A laboratory captured ‘giving way’ episode during a single-leg landing task in an individual with unilateral chronic ankle instability

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ABSTRACT

An episode of ‘giving way’ at the ankle is described as excessive inversion of the rearfoot that does not result in an acute ankle sprain and is a unique feature associated with chronic ankle instability (CAI). Limited data currently exists describing the preparatory movement patterns and those that occur during an episode of ‘giving way’. Therefore, this case report describes the movement patterns and the forces generated during an unintentional ‘giving way’ captured while an individual with unilateral CAI was performing a single-leg landing task in a research laboratory. The participant completed five single-leg landing trials for both limbs. 3D lower extremity kinematics and kinetics for the sagittal and frontal plane were extracted from 200 ms before and after initial contact (IC). Relative to the affected and un-affected single-leg landing trials, the ‘giving way’ episode was characterized by an increase in plantarflexion and hip extension moments before and after IC. The plantarflexion deviation dissipated (50 ms post-IC) and was followed by excessive ankle inversion. The ankle began to plantarflex again (150 ms post-IC) and the knee extended (50 ms post-IC) and adducted (100 ms post-IC). As a result, the ankle inversion angle plateaued at 150 ms post-IC. Furthermore, large sagittal plane internal joint moments were observed. In the frontal plane, the ‘giving way’ trial generated a large inversion joint moment which was counteracted by a large internal eversion joint moment. The observed plantarflexion and knee extension and adduction after initial contact likely contributed to preventing the ankle from continuing to invert and avoid an ankle sprain.
2. Methods

2.1. Participant

A college-aged male (age = 23, height = 187.96 cm, mass = 97.7 kg) agreed to participate in a case-control study aimed at comparing bilateral lower extremity movement patterns during a single-leg landing task. The inclusion criteria for the case-control study was based on the recommendations set by the International Ankle Consortium (Gribble et al., 2014). Using these recommendations, the participant was classified as having unilateral CAI (Table 1). The participant read and signed an informed consent approved by the university institutional review board.

2.2. Instrumentation

A Vertec vertical jump tester (Sports Imports, Columbus, OH, USA) was used to measure the maximum vertical jump height and to serve as a target during each single-leg landing trial. Reflective markers were placed at selected anatomic landmarks of the pelvis and throughout each leg/foot (McCann et al., 2017). Kinematic data were captured at 200 Hz using four Raptor-E cameras, six Raptor-4S cameras (Motion Analysis Corporation, Santa Rosa, CA) and Cortex 6.2 motion capture software (Motion Analysis Corporation, Santa Rosa, CA) (McCann et al., 2017). Force data were collected at 1000 Hz using an embedded Bertec Force Plate (Bertec FP6090-15-2000; Bertec Inc., Columbus, OH) (McCann et al., 2017). Raw motion capture data for each single-leg landing trial was imported and processed in Visual 3D (version 5, C-Motion, MD). Sagittal and frontal plane joint rotations, internal moments and ground reaction forces for each single-leg landing trial were extracted. Data for the five successful single-leg landing trials for the affected and un-affected sides were averaged and the 95% confidence intervals (CI) were calculated. Areas of nonoverlap between the “giving way” trial and the mean ensemble curves for the affected or unaffected limb were examined across all phases of the landing task. Because of the comparison to a single ‘giving way’ trial limiting statistical analyses, results will be presented descriptively.

2.3. Experimental procedures

Testing the affected limb first, the task required the participant to stand 70 cm from the center of the force plate, jump from two feet in a forward direction, touch a Vertec vane (set to 50% of maximum vertical jump height) and land on the designated limb (Gribble and Robinson, 2009; McCann et al., 2017). After landing the participant was asked to fold his arms across his chest as quickly as possible and balance for five seconds (Gribble and Robinson, 2009; McCann et al., 2017). The participant was given four practice trials before performing five test trials on each leg. Failed trials were identified if the participant missed the Vertec vane, missed the force plate upon landing or was unable to balance for five seconds after landing.

2.4. Data processing

Using Visual 3D processing software, a static standing trial of the participant was first created and aligned with the laboratory coordinate system. From this, a kinematic model consisting of a pelvis and bilateral thigh, shank and foot segments with 36 degrees of freedom was created. The hip joint center was defined using previously described methods (Bell et al., 1990). The knee joint center was defined as the linear distance between the medial and lateral femoral epicondyle markers (Sinclair et al., 2015; Thewlis et al., 2008). The ankle joint center was defined as the linear distance between the markers placed on medial and lateral malleoli (Ounpuu et al., 1991).

Joint rotations were determined based on the initial static trial and were calculated using an x-y-z Cardan angle sequence. Net internal joint moments were calculated using an inverse dynamic procedure and normalized to body weight(kg). Additionally, vertical, anterior-posterior and medial-lateral ground reaction force data was normalized to body weight(kg).

Using previously defined periods examining lower extremity joint kinematics and kinetics during single-leg landing tasks, (Delahunt et al., 2006; Doherty et al., 2015a–c) we extracted time-averaged data from 200 ms to 200 ms post-IC. Initial contact was defined as the instance in which the force plate exceeded 10 N of force (McCann et al., 2017).

2.5. Statistical Analysis

Sagittal and frontal plane joint rotations, internal moments and ground reaction force data for each single-leg landing trial were extracted. Data for the five successful single-leg landing trials for the affected and un-affected sides were averaged and the 95% confidence intervals (CI) were calculated. Areas of nonoverlap between the “giving way” trial and the mean ensemble curves for the affected or unaffected limb were examined across all phases of the landing task. Because of the comparison to a single ‘giving way’ trial limiting statistical analyses, results will be presented descriptively.

3. Results

While completing the 4th single-leg landing trial for the affected limb, a noticeable abnormal movement pattern occurred at the ankle. This prevented the participant from successfully completing the five second balance after landing because the un-involved limb touched down shortly post-IC (~300 ms). In agreement with the participants' previous experiences, the research team determined to classify the event as a ‘giving way’ and not an injury because the participant did not report having elevated levels of acute pain, swelling or a loss of function. After a sufficient amount of time (7–10 min), the participant self-selected to continue and was able to complete the remaining test session without any complaints.

The average (95% CI) for the sagittal and frontal plane kinematics, kinetics, and ground reaction forces for both limbs, as well as the data from the single ‘giving way’ trial can be found in Figs. 1–3.

3.1. Kinematics

During the ‘giving way’ trial, the ankle was more plantarflexed and the hip was more extended moments before and after initial contact compared to the average landing pattern for the affected and un-affected limb. Within 50 ms post-IC, the deviation in sagittal plane ankle rotation dissipated compared to the affected limb.
Between 100 and 150 ms post-IC, there was a sharp decrease in ankle eversion during the ‘giving way’ trial compared to both limbs. At 150 ms post-IC, the ankle plantarflexed and the frontal angle plateaued. As the ankle started to move towards inversion, the knee adducted and extended at 50 ms and 100 ms post-IC, respectively.

3.2. Joint moments

The ‘giving way’ trial generated large plantarflexion, knee extension and hip flexion internal joint moments compared to that of the affected and un-affected limbs. Whereas in the frontal plane, the ‘giving way’ trial produced a large inversion joint moment at the ankle between 50 and 100 ms post-IC. This was quickly followed by an eversion joint moment that peaked after 150 ms post-IC. A similar pattern in joint moments was observed at the knee, whereby an early adduction joint moment was followed by a large abduction moment peaking after 150 ms post-IC.

3.3. Ground reaction force

The ‘giving way’ trial produced a vertical ground reaction force that was 2x larger than that produced during all other landing trials. Additionally, there was a large laterally directed ground reaction force that peaked shortly after 50 ms post-IC. This was followed by a more medially directed ground reaction force throughout the remaining trial. Finally, the ‘giving way’ trial first
produced a posterior ground reaction force that quickly transi-

tioned anteriorly.

4. Discussion

We described the lower extremity kinematic and kinetic pat-
terns of a laboratory captured ankle ‘giving way’ episode that
occurred during a single-leg jump landing trial by an individual
identified as having unilateral CAI. There has only been one previ-
ous research report detailing the movement patterns of a ‘giving
way’ trial in a person with CAI. While performing an Agility T-
Test protocol, Remus et al. (2018) recorded large peak plantarflex-
ion ($797^{\circ}$/s), internal rotation ($1088^{\circ}$/s) and foot adduction ($1734^{\circ}$/
s) rotational velocities during the early phases of the ‘giving way’
trial. These high rotational velocities were immediately followed
by fast external rotation, abduction and dorsiflexion rotational
velocities. The authors speculated that by moving the ankle into
a more closed-packed position, the participant was able to prevent
an acute injury from occurring (Remus et al., 2018).

To further understand the movement patterns behind an epi-

dose of ‘giving way’, we examined the kinematic and kinetic data
before and after ground contact for both the affected and un-
affected limbs. First, there were distinct differences throughout
the lower extremity before initial contact between limbs for the
successful trials. For example, the knee of the affected limb was
more extended and abducted compared to the un-affected

-\[ \text{Fig. 2. Average (95\% CI) sagittal and frontal plane joint moments at the ankle, knee and hip for the affected, un-affected and 'giving way' trial (200 before and after initial contact).} \]
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Declaration of Competing Interest

I affirm that the authors have no financial affiliations (including research funding’s) or investment with any commercial organization that has a direct financial interest in any matter included in this manuscript. Additionally, I affirm that the authors have no conflict of interest (i.e. personal associations or involvements as a director, officer, or expert witness).

References


