INVESTIGATING AND PREVENTING SPORT-RELATED ANKLE SPRAIN INJURY

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Ankle sprain injury is very common in sports. It is worth investigating and preventing it. From the literature, two aetiologies were identified: (1) incorrect landing posture, and (2) delayed peroneal muscle reaction. To investigate the injury mechanism, a model-based image-matching motion analysis technique was developed to analyze real injury incidents captured in televised events. The study provided data for establishing a threshold to identify ankle sprain injury hazard by the inversion velocity as monitored by a uni-axial gyrometer. To prevent the injury, a myoelectric stimulation system was developed to initiate peroneal muscle contraction in a very short time (within 25ms) to accommodate the injurious motion (within 50ms) before the muscle could react (60-90ms). The invention will be commercialized as a prophylactic sport apparel in the coming years
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KEY WORDS: Ankle ligamentous sprain, sports injury, injury prevention, prophylactic device.

INTRODUCTION: Ankle ligamentous sprain injury caused by excessive inversion is very common in sports. However, only 15% of the patients would consult orthopaedic specialists or physiotherapists for evidence-based sports medicine treatment (Chan, Fu, & Leung, 1984). Without proper care, an ankle sprained for 5 or more times may be more prone to chronic ankle instability (Yeung, Chan, So, & Yuan, 1994), which may lead to articular cartilage defect and early osteoarthritis at the ankle joint. Sports biomechanists can contribute in injury prevention, by analysing injury aetiology and mechanism, designing preventive intervention, and evaluating the effectiveness in a biomechanics laboratory (Chan, Fong, Hong, Yung, & Lui, 2008). This paper presents my work on investigating and preventing sport-related ankle sprain injury, while being a sports biomechanist working in a clinical orthopaedic department.

Epidemiology: I first conducted a systematic review which summarized 227 studies published since the first ever ankle sprain epidemiology study 36 years ago (Garrick, 1977) and suggested that the ankle joint was the second common injured body site in sports, with inversion sprain being the most common diagnosis accounting for 84% (Fong, Hong, Chan, Yung, & Chan, 2007). The injury incidence was highest in rugby, football, volleyball, handball and basketball. Another local study on the audit of the attendance to accident and emergency department revealed that 14% of the sport-related attendances were on the ankle joint, with 81% being ligamentous sprains and 10% being fracture, sustained mainly in basketball (37%) and football (29%) sports (Fong, Man, Yung, Cheung, & Chan, 2008). An earlier report suggested that only one-sixth of the patients having sports injury would attend accident and emergency department, and therefore the total number of sports injuries could be estimated the greatest among all kinds of injuries (Chan, Yuan, Li, Chien, & Tsang, 1993). Although we now have “better” sports shoes and protective gear (Fong, Hong, & Li, 2007), the prevalence and incidence of ankle sprain is still comparable to the previous 36 years.

Aetiology: There are two major aetiologies which cause an ankle inversion sprain injury (Fong, Chan, Mok, Yung, & Chan, 2009a). Firstly, an incorrect landing posture with a slightly inverted or supinated ankle joint would cause a ground reaction force acting on the lateral foot edge to point medially and not pass through the ankle joint centre, thus creating a vigorous inward twisting torque, subsequent excessive inversion, and finally high ligament strains which tear the lateral ligaments. Secondly, the reaction of the peroneal muscles, which function to resist ankle inversion, is too slow (60-90ms) to catch up to accommodate the sudden explosive inversion which happened within 50ms after a foot strike. The stability of a joint depends on both the contraction of the muscles and the contribution from the ligaments, therefore, when the muscles are inactive, the joint stability would rely mainly on the ligaments. Since the ligaments possess viscoelastic property, a sudden explosive stretch would tear them.

Mechanism: There are many ways to further study the injury mechanism, and the most direct one is to study the real injury incidents. In 2007, I was fortunate enough to collect video and plantar pressure data when a subject sustained a Grade I ligamentous sprain injury while performing a cutting motion in a laboratory during a sport shoe stability experiment. The comprehensive biomechanics data were later reported in the first ever ankle sprain case report with biomechanically presented mechanism (Fong et al, 2009b). The data suggested that the peak inversion has reached 48 degrees, and such a range of inversion is often regarded as normal from the literature. Moreover, a dorsiflexed instead of plantarflexed ankle orientation was observed, and this was not in agreement with the supination mechanism clinically suggested. The peak inversion velocity reached 638 deg/s, and this was the first time such a value was reported. I and my other co-investigators could not compare to the literature but we believed that such a vigorous twist should have had injured the ankle ligament, which was diagnosed immediately by an orthopaedic surgeon right after the incident. It was exciting to have these data, and there is also a need to have data from more injury cases before we could draw conclusion. However, one could not just wait for another accident to happen, and therefore we must plan for another research methodology.

A new method for investigation: Since 2007 I developed a model-based image-matching motion analysis technique to study ankle sprain mechanism (Mok et al, 2011b), and utilized the method to study two injury cases during the 2008 Beijing Olympics (Mok et al, 2011a). I continued to analyze five cases from tennis competitions (Fong, Ha, Mok, Chan, & Chan, 2012), and the data from these reports suggested that the ankle joints were all in an inverted and internally rotated orientation, plus either a dorsiflexed or plantarflexed ankle orientation. Nevertheless, all data showed high inversion velocities (>500 deg/s) which were all greater than that collected during common sporting activities (Chu et al, 2010). I further used the profile of ankle kinematics data to drive a computational foot and ankle model (Fong & Wei, 2012) to simulate the injury, and the result suggested that an inversion moment of 23Nm and an internal rotation moment of 11Nm were presented, resulting in a 15-20% strain at the anterior talofibular ligament (Wei, Fong, Chan, & Haut, in press).

An innovative invention for prevention: There are many modalities for injury prevention and I started with the shoes (Fong, 2012), as I believed that the design of the construct of shoes or inserts may change the foot and ankle biomechanics, hopefully in a desired way (Fong et al, 2008c; Fong, Pang, Chung, Hung, & Chan, 2012). Based on the two identified aetiologies, a monitor system was designed to detect incorrect landing posture, and a corrective system was designed to overcome the delayed peroneal muscle reaction.

For the monitor system, the first attempt was to monitor the ankle joint supination torque. In a biomechanics laboratory, such is often determined by inverse dynamic calculation with kinematics, kinetics and anthropometry data. I first devised a method to estimate complete ground reaction force from pressure insoles (Fong et al, 2008a), and further calculated the ankle joint supination torque (Fong et al, 2008b). Although we reported that a 23Nm inversion moment was observed during an ankle sprain injury (Wei, Fong, Chan, & Haut, in press), there was a need to determine the threshold which the ligament started to tear. For this purpose, a cadaveric biomechanics study was conducted (Fong, Chung, Chan, & Chan, 2012b), but the attempt was suspended after all because the twisting speed on the cadaveric specimen had not been concerned, and the device utilizing pressure sensors for estimation would record no data when a foot rolls over the lateral edge to sustain an ankle sprain injury.

The second attempt was to use motion sensors to identify injury-like and normal motion. For this purpose, a mechanical sprain simulator was built (Chan, Fong, Yung, Fung, & Chan, 2008), and a total of 300 injury-like and 300 normal motions were collected by eight motion sensors attached to the dorsal foot. A support vector machine model was used to identify these motions, and the method reached an accuracy of 91.3% (Chan et al, 2010). However, the method was also suspended as the identification could only be done post data collection, but not in a real-time manner. The final attempt was to use a uni-axial gyrometer attached to the heel counter and to identify the injury hazard by the inversion velocity (Fong & Chan, 2010). The threshold was based on the data from the reported injury incidents (Fong et al, 2009b; Fong et al, 2012c; Mok et al, 2011a) and the normal motions we collected (Chu et al, 2010).

For the corrective system, the first attempt was to design a semi-rigid brace with magnetorheological fluid which turns rigid in a very short time when a magnetic field is present – this was done by closing the circuit of an electric coil in our device (Tang, Wu, Liao, & Chan, 2010). However the attempt was suspended as the material cost was high, and we were not sure if there is any potential health hazard in case of leakage of the metal fluid. The current attempt is to deliver myoelectric stimulation to the peroneal muscles to initiate very fast ankle eversion or pronation within 25ms to resist the injury mechanism which happens within 50ms after the foot strike (Fong, Chu, & Chan, 2012a). The system has been evaluated to be effective in a biomechanics laboratory, and was granted US patent in 2012 (Chan, Fong, & Yung, 2012). Because of the position of the peroneal muscle belly, the stimulation has to be delivered at the upper shank for the best effect (Fong, Wang, Chu, & Chan, 2013), and the system is currently carried by a pair of wireless wearable parts, or a sport legging covering the whole shank. The device only gives mechanical support by assisting the muscle reaction to generate muscular forces when in need, and allows the athlete to have an agile ankle joint for most of the time for the best performance.

On-going work: The intelligent anti-sprain system is being revised for better accuracy in identifying injury risk, and for better agility, comfort, durability and user setting interface when it is being carried in a pair of sport legging. The invention will be commercialized as a prophylactic sport apparel in the coming years.

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