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Original research

Lower limb joint motion during a cross cutting movement differs in individuals with and without chronic ankle instability☆

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A B S T R A C T

Objective: To compare the kinematics of lower limb joints between individuals with and without chronic ankle instability (CAI) during cross-turn and -cutting movements.
Design: Cross-sectional study.
Setting: Motion analysis laboratory.
Participants: Twelve subjects with CAI and twelve healthy controls.
Main outcome measures: Hip flexion, adduction, and internal rotation, knee flexion, and ankle dorsiflexion and inversion angles were calculated in the 200 ms before initial ground contact and from initial ground contact to toe-off (stance phase) in a cross-turn movement during gait and a cross-cutting movement from a forward jump, and compared across the two groups.
Results: In the cross-cutting movement, the CAI group exhibited greater hip and knee flexion than the control group during the stance phase, and more hip abduction during the period before initial contact and the stance phase. In the cross-turn movement the joint kinematics were similar in the two groups.
Conclusions: CAI subjects exhibited an altered pattern of the proximal joint kinematics during a cross-cutting movement. It is important for clinicians to assess the function of the hip and knee as well as the ankle, and to incorporate coordination training for the entire lower limb into rehabilitation after lateral ankle sprains.

1. Introduction

Lateral ankle sprain is one of the most common injuries in many sports, including basketball, volleyball, and football (Fong, Hong, Chan, Yung, & Chan, 2007). The recurrence rate has been reported to exceed 70% in basketball (Yeung, Chan, So, & Yuan, 1994). Approximately 40–75% of individuals who sprain their ankle go on to develop chronic ankle instability (CAI) (Gerber, Williams, Scoville, Arciero, & Taylor, 1998), defined as recurrent ankle sprain, repetitive 'giving way' of the ankle joint, or a feeling of instability in the ankle joint (Delahunt, Coughlan, Caulfield, Nightingale, Lin, & Hiller, 2010). Individuals with CAI may have mechanical ankle instability (MAI) or functional ankle instability (FAI). MAI is characterized by pathological laxity of lateral ankle ligaments, and FAI is characterized by impaired neuromuscular control, proprioception or postural control without ligamentous laxity (Delahunt et al., 2010). These residual symptoms have been linked to increased risk of osteoarthritis at the ankle (Valderrabano, Hintermann, Horisberger, & Fung, 2006).

The biomechanics of the lower limb joints in individuals with CAI have been investigated during dynamic tasks. Individuals with CAI had a more inverted ankle position than healthy individuals before and after heel strike during gait (Delahunt, Monaghan, & Caulfield, 2006a; Monaghan, Delahunt, & Caulfield, 2006). Individuals with CAI also had a more inverted ankle position than healthy individuals during running (Lin, Chen, & Lin, 2011), single-leg landing (Delahunt, Monaghan, & Caulfield, 2006b), and lateral

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hop (Delahunt, Monaghan, & Caulfield, 2007). However, some studies have reported findings that are inconsistent with these studies (Brown, 2011; Brown, Padua, Marshall, & Guskiewicz, 2008; Kipp & Palmieri-Smith, 2012). These studies have all used gait, running, and landing to evaluate the biomechanics of the lower limb joints in individuals with CAI. Lateral ankle sprains often occur during twisting and turning movements (McKay, Goldie, Payne, & Oakes, 2001; Woods, Hawkins, Hulse, & Hodson, 2003); however, the biomechanics of the lower limb joints in individuals with CAI have not been well investigated in turning or cutting movements. Previous studies have shown altered plantar pressure, position of center of pressure (Huang, Lin, Kuo, & Liao, 2011), and leg muscle activity (Suda & Sacco, 2011) during a lateral shuffle movement (sideward lateral cutting) in individuals with CAI and, during a v-cutting movement, vertical ground reaction force (GRF) was greater on the side of the unstable ankle than on the contralateral side of the uninjured ankle (Dayakidis & Boudolos, 2006). These studies focused on the lateral shuffle and v-cutting movements, but the biomechanics during cross-turn or -cutting movements have not yet been investigated. The cross-turn movement involves a change of direction to the lateral side against the supporting leg, thus the center of plantar pressure may shift laterally, and forced inversion motion may occur at the ankle of the supporting leg. These tasks may put the ankle at risk of giving way or laterally spraining in individuals with CAI.

Previous studies have suggested that individuals with MAI or FAI have altered kinematics of the hip and knee joints during a stop jump (Brown, Padua, Marshall, & Guskiewicz, 2011) and a single-leg landing (Caulfield & Garrett, 2002; Delahunt et al., 2006b; Gribble & Robinson, 2010), but there is not yet a consensus on this topic. The kinematics of the proximal joints may change to compensate for instability or decreased function of the ankle in individuals with CAI. Such changes may be pre-existing, thus playing a role in the development of CAI. Quantifying the kinematics of the lower limb joints in individuals with CAI during cross-turn and -cutting movements may help us to understand the movement patterns used, and why these individuals experience 'giving way' or recurrent ankle sprains. In addition, we believe that understanding the patterns of movement aids in the development of rehabilitation interventions that specifically address deficits or factors that contribute to the pathogenesis of CAI. Therefore, the purpose of this study was to determine the kinematics of the hip, knee, and ankle joints during cross-turn and -cutting movements in individuals with CAI. We hypothesized that individuals with CAI would have altered hip and knee kinematics, and greater ankle inversion, than healthy control subjects.

2. Methods

2.1. Subjects

The participants were recruited from among athletes belonging to a variety of sport clubs at our university. A total of 24 athletes participated in this study. Based on our pilot study (comprising four CAI and four control athletes), we performed a priori power analysis using the t test model of G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007). As a result, a sample size of 22–24 subjects (11–12 subjects per group) was found to be necessary to achieve a power of 0.80 for the ankle inversion angle. Participants were instructed on the experimental procedure and were required to sign informed consent forms before the study began. Ethics approval was obtained from the university Institutional Review Board.

Twelve athletes (ten males; two females) met the following criteria and formed the CAI group based on the previous studies (Delahunt et al., 2006a; Gribble et al., 2013): (1) a history of at least one lateral ankle sprain requiring non-weight bearing and/or immobilization and/or abnormal gait; (2) a history of at least two lateral ankle sprains; (3) at least one lateral ankle sprain within the past two years; (4) episodes of the ankle 'giving way'; (4) a Cumberland Ankle Instability Tool (CAIT) score of 27 or less (Delahunt et al., 2010; Hiller, Refshauge, Bundy, Herbert, & Kilbreath, 2006); (5) not receiving rehabilitation at the time of testing. The remaining twelve athletes (ten males; two females) had no history of lower limb injuries, ankle joint instability or episodes of 'giving way' and formed the age- (within two years) and gender-matched healthy control group. Subjects were excluded if they met the following criteria based on a previous study (Gribble et al., 2013): (1) a history of fracture or surgery in the lower limb or major musculoskeletal injuries (other than a history of lateral ankle sprain in the CAI group); (2) inflammation and swelling at the ankle at the time of testing; (3) a history of acute injuries of other joints of the lower limb within three months. All subjects were participating in sports activities at least two times a week. The subjects participated in a variety of sports (e.g. basketball, lacrosse, track and field, tennis, sepak takraw, and soccer). Most subjects engaged in sports involving jumping, landing and cutting tasks. If CAI subjects had CAI in both ankles, the more affected side, as determined by CAIT score, was studied. The CAI and control group were matched on dominance of the limb tested (nine dominant and three non-dominant limbs tested). The dominant leg was determined by asking which leg the subject would use to kick a stationary ball (Rein, Fabian, Zwipp, Mittag-Bonsch, & Weindel, 2010).

2.2. Equipment

Twenty-five reflective markers were placed on the skin of the lower limbs using double-sided adhesive tape. Markers were placed according to a modified Helen Hayes marker set (Kadaba, Ramakrishnan, & Wootten, 1990): At the sacrum, and bilaterally on the anterior superior iliac spine, greater trochanters, lateral aspect of the thighs, lateral and medial femoral epicondyles, lateral aspect of the shanks, lateral and medial malleoli, posterior heels, and first, second and fifth metatarsal heads. All subjects wore the same type of shoes (Artic Mesh M, Adidas, Herzogenaurach, Germany) in a fitting size. Holes were cut in the shoes to enable markers to be placed directly on the skin of the foot. Lower limb kinematic and GRF data were collected using six digital cameras (Hawk cameras, Motion Analysis Corporation, Santa Rosa, CA, USA) and a force plate (Kistler, Winterthur, Switzerland) that were time-synchronized and sampled at 200 Hz and 1000 Hz, respectively.

2.3. Procedure

After a static trial was collected with the subject standing, the medial femoral condyle and medial malleoli markers on the non-test leg were removed before the movement tasks were performed. Subjects were instructed to perform a cross-turn movement and a cross-cutting movement. The cross-turn movement was based on the movement presented by Houck and Yack (2003). The subjects walked straight on a walkway at their natural speed while looking straight ahead so as not to look the force plate. They then planted their test limb on the force plate and changed direction to the side of the supporting leg at 45° and walked for approximately 2.5 m (Fig. 1a). The cross-cutting movement was based on the movement described in a previous study (Ford, Myer, Toms, & Hewett, 2005). Subjects were positioned in a crouched position 0.4 m in front of the force plate with their knees flexed to approximately 45°. Upon hearing an audio cue played by the examiner, subjects were instructed to perform a forward jump onto