Lower extremity function during gait in participants with first time acute lateral ankle sprain compared to controls

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1. Introduction

Ankle sprain injury has consistently been reported to be a significant risk for participants of a wide range of activity types (Doherty et al., 2014b). Indeed, ankle sprain accounts for between 11% and 12% of all injury diagnoses during activities such as soccer, field hockey, basketball, volleyball and orienteering, with a cumulative incidence of between 3.9 and 4.9 ankle sprains per 1000 h of exposure (Doherty et al., 2014b). The consequences of this injury extend beyond acute maladies however, as it has been reported that 32–74% of individuals with a history of ankle sprain report and endure beyond acute maladies however, as it has been reported that 32–74% of individuals with a history of ankle sprain report and endure episodes of “giving-way” of the ankle joint, perceived instability, as well as recurrent sprain (Anandacoomarasamy and Barnsley, 2005; Konradsen et al., 2002). Chronic ankle instability (CAI) is the encompassing term used to classify these symptoms (Delahunt et al., 2010; Gribble et al., 2013; Gribble et al., 2014a,b).

Aberrancy of sensorimotor variables of neuromuscular control as determined using biomechanical analysis is a characteristic feature associated with CAI (Hiller et al., 2011). Biomechanical measures of CAI populations are typically laboratory-based, and involve active movements such as gait (Delahunt et al., 2006; Monaghan et al., 2006; Spaulding et al., 2003). For example, previous biomechanical analyses have shown that participants with CAI display increased ankle joint inversion (Delahunt et al., 2006; Monaghan et al., 2006) and increased plantarflexion (Spaulding et al., 2003), with a greater concentric evertor moment at the ankle joint, around heel strike (HS) (Monaghan et al., 2006), and reduced plantarflexion (Spaulding et al., 2003) at toe-off (TO). However, research utilising biomechanical measures to evaluate neuromuscular control during gait in participants with CAI is sparse. It is possible that a sample

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group of participants with acute LAS may display movement insufficiencies that are continuous with, and therefore contribute to, those observed in their counterparts in the chronic phase of injury. As such, an evaluation of active movement patterns during gait in a group with first-time acute LAS injury may advance current understanding of the potentially anomalous movement patterns that persist and contribute to the onset of the chronic sequelae of CAI.

Therefore, the objective of the current study was to determine if participants with acute LAS display movement patterns continuous with their chronically impaired counterparts when compared to a non-injured control group, using kinetic (joint moment) and kinematic (angular displacement) laboratory measures around the HS and TO components of the gait cycle.

2. Methods

2.1. Participants

Sixty eight participants (forty-six males and twenty-two females; age 23.26 ± 4.94 years; body mass 76.43 ± 14.33 kg; height 1.74 ± 0.09 m) were referred from a University-affiliated hospital Emergency Department with acute, first time, LAS injury. Nineteen non-injured participants (fifteen males and four females; age 22.5 ± 1.7 years; body mass 71.55 ± 11.30 kg; height 1.74 ± 0.1 m) were recruited from the hospital catchment area population using posters and flyers to act as a control group. The injured group were recruited within 2-weeks of sustaining their injury. The project was approved by the local ethics committee, and written consent was obtained from each subject prior to data collection. The following exclusion criteria were applied: (1) no previous history of ankle sprain injury (excluding the recent acute episode for the injured group); (2) no other lower extremity injury in the last 6 months; (3) no history of ankle fracture; (4) no previous history of major lower limb surgery; (5) no history of neurological disease, vestibular or visual disturbance or any other pathology that would impair their motor performance (Doherty et al., 2014a).

2.2. Questionnaires

The activities of daily living and sports subscales of the Foot and Ankle Ability Measure (FAAMadl and FAAMsport), and the Cumberland Ankle Instability Tool (CAIT), were used to quantify self-reported function, patient reported symptoms and functional ability as measures of LAS severity (Carcia et al., 2008), and overall self-reported function, patient reported symptoms and functional ability as measures of LAS severity (Hiller et al., 2006) respectively. All participants completed the subscales of the FAAM and CAIT on arrival to the laboratory.

2.3. Swelling

Ankle joint swelling was assessed using the figure-of-eight method (Esterson, 1979). High intra-rater and inter-rater reliability has been reported using this technique (ICC = 0.99) (Tatro-Adams et al., 1995). To determine the degree of swelling, the mean value (of 2 measures) was subtracted from the mean value of the non-injured ankle. For control participants the mean value of the non-dominant limb was subtracted from the mean value of the dominant limb. The leg the participant considered preferable to kick a soccer ball as far as possible was deemed the dominant leg.

2.4. Experimental procedures

Gait data acquisition was made using 3 Codamotion cx1 units (Charnwood Dynamics Ltd, Leicestershire, UK). Twenty-two markers from the Codamotion marker set were applied according to manufacturer guidelines by the same investigator in all participants (Monaghan et al., 2007). Markers were positioned on the lateral aspect of the knee joint line, the lateral malleolus, the heel, and the fifth metatarsal head. Wands with anterior and posterior marker attachments were positioned on the pelvis, sacrum, thigh, and shank. The markers were fixed to the skin with double sided adhesive tape. This system was fully integrated with two AMTI walkway embedded force plates (Watertown, MA); the Codamotion cx1 units were time synchronized with the force plates. Kinematic data acquisition was made at 250 Hz and kinetic data at 1000 Hz. Kinetic and kinematic data were passed through a fourth-order zero phase Butterworth low-pass digital filter with 40 Hz and 6- Hz cut-off frequencies respectively (Winter, 2009).

Participants were familiarised with the testing procedures prior to commencement. Anthropometric data were obtained for the calculation of internal joint centres at the hip, knee, and ankle joints, after the participants' height and weight were recorded. A neutral stance trial was used to align the participant with the laboratory coordinate system and to function as a reference position for subsequent kinematic analysis (Wu et al., 2002).

During testing, participants walked barefoot across a 10 m walkway at a self-determined speed. Each participant was instructed to look at a distant mark to inhibit them from looking down at the floor. Five ‘clean’ gait cycles, defined by both the participant’s feet landing fully on each of the force plates, were identified and saved for future analysis. Any data obtained whereby the participant did not strike the force plate fully was discarded. Prior to data analysis all values of force were normalised with respect to each subject’s body mass (BM).

2.5. Data analysis

Kinematic data were calculated by comparing the angular orientations of the coordinate systems of adjacent limb segments using the angular coupling set “Euler Angles” to represent clinical rotations in 3 dimensions (Winter, 2009). Marker positions within a Cartesian frame were processed into rotation angles using vector algebra and trigonometry (CODA mpx30 User Guide, Charnwood Dynamics Ltd, Leicestershire, UK). A full description of the kinematic model underlying this analysis has been previously published (Monaghan et al., 2007) Lower limb internal joint moments at the hip, knee and ankle were expressed in a global orthogonal reference frame and calculated from the force plate, lower extremity kinematics, and anthropometric data using a standard inverse dynamics approach (Gagnon and Gagnon, 1992). Kinematic and kinetic data relating to two periods for both limbs were analysed using the Codamotion software: period 1 extended from 200 ms pre-HS to 200 ms post-HS (coinciding with terminal swing, HS, loading response and mid-stance) and period 2 extended from 200 ms pre-TO to 200 ms post-TO (coinciding with terminal stance, pre-swing, TO and initial swing).

These time windows were chosen for analysis as they have previously been used to investigate CAI-associated movement pattern anomalies during gait (Delahunt et al., 2006; Monaghan et al., 2006; Spaulding et al., 2003), thus fulfilling our primary objective. Furthermore, these time-windows chart the interaction between the motor apparatus and its external environment by quantifying the transitions between stance (closed kinetic chain) and swing (open kinetic chain). Thus, they consume an important period within which the motor control system must integrate afferent feedback with an appropriate efferent motor response (McVeag, 2005). Accurate positioning at HS and TO are very important in the interest of maintaining safe locomotion of the motor apparatus as increased plantar flexion as well as inversion of the ankle joint stand to increase ground reaction force moments about the
sub-talar joint with significant potential for re-sprain of the injured ankle (Tropp, 2002; Wright et al., 2000).

A vertical component GRF threshold of 10 N with the force plate was used to identify initial foot contact (for HS) and last foot contact (for TO) (Sparrow and Tirosh, 2003).

See Fig. 1 for an illustration of period 1 and period 2.

The following axis conventions were utilised for kinematic and kinetic data: x axis = frontal-plane motion; y axis = sagittal-plane motion; z axis = transverse-plane motion. After analysis in the Codamotion software, data were then converted to Microsoft Excel file format. The number of output samples per gait period analysed (200 ms pre- to 200 ms post-HS and 200 ms pre- to 200 ms post-TO separately) was set at 100 ± 1 in the data-export option of the Codamotion software, which represented each gait period as 100%, for averaging and further analysis. Thus, 1% of either gait period represented a 4 ms time interval. Time-averaged 3-dimensional angular displacement profiles for the hip, knee and ankle joints were calculated for each limb of all participants in the specified gait periods (Monaghan et al., 2006). Time averaged, sagittal plane hip, knee and ankle moments were identified from the kine-

Illustrative depiction of a link segment model completing period 1 (200 ms pre-HS to 200 ms post-HS), and period 2 (200 ms pre-TO to 200 ms post-TO) of the gait cycle. Abbreviations: HS = heel strike; TO = toe off. Stance limb = limb in bold.

2.6. Statistics

For the injured group, the injured limb was labelled as "involved" and the non-injured limb as "uninvolved". In all cases the limbs in the control group were side matched to the injured group; for each control subject, one limb was assigned as "involved" and one as "uninvolved" so that an equal proportion of right and left limbs were classified as "involved" and "uninvolved" in both the LAS and control groups.

Participant characteristics and swelling were compared between the LAS and control groups using multivariate analysis of variance. The dependent variables were age, mass, sex, height and ankle joint swelling. The independent variable was status (injured vs non-injured). The significance level for this analysis was set a priori with a bonferroni adjusted alpha level of p < 0.01.

To determine whether the injured group would demonstrate decreased function compared to the control group a multivariate analysis of variance was undertaken. The independent variable was group (injured vs control). The dependent variables were CAIT score, FAAMadl score and FAAMsport score for the involved limb. The significance level this analysis was set a priori with a bonferroni adjusted alpha level of p < 0.017.

Between-group differences in involved and uninvolved limb 3-dimensional, time-averaged angular displacement profiles were tested for statistical significance using independent-samples t-tests for each data point for each period of gait. Similarly, between-group differences in involved and uninvolved limb sagittal plane time-averaged hip, knee and ankle moment of force profiles, in addition to frontal plane ankle moment of force profiles, were tested for statistical significance using independent-samples t-tests for each data point for each period of gait. The significance level for these temporal analyses was set a priori at p < 0.05. Effect sizes were not calculated secondary to the number of separate comparisons for each variable.

All data were analysed using Predictive Analytics Software (Version 18, SPSS Inc., Chicago, IL, USA).

### 3. Results

Regarding participant characteristics and swelling there was a statistically significant difference between the injured and control groups on the combined dependent variables, $F(81.5) = 4.24$, $p = 0.002$; Wilk’s Lambda = 0.79; partial eta squared = 0.21. When the results of the dependent variables were considered separately, swelling ($F(1, 85) = 17.34$, $p = 0.000$, partial eta squared = 0.17) was the only variable to reach statistical significance. An inspection of the mean scores indicated that injured participants had increased swelling on their involved limb compared to controls (11.09 [SD: 8.8 cm] vs 2.47 [SD: 3.4 cm]).

Regarding function a statistically significant main effect was observed for the combined dependent variables, $F(3, 77) = 75.147$, $p < 0.01$, Wilk's Lambda = 0.255, partial eta squared = 0.745 (Table 1).

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Questionnaire scores (mean ± SD with 95% CIs) for the LAS and control groups.</th>
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<td></td>
<td>CAIT</td>
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<tr>
<td>Injured</td>
<td>11.60 ± 7.21*</td>
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<tr>
<td>Control</td>
<td>30 ± 0</td>
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| * Significantly different from control group. |

Time-averaged 3-dimensional kinematic profiles revealed that the injured group displayed reduced hip adduction and increased knee valgus on their involved limb, and bilateral increases in knee flexion and reductions in ankle plantar flexion compared to the control group in the time period from 200 ms pre HS to 200 ms post HS (specific details of angular displacement data for period 1 are presented in Fig. 2).
In the period from 200 ms pre TO to 200 ms post TO, the injured group displayed reduced hip extension on their involved limb and bilateral increases in ankle inversion and reductions in ankle plantar flexion compared to the control group (specific details of angular displacement data for period 2 are presented in Fig. 3).

Time-average sagittal plane moment of force profiles revealed that the injured group displayed reduced hip extension moment on their involved limb and bilateral increases in knee extension moment and ankle extension (dorsiflexion) moment compared to control participants in the time period from 200 ms pre HS to 100 ms post HS.

Fig. 2. Hip-joint adduction-abduction, knee joint varus-valgus and flexion-extension, and ankle joint dorsiflexion-plantar flexion angular displacement during period 1 of the gait cycle from 200 ms pre-heel strike to 200 ms post-heel strike for the involved and uninvolved limbs of LAS and control groups. Adduction, varus, flexion and dorsiflexion are positive; Abduction, valgus and plantar flexion are negative. Black line with arrow = heel strike. Shaded area = area of statistically significant difference between LAS and control groups. Abbreviations: LAS = lateral ankle sprain.

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200 ms post HS (specific details of moment of force data for all lower extremity joints for period 1 are presented in Fig. 4). Furthermore, there was a bilateral increase in ankle inversion moment in this time period (specific details of moment of force data for the ankle joint during period 1 are presented in Fig. 5).

In the period from 200 ms pre TO to 200 ms post TO, the injured group displayed bilateral reductions in hip flexor moment, increases in knee extension moment and reductions in ankle flexion (plantarflexion) moment (specific details of moment of force data for all lower extremity joints for period 2 are presented in Fig. 6). Furthermore, there was a bilateral increase in ankle inversion moment in this time period (specific details of moment of force data for the ankle joint during period 2 are presented in Fig. 7).

4. Discussion

The current investigation was designed to determine whether participants with acute first-time LAS display movement patterns similar to their chronically impaired counterparts with established CAI. Our findings demonstrate a number of injury-associated movement patterns consistent between a group with acute LAS injury (who reported significant functional impairment as determined by the CAIT and subscales of the FAAM) and individuals with CAI compared to non-injured controls.

In the current analysis, we did not observe any significant differences between LAS and control participants for frontal plane ankle motion around HS. However, the injured group did display a significant increase in ankle joint inversion (bilaterally) around TO, which is in agreement with the findings of Drewes et al. (2009). Monaghan et al. (2006), Drewes et al. (2009) and Delahunt et al. (2006) have previously reported that participants suffering recurrence following an acute LAS display increased inversion at the ankle joint around HS (the equivalent of period 1 in the current study). In contrast, and in agreement with the current findings, Chinn et al. (2013) reported no differences in this time window in the same sample. The increase in ankle inversion around TO in the current study coincided with a motor pattern of increased inversion moment at the ankle joint in both limbs prior to, and following, TO.

Fig. 3. Hip-joint flexion-extension, ankle joint inversion-eversion and dorsiflexion-plantar flexion angular displacement during period 2 of the gait cycle from 200 ms pre-toe off to 200 ms post-toe off for the involved and uninvolved limbs of LAS and control groups. Flexion, inversion, dorsiflexion are positive; Extension, eversion and plantar flexion are negative. Black line with arrow = toe off. Shaded area = area of statistically significant difference between LAS and control groups. Abbreviations: LAS = lateral ankle sprain.
LAS participants also displayed a bilateral reduction in ankle joint plantar flexion during both period 1 and period 2 of the current analysis, which is in contrast to the findings of Spaulding et al. (2003) and Chinn et al. (2013), who evaluated movement patterns on the involved limb only, both finding increased plantar flexion in CAI participants during the stance phase of gait. To the authors’ knowledge to date, the movement pattern anomalies unique to CAI populations compared to non-injured controls are isolated to frontal plane and sagittal plane ankle joint motion (Hiller et al., 2011).

These movement patterns may be adopted in the interest of minimising perceived risk during task performance; the net displacement of the body constitutes a summation of all the forces and motions acting upon, and concerned with, its safe translation during locomotion (Saunders et al., 1953). These forces however are limited by the anatomical constraints within which they operate (Winter, 1993). Hence, this translation is potentially altered by acute LAS, and can be seen to be evident in the kinematic and kinetic findings of the current investigation.

The disruption caused by acute insult to the foot and ankle in injured participants can be seen to have been compensated for by local and global modifications. These modifications may have been adopted in the aim of minimising risk of further injury; to protect the vulnerable ankle joint, there developed an increased reliance on more proximal structures to absorb impact force. This reliance was concurrent with a decrease in the propulsive forces.

Fig. 4. Sagittal plane joint moment-of-force profiles for the hip, knee and ankle during period 1 of the gait cycle from 200 ms pre-heel strike to 200 ms post-heel strike for the involved and uninvolved limbs of the LAS and control groups. Extension and plantar flexion moments are positive; flexion and dorsiflexion moments are negative. Black line with arrow = heel strike. Shaded area = area of statistically significant difference between LAS and control groups. Abbreviations: LAS = lateral ankle sprain; Mh = Hip moment; Mk = Knee Moment; Ma = Ankle moment.

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that have the potential to augment the magnitude of these impacts (Saunders et al., 1953). Specifically, with regards to period 1, functional impairment at the ankle joint may have stimulated the knee joint to exaggerate its primary role in the attenuation of impact forces. This was evident in the bilateral increase in LAS participants’ knee flexion and valgus angular displacement, with a greater knee extensor moment pattern at HS (\( \approx 0.2 \) in LAS participants vs \( \approx 0.17 \) N m/kg in controls, at HS). The ankle planter flexors, hip flexors, and hip extensors are the main muscle groups that contribute to energy generation in the sagittal plane (Chen et al., 1997; Olney et al., 1994; Winter, 1991), while the knee joint muscles act mainly eccentrically in the absorption of impact energy (Olney et al., 1994; Saunders et al., 1953).

The implications of the exaggerated motor pattern of absorption at the knee became evident at the hip, as the increase in knee valgus coincided with a decrease in hip adduction, and a reduced extensor moment pattern (\( \approx 0.1 \) in LAS participants vs \( \approx 0.2 \) N m/kg in controls, at HS) on the involved limb in the LAS group. Frontal plane hip motion (and its corollary of frontal plane knee motion) is one of the primary determinants of the rhythmic displacement of the body’s centre of gravity during gait (Saunders et al., 1953), and a reduced extensor pattern at the hip facilitates collapse and thus the absorptive capacity of the extremity (Winter, 1980). Furthermore, the increase in knee flexion was precipitous to ankle motion, where a decrease in planter flexion and an increase in the extensor (dorsiflexion) moment at this joint were evident in LAS participants (\( \approx 0.4 \) in LAS participants vs \( \approx 0.01 \) N m/kg in controls, at HS). This resultant ‘closed-pack’ position of reduced plantar flexion, which is closer to sagittal plane neutral, affords the ankle joint of LAS participants greater stability secondary to an increase in the congruity between the inferior aspects of the tibia and fibula, and the superior aspect of the talus (Willems et al., 2005). Overall, this could reflect a compensatory mechanism to maintain the integrity of the vulnerable ankle joint by using a global strategy of attenuating impact forces by exploiting joints proximal to the ankle. Muscle model driven computer simulations have previously shown that an increased HS plantar flexion may cause an increased likelihood of an ankle sprain (Wright et al., 2000). Thus, the motor apparatus of LAS participants may have organised its proximal component (in this case, the knee joint), to adjust to the injury constraint.

With regards to period 2, the propulsion of the body through space is achieved primarily via the output of the hip and ankle (Olney et al., 1994; Saunders et al., 1953; Teixeira-Salmela et al., 2001). LAS participants displayed movement and motor patterns conducive to a reduction in propulsion: the decrease in hip extension and the coinciding reduction in the net flexor pattern at this joint (\( \approx 0.4 \) in LAS participants vs \( \approx 0.6 \) N m/kg in controls, 100 ms pre-TO), combined with the reduction in ankle plantar flexion and the net flexor (plantar flexion) pattern at this joint prior to TO (\( \approx 0.75 \) in LAS participants vs \( \approx 1.2 \) N m/kg in controls), may indicate a reduced requirement to pull the hip forward in preparation for swing due to its less extended position and a reduction in the propulsive motor patterns during terminal stance respectively. This shift may be part of a strategy to reduce ankle joint loading by limiting the forces associated with locomotion. The increase in ankle inversion moment at TO previously described could be a compensatory mechanism to restore normal propulsive patterns at the ankle joint: the reduction in propulsive ankle function may have been compensated for using the rigidity of inversion in the supinating ankle joint as an assistant to push-off, and which may have its root in previously established altered motor patterns of the peroneous longus (PL) muscle. Previous researchers have suggested that individuals with ankle instability adopt a new “feed-forward” motor control pattern in preparation for HS during gait (Delahunt et al., 2006). Pre-activation of the PL is one such motor pattern which is considered to protect the ankle against an inversion moment at HS (Delahunt et al., 2006). In the context of the gait cycle, the biomechanical function of the PL is more to provide dynamic stability to the ankle joint in weight-bearing than to actively evert the ankle. Lateral dynamic stability during weight-bearing is achieved via the action of the PL in pulling down the first ray of the foot during pronation, and subsequently stabilizing the first-ray as a rigid lever for forward propulsion (Feger et al., in press). The value of PL pre-activation has been called into question though (Feger et al., in press), particularly because healthy controls do not activate their PL until mid-stance (Lacquaniti et al., 2012). It has recently been hypothesised that although pre-activation of the PL as an open chain evertor in the presence of excessive inversion (Delahunt et al., 2006; Feger et al., in press), prior to HS may improve foot positioning at HS, this motor pattern may substantially decrease the ability of the PL in assisting pronation and
stabilizing the first-ray during weight-bearing, thus contributing to a laterally deviated COP during the propulsive phase of gait in CAI populations (Feger et al., in press; Schmidt et al., 2011; Willems et al., 2005). Combined with a more inverted positioning prior to TO, this may indicate that injured participants load the lateral column of their foot to a greater extent during the latter part of stance (Delahunt et al., 2006). The current study has also elucidated an increase in inversion moment with a coinciding increase in ankle inversion around TO; one could speculate that the increased inversion positioning seen in late stance and early swing is a consequence of the abnormal loading response, and may be predicated by early activation of the PL in the swing phase of gait, which has been demonstrated in CAI participants (Chinn et al., 2013).

Greater inversion around the subtalar joint axis is likely to produce an external load that further forces the foot into inversion, increasing the potential risk of lateral ligamentous trauma (Tropp, 2002).

The bilateral nature of the observed results is in agreement with previous findings in participants with recurrence following LAS (Hass et al., 2010; Wikstrom et al., 2010), and are the first indication that these deficits may present immediately following the acute injury during gait. That unilateral injury had bilateral manifestations may be linked to an alteration in alpha motoneuron pool excitability (Sedory et al., 2007), suggesting that spinal-level motor control mechanisms have changed. We concur with the speculations of previous researchers who have theorised that because in vivo measures of sensorimotor function require conscious perception of peripheral joint and muscle information, supraspinal aspects of motor control

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Fig. 6. Sagittal plane joint moment-of-force profiles for the hip, knee and ankle during period 2 of the gait cycle from 200 ms pre-toe off to 200 ms post-toe off for the involved and uninvolved limbs of the LAS and control groups. Extension and plantarflexion moments are positive; flexion and dorsiflexion moments are negative. Black line with arrow = toe off. Shaded area = area of statistically significant difference between LAS and control groups. Abbreviations: LAS = lateral ankle sprain; Mh = Hip moment; Mk = Knee Moment; Ma = Ankle moment.
are also altered following LAS (Hass et al., 2010; Hertel, 2008). From a rehabilitation perspective, the findings of the current investigation imply that it may be pertinent to concentrate on the restoration of proximal neuromuscular control strategies using gait-retraining programmes that are bilaterally applied.

While our results are important, this study was not without its limitations. One issue with the current findings is that externally placed skin markers typically over-estimate tibiocalcaneal rotations, and that these overestimations can be up to 11° (Reinschmidt et al., 1997). This dictates that motions of the tibio-talar and sub-talar joints be combined into a composite measure of ankle joint complex motion, with the result that measures of inversion/eversion about an anterior–posterior axis are not specifically representative of the sub-talar joint axis. This issue is common to similarly designed studies of gait analysis however, as it has been recognised that the use of non-invasive, external anatomical landmarks does not allow talocrural and sub-talar joint motion to be distinguished (Wu et al., 2002). Furthermore, due to the design of the current study, it is unknown as to whether the movement patterns observed preceded or occur as a result of LAS, and whether they actually have any implication for the onset of CAI in the longer term recovery of these participants. Future studies would benefit from a follow-up period to determine the gait-related movement risk factors for CAI, and subsequently the movement characteristics that are associated with recovery or chronicity.

5. Conclusion

The findings of this study advance current understanding of how individuals with acute first-time LAS achieve walking locomotion. The results suggest that participants with acute first-time LAS demonstrate bilateral differences in gait movement patterns compared to uninjured controls, which adhere intuitively to the fundamental goals of safe and efficient locomotion, and which may have potential links to the progression of chronic sequelae.

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Conflicts of interest

No conflicts of interest were associated with the authors and the results of this research.

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References


Calibhe Doherty graduated from the UCD School of Public Health, Physiotherapy and Population Science in 2007. Upon graduation he was the recipient of a HRB post-graduate research scholarship, to undertake a longitudinal investigation into the motor control and movement predictors of chronic ankle instability. This project is currently ongoing and will contribute to his doctorate studies.

Chris Bleakley graduated from the University of Ulster in 2000 with BSc (Hons) in Physiotherapy. Between 2000 and 2004, he completed his doctorate in acute soft tissue injury management. He is currently a member of academic staff at the Ulster Sports Academy and the Course Director for the MSc Sport and Exercise Medicine at the University of Ulster. His research interests include: acute soft tissue injury management; ankle sprain prognosis and rehabilitation; cryotherapy and recovery; and monitoring injury risk factors.

Jay Hertel is the Joe H. Gieck Professor of Sports Medicine in the Department of Kinesiology at the University of Virginia where he directs the graduate programs in Athletic Training and Sports Medicine and the Exercise & Sport Injury Laboratory. His primary area of research is lateral ankle instability which he studies from a multifactorial perspective using diverse methods ranging from laboratory-based assessments of biomechanics and motor control to evidence-based practice principles inherent to clinical epidemiology. He is a fellow of both the American College of Sports Medicine and the National Athletic Trainers’ Association.

Brian Caufield is a Director of the Insight Centre for Data Analytics (www.insight-centre.org), is the Lead Investigator in the Applied Research for Connected Health Centre (www.arch.ie), and is also the Dean of Physiotherapy at University College Dublin. Professor Caufield’s research interests fall within the areas of motor control and exploitation of technology to advance rehabilitation science in the medical field. His early work focused on the role of disordered motor control in the development of soft tissue injuries (such as ankle and knee sprains) and investigation into the effectiveness of rehabilitation interventions for these injuries. More recently the focus of his work has moved towards the integration of sensor and computer technology to develop novel methods of motion and physiological analysis and therapies for motor and sports performance enhancement, including the development of novel methodologies for electrical stimulation of muscle. He has co-authored over 200 scientific publications and patent documents.

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John Ryan is an associate clinical professor at St. Vincent’s University Hospital, and has developed several links in the area of research to a number of centres in University College Dublin. He is a consultant in Emergency Medicine, with a particular interest in Sports and Exercise Medicine. He is a board member of the Faculty of Sports and Exercise Medicine in Ireland, and has been team doctor to Leinster Rugby since 2007.

Eamonn Delahunt graduated with a 1st Class Honours Degree from the UCD School of Physiotherapy in 2003 placing first in his class. Upon graduation he was the recipient of a prestigious IRCSET post-graduate research scholarship, to undertake and investigate into motor control and movement dysfunction in patients with chronic ankle instability. He was awarded his PhD from the UCD School of Physiotherapy and Performance Science in 2006. Eamonn has been the recipient of numerous research bursaries for his research on chronic ankle instability and has published extensively on this topic in all the leading sports medicine/science journals. To date he has published more than 50 peer-reviewed papers. He currently works as a senior lecturer in the UCD School of Public Health, Physiotherapy and Population Science, and acts as the programme coordinator for the BSc Health and Performance Science degree programme. Eamonn also has extensive clinical experience having previously worked as a Chartered Physiotherapist in the area of sports medicine. He was recently awarded the honorary title of “Specialist Member” of the Irish Society of Chartered Physiotherapists. Dr Delahunt is an editorial board member of the Journal of Science and Medicine in Sport.