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Short communication

A laboratory captured "giving way" episode in an individual with chronic ankle instability

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ABSTRACT

This brief report details the first ever instrument-based motion description of an accidental "giving way" episode of the ankle joint incurred by a recreational male athlete (age = 22 years; height = 1.78 m; body mass = 97 kg) with chronic ankle instability whilst he was performing a change of direction task. Five inertial measurement units, as well as a high-speed video camera captured his lower limb kinematics during the performance of a maximum effort Agility T-Test, including his accidental "giving way" episode. This episode was analysed and compared to a previous trial during which no incident occurred. Analysis of the inertial measurement unit data revealed that the "giving way" episode was characterised by plantar flexion of the ankle joint, as well as internal rotation and adduction of the ankle-foot complex, with peak rotational velocities reaching 797°/s, 1088°/s and 1734°/s, respectively. This instrument-based motion description provides a unique insight into the characteristic features of a "giving way" episode experienced by a recreational athlete with chronic ankle instability. These findings could inform the development of rehabilitation programmes and the design of protective equipment for individuals with chronic ankle instability.

1. Introduction

Lateral ankle sprain is the most frequent musculoskeletal injury incurred by individuals who participate in sports and recreational physical activities (Doherty et al., 2014b; Fong et al., 2007; Hootman et al., 2007). The recurrence rate of lateral ankle sprain injury is very high (Verhagen et al., 2005) and coincides with the progression of a number of long-term sequalae including pain, persistent swelling, episodes of ankle joint "giving-way", a subjective feeling of ankle joint instability, recurrent sprain and reduced functional capacity (Gribble et al., 2016, 2014a, 2014b, 2013). These long-term sequalae are the characteristic features of chronic ankle instability (CAI) (Delahunt et al., 2010).

Understanding the mechanisms of lateral ankle sprain injury, ideally with biomechanical measures, is a central component required for the development of injury prevention protocols and the design of protective equipment (Bahr, 2005). Numerous reports exist in the published scientific literature, which detail the mechanisms of lateral ankle sprain injury (Andersen et al., 2004; Fong et al., 2012, 2009a, 2009b; Gehring et al., 2013; Kristianslund et al., 2011; Mok et al., 2011; Terada and Gribble, 2015). Whilst the mechanisms of contact and non-contact lateral ankle sprain injury are well documented, little is known about the biomechanical quantities of "giving-way" episodes of the ankle joint. "Giving-way" of the ankle joint has been defined as *"the regular occurrence of uncontrolled and unpredictable episodes of excessive inversion of the rear foot (usually experienced during initial contact during walking or running), which do not result in an acute lateral ankle sprain*" and is a characteristic feature of CAI (Delahunt et al., 2010). Understanding the mechanisms of "giving-way" episodes of the ankle joint in individuals with CAI is required to develop improved rehabilitation and injury prevention programmes. This brief report provides an instrument-based motion description of an episode of "giving-way" of the ankle joint incurred by a male recreational athlete with CAI, whilst he was performing a maximum effort Agility T-Test in a university sports hall.

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2. Injury case

A recreational male athlete (age = 22 years; height = 1.78 m; body mass = 97 kg) with a history of bilateral CAI volunteered to participate in a case-control study with the aim of investigating the influence of CAI on lower limb movement profiles during the performance of sports-related performance tests. The participant belonged to the study group of CAI participants; as per the criteria endorsed by the International Ankle Consortium (Table 1) (Delahunt et al., 2010; Gribble et al., 2016, 2014a, 2014b, 2013). Before testing the participant provided written informed consent in accordance with the recommendations of the University Human Research Ethics Committee. The protocol for the experimental set-up required the participant to perform the following sports-related performance tests: (1) Change of Direction and Acceleration Test (Lockie et al., 2013) (2) Agility T-Test (Raya et al., 2013) (3) drop vertical jump (Doherty et al., 2014a). All performance tests were undertaken by the participant with and without an ankle brace (Aircast© A60). He wore the brace on his right ankle during the braced conditions, as it was deemed his most unstable ankle, as confirmed by his Cumberland Ankle Instability Tool (Hiller et al., 2006) scores. Accidentally, he experienced an episode of "giving way" of his non-braced, left ankle joint during his maximum effort "braced" right-sided Agility T-Test. Fig. 1 describes the testing protocol. He was not injured during this "giving way" episode and was able to complete the test in 10.06 s. Upon completion of the Agility T-Test, he reported no symptoms of acute lateral ankle sprain injury such as pain, swelling or decreased weight-bearing status. He described the incidence as a typical "giving-way" episode. He was followed up 24 h and one-week after the testing session and reported no acute lateral ankle sprain injury symptoms in his left ankle and had not had to restrict his participation in any physical activity.

3. Lower limb movement profiles acquisition and analysis

The ankle joint "giving way" episode was recorded on a Sony HDR-A15 video camera sampling at 120 Hz. The participant's lower limb movement profiles were also simultaneously recorded by five Shimmer 3 inertial measurement units (IMUs) (Shimmer Research, Dublin, Ireland), sampling at 256 Hz; these were attached bilaterally to the participant's feet, shanks and sacrum. Only signals from the left limb and back were analysed in this report. The tri-axial accelerometer and gyroscope signals were enabled and set to ranges of ±16 G and ±2000°/s, respectively. Accelerometer and gyroscope data were re-sampled to 240 Hz. Custom written code in MATLAB 2016b (The MathWorks, Natwick, USA) allowed for IMU and video camera data synchronisation. After synchronisation, initial contact of the "giving-way" episode was identified in the video sequence. A period of 200 ms pre-initial contact to 800 ms post-initial contact was extracted from all accelerometer and gyroscope signals for analysis. The same procedure of IMU data extraction was performed for the participant's non-braced maximum effort right-sided Agility T-Test, which was used as a non-injured comparison test.

Table 1
Athlete's ankle injury characteristics and patient reported outcome scores.

CAIT (Left Ankle)	23
CAIT (Right Ankle)	11
idFAI (Left Ankle)	18
idFAI (Right Ankle)	25
FAAM-ADL (Left Ankle)	67%
FAAM-ADL (Right Ankle)	60%
FAAM-Sport (Left Ankle)	56%
FAAM-Sport (Right Ankle)	53%
Number of Lateral Ankle Sprains (Left Ankle)	4+
Number of Lateral Ankle Sprains (Right Ankle)	5+

CAIT = Cumberland Ankle Instability Tool (Hiller et al., 2006); idFAI = Identification of Functional Ankle Instability Questionnaire (Gurav et al., 2014); FAAM-ADL = Foot and Ankle Ability Measure Activities of Daily Living (Carcia et al., 2008); FAAM-Sport = Foot and Ankle Ability Measure Sport (Carcia et al., 2008).

4. Qualitative video analysis of the "Giving-way" episode

Qualitative video analysis of the athlete's performance of the Agility T-Test, including the epoch of the "giving-way" episode, was performed independently by three researchers (AR, CD and ED). Following completion of this initial step a consensus meeting was convened to agree upon the common features of the independent qualitative assessments. The full video can be viewed in the Supplementary Video file.

5. Results

5.1. Lower limb movement profiles

Figs. 2 and 3 show the key shank and foot IMU signals of the "giving-way" episode, respectively, overlaid with the corresponding IMU signals for the non-injured comparison trial. An expanded description of the IMU signals is found in Appendix Table A1 (shank) and Appendix Table A2 (foot). The accidental "giving way" episode was characterised by plantar flexion of the ankle joint, as well as internal rotation and adduction of the ankle-foot complex, with peak rotational velocities reaching 797°/s, 1088°/s and 1734°/s, respectively. All other signal plots for the back, shank and foot sensors are provided in the Appendix Figures A1–A3.

5.2. Qualitative video analysis

Nine key events of the Agility T-Test up to and including the "giving-way" episode are highlighted in Fig. 4. An expanded description of the mechanism occurring in each of the key events is found in the supplemental Appendix Table A2.

6. Discussion

To the knowledge of the authors, this brief report details the first instrument-based motion description of an episode of "giving-way" of the ankle joint incurred by a recreational athlete with CAI, whilst performing a change of direction task. This opportunistic dataset included linear acceleration and rotational velocities recorded from 5 IMUs, as well as high-definition video camera footage.

Nine key events were identified throughout the performance Agility T-Test, which were deemed integral to the mechanism of the "giving way" episode incurred by the athlete (Fig. 4 and Appendix Table A2). Qualitative analysis identified that the "giving way" episode was characterised by plantar flexion of the ankle joint, as well as internal rotation and adduction of the ankle-foot complex. Evaluation of the IMU signals revealed high rotational velocities, comparable to those of previously published reports of lateral ankle sprain injury incidents (Andersen et al., 2004; Fong et al., 2012, 2009a, 2009b; Gehring et al., 2013; Kristianslund et al., 2011; Mok et al., 2011; Terada and Gribble, 2015). Following the "giving way" episode the participant utilised his right limb and trunk to "pull" his body mass towards the right, to continue the completion of the Agility T-Test (Key event 9; Fig. 4i). He completed the Agility T-Test without any further identified movement aberrancies.

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