But there were no reports for badminton until Fong et al. (2021). The size and the design the badminton court make it very suitable for the forensic video analysis technique, which requires perpendicular lines of known distance always visible during the incidence, to allow matching of the image on a virtually built badminton court in the computer environment. The recent inclusion of linesmen's view and sky view in some televised badminton games also make it much more feasible. Therefore, we decided to use forensic video analysis method to conduct a series of total 30 MBIM cases to examine the kinematics of acute lateral ankle sprain sustained during a televised badminton match. The purpose is to verify the validity and reliability of this research method and see if there are any patterns on lateral ankle sprain. The case in this paper is one of the 30 cases.

METHODS: The case's video was obtained from YouTube involve a player who was competing in a mixed doubles final in SaarLorLux Open 2020. The frame width and height of the video is 640x360, the Frame rate of the video is 30 frame/s. Prior to the image-matching procedure, the selected video was processed, and the required material was edited from the original video, starting from the last movement prior to the sprain and ending when the ankle stopped moving. The data was then stored in the AVI format using Premiere Pro. Each camera view was then manually synchronised to a 1-Hz video sequence using After Effects (version 5.0, Adobe Systems Inc., San Jose, CA, USA). Finally, the 3D modelling programme Poser ® 4 and Poser ® Pro Pack (Curious Labs, Inc., Santa Cruz, California, USA) were used to match the field line and bones of the injured player on a frame-by-frame basis. This was done for the entire video. The International Badminton Federation provided figures for the dimensions of a badminton court. The courts were matched by comparing the camera positions already established to a conventional court line model. The virtual environment was matched to the background of each image frame in each camera view using calibration settings for the camera's position, orientation, and focal length, as well as keyframe and spline interpolation techniques. Finally, frame-by-frame tweaks were made to each situation to obtain somewhat fluid camera movement. A skeletal model was used to adjust the lower limbs, including the foot, tibia/fibula, thigh, and pelvis, to the height of the injured athlete. Detailed descriptions of the motion analysis technique can be found in previous studies (Mok et al. 2011). By importing the ankle angles and angular velocities in all three planes into Matlab, the final ankle angles and angular velocities were determined. The Figure 1 shows the skeletal model based on the injury incidence.

Figure 1: skeletal model based on the ankle sprain incidence.

RESULTS: The peak ankle joint angle, angular velocity, and time to peak ankle joint angle are shown in Table 1. Damage process could be categorized into three phases based on the observed kinematic-temporal pictures of the joint: 0-0.08s (phase 1), 0.08-0.16s (phase 2), and 0.16-0.28s (phase 3) of the contact phase. During phase 1, the forefoot landing was detected in addition an abrupt rise in the ankle inversion and plantarflexion angles, with inversion increasing from 10° to 34° and plantarflexion increasing from 14° to a maximum of 22°. Both the internal rotation and inversion angles of the ankle increased in the second phase, with the inversion angle reaching a maximum of 92°. In contrast, the plantarflexion angles varied but generally decreased, and the knee flexion angle steadily increased as the centre of gravity shifted to the injured side of the ankle. When the wounded athlete was unable to support his body weight and fell to the ground, the ankle inversion angle decreased, and the internal rotation angle increased to a maximum of 57°. In comparison to the 20 previously published case studies, the greatest angular velocities for plantarflexion, internal rotation, and internal rotation were 492°/s, 921°/s, and 969°/s, respectively. The findings were consistent with those reported in other cases

Table 1: Peak ankle joint angle, angular velocity, and time to peak ankle joint angle as observed in the case study.

Variable	Value
Peak inversion (˚)	91
Peak inversion angular velocity (˚/s)	921
Time of peak inversion (s)	0.2
Peak plantarflexion (˚)	22
Peak plantarflexion angular velocity (˚/s)	492

Time of peak plantarflexion (s)	0.08
Peak internal rotation (˚)	57
Peak internal rotation angular velocity (˚/s)	969

DISCUSSION: In rare circumstances, athletes would bend their knees and spin their thighs outwards to avoid putting weight on the ankle joint (Andersen et al., 2004). However, when the athlete unable to cheat, he was forced to place weight on the ankle, resulting in injury. The athlete in this case study produced less knee flexion, increased knee inversion and hip adduction, and landed at 0.08 seconds with ankle plantarflexion in video (Fig.1). The centre of the pressure on his foot shifted to the forefoot, his toe landed while his hindfoot was still raised, his forefoot touched the ground to support his body weight, and his hindfoot drifted outwards. This sprain was comparable to those found in earlier studies (Mok et al., 2011; Fong et al., 2012; Panagiotakis, Mok, Fong and Bull, 2017; Fong et al., 2021; Fong et al., 2009; Kristianslund, Bahr and Krosshaug, 2011; Gehring, Wissler, Mornieux and Gollhofer, 2013; Terada and Gribble, 2015; Remus et al., 2018; Li et al., 2019). Garrick (1977) reported that an ankle ligament injury was typically caused by a combination of internal rotation, inversion, and plantarflexion. This inwardly twisted and inwardly turned plantarflexion of the ankle causes the ankle's centre to swing outward, shifting the ankle away from the point of application of ground reaction forces (Mok et al., 2011). The laterally shifted centre of pressure is a risk factor for ankle sprains and so may increase the risk of spraining the ankle (Wright et al., 2000). The application of a model-based image-matching technique to analyse ankle sprains is more practical for badminton than for other sports. This is because badminton courts have a fixed size and have defined edge lengths; in addition, the area of the court is modest in comparison to other sports. Furthermore, the number of participants is low, it is relatively easy to match the court lines and skeletal models, which may help reduce errors caused by manual matching. Additionally, during live badminton matches, the camera is typically positioned parallel to the two bottom lines to determine if the ball is out of bounds when it hits the ground; hence, the camera can zoom in on a view of the injured player, and the resultant image is more likely to accurately capture the player at the time of their injury (Fong et al., 2021).
However, because the video clips obtained from the initial YouTube search had very low frame rates, oscillation effects were observed in the curves generated. Additionally, the video for the current case study was only 0.48 s long and could only 13 data points could be obtained. The video began 0.08 seconds before the foot struck the ground and ended 0.4 seconds after landing, during which the ankle transitioned from imminent excessive plantarflexion inversion and internal rotation to a position where there was no further ankle movement, followed by a return to normal activity. Although the process of matching the image to the motion was certainly conceivable, the video frame rate could be increased in the future to produce more precise results and a smoother curve. Additionally, the process of matching images by hand is subject to human error and is likely to yield inconsistent results when the same image is matched by different people. Thus, in the future, artificial intelligence techniques can be used to reduce human errors, as they can not only rapidly produce findings, but can also significantly accelerate the matching speed required of this methodology, thereby resolving the problems related to insufficient sample size.

CONCLUSION: We evaluated a single badminton instance of a lateral ankle injury and compared it to 20 previously reported cases. Our data imply that the ankle injury occurred as a result of the ankle inversion and internal rotation movements after strike. To help reduce ankle injuries in badminton, players should maintain a controlled landing position while controlling environmental factors and do additional strength and conditioning training on their landing skills and ability. By reducing ankle angles while landing, injuries can be avoided, particularly when completing a combined lateral and backward stride, which is highly prevalent in badminton footwork. Furthermore， it is more practical to use model-based image matching approaches to analyse ankle sprains in badminton than in other sports. This is because the court edges are well-defined and the number of participants is minimal, which may assist reduce errors caused by human matching.

However, because to the small number of video frames analysed, which results in curvilinear oscillation effects and fewer data points, the accuracy of video analysis could be boosted in the future from the perspective of intercepted video.

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