



<b>Title</b>	Coordination and symmetry patterns during the drop vertical jump, 6-months after first-time lateral ankle sprain
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4 ankle sprain.  
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7 **Running title:** Movement patterns during a drop-jump  
8

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## Abstract

**Purpose:** To evaluate the adaptive movement and motor control patterns of a group with a 6-month history of a lateral ankle sprain (LAS) injury during a drop vertical jump (DVJ) task.

**Methods:** Fifty-one participants with a 6-month history of first-time acute LAS injury and twenty controls performed a DVJ task. 3D kinematic and sagittal plane kinetic profiles were plotted for the lower extremity joints of both limbs for the drop jump (phase 1) and drop landing (phase 2) phases of the DVJ. Inter-limb symmetry and the rate of force development (RFD) relative to bodyweight (BW) during both phases of the DVJ were also determined.

**Results:** LAS participants displayed bilateral increases in knee flexion and an increase in inversion during phases 1 and 2 respectively. They also displayed reduced ankle plantar-flexion on their injured limb during both phases of the DVJ ( $p < 0.05$ ); increased inter-limb asymmetry of RFD was noted for both phases of the DVJ, while the moment-of-force profile exhibited bilaterally greater hip extensor dominance during phase 1.

**Conclusion:** Participants with a 6-month history of LAS display some movement patterns consistent with those observed in CAI populations during similar tasks.

**Key words:** ankle joint [MeSH]; biomechanics [MeSH]; kinematics [MeSH]; kinetics [MeSH]; Task Performance and Analysis [MeSH].

## INTRODUCTION

Biomechanical laboratory analyses have previously been utilised to identify certain movement patterns which characterise participants suffering from recurrence after acute lateral ankle sprain (LAS) injury<sup>1-3</sup>. Typically, these movement patterns, and the motor control strategies that underlies them, are evaluated using functional tasks analogous to activity based manoeuvres which have a tendency to be injurious to their participants<sup>4</sup>. For example, the drop vertical jump (DVJ) task has consistently been used to identify several movement patterns contingent with anterior cruciate ligament (ACL) injury<sup>5-7</sup>. As a task, the

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2  
3 advantage of the DVJ is that it demands inter-limb synchrony to fulfil both predictive [pre-  
4 initial contact (IC)] and reactive (post-IC) actions of neuromuscular control <sup>8</sup> in achieving  
5 dynamic balance and a performance output of maximal jump height.  
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10 In instances of injury, the sensorimotor system is challenged to balance the performance  
11 output of the DVJ whilst maintaining integrity of the motor apparatus <sup>4,9</sup>. As such,  
12 kinematic<sup>5</sup>, kinetic<sup>6</sup> and inter-limb symmetry<sup>7</sup> variables have all been quantified during both  
13 the drop jump (phase 1) and/or the drop land (phase 2) components of the DVJ to elucidate  
14 task-specific movement compromises predictive and/or consequent of ACL injury<sup>4,9</sup>.  
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20 Similarly, and because LAS is a significant injury risk in activities with repetitive jumping  
21 and rebounding movements<sup>10</sup>, biomechanical analyses have adopted DVJ based tasks in a  
22 comparable manner to the ACL literature in identifying those movement patterns which  
23 characterise individuals experiencing recurrence following their initial LAS<sup>1-3</sup>. However, in  
24 contrast to the ACL literature, key predictors of long-term chronicity following LAS have yet  
25 to be identified. Herein lies a prominent gap in the literature, and in light of the potential for  
26 an acute LAS to degrade into the array of chronic sequelae collectively termed ‘chronic ankle  
27 instability’ (CAI) <sup>11</sup>, priority should be placed in its mitigation.  
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38 It has been hypothesised that recovery following LAS is dependent on the emergence of new  
39 coordination strategies of neuromuscular control, and it is the success or failure of these  
40 strategies that manifests in ‘coper’ or CAI status respectively<sup>12</sup>. However, because  
41 individuals can only be classified as being copers or as having CAI a minimum of 1 year  
42 following injury<sup>11,12</sup>, greater certainty as to the key contributors to recovery can only be  
43 gained by evaluating individuals ‘on course’ to their outcome, thus culminating in a set of  
44 DVJ-based biomechanical prediction rules for recovery. The current investigation is part of a  
45 series designed to identify such predictors. In this exploratory analysis, lower extremity  
46 movement patterns (kinematics), motor control (moment of force profiles), landing force and  
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3 symmetry analyses were combined to evaluate DVJ task strategies in a group with a 6-month  
4 history of LAS injury. Our experimental objective was to identify movement and motor  
5 control pattern which are likely to be predictive of long-term outcome following LAS; this  
6 experiment stands to inform our choice of variables for future longitudinal analyses.  
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## 9 10 11 **METHODS**

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13 Fifty-one participants (thirty-five males and sixteen females; age =  $23.14 \pm 4.45$  years; height  
14 =  $1.74 \pm 0.09$  m; body mass =  $74.5 \pm 14.1$  kg) were recruited from a local hospital  
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18 Emergency Department (ED) within 2-weeks of sustaining a first-time acute LAS injury; this  
19 manuscript pertains to data collected six-months following recruitment from the ED. Another  
20 group of twenty control participants (fifteen males and five females, age =  $22.6 \pm 1.7$  years;  
21 height =  $1.73 \pm 0.1$  m; body mass =  $71.4 \pm 11.29$  kg) with no history of prior LAS were  
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23 recruited from the hospital catchment area population using posters to act as a control group.  
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27 The following exclusion criteria were applied to all participants at the time of recruitment (for  
28 both limbs, where applicable): (1) no previous history of ankle sprain injury (excluding the  
29 recent episode for the injured group); (2) no other lower extremity injury in the last 6 months;  
30  
31 (3) no history of ankle fracture; (4) no previous history of major lower limb surgery; (5) no  
32 history of neurological disease, vestibular or visual disturbance or any other pathology that  
33 would impair their motor performance<sup>13</sup>. All participants completed the Cumberland Ankle  
34 Instability Tool (CAIT) and the activities of daily living and sports subscales of the Foot and  
35 Ankle Ability Measure (FAAMadl and FAAMsport) to assess overall ankle joint function and  
36 patient reported functional ability respectively on arrival to the laboratory<sup>11</sup>.  
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40 The experimental protocol was approved by the institution's ethical review board and  
41 informed written consent was acquired from each participant prior to testing.  
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45 Following completion of the questionnaires, participants were instrumented with 22 infrared  
46 markers as part of the Codamotion (CODA) bilateral lower limb gait set-up (Charnwood  
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3 Dynamics Ltd, Leicestershire, UK). Following the collection of the anthropometric measures  
4 required for the calculation of internal joint centres at the hip, knee and ankle joints, lower  
5 limb markers and wands were attached as described by Monaghan et al.<sup>14</sup>. For each subject  
6 an initial neutral stance trial was acquired to function as a reference position for kinematic  
7 analyses and to align the subject with the laboratory coordinate system<sup>15</sup>. Participants then  
8 completed three trials of a DVJ task following a practice period during which they  
9 familiarised themselves with the experimental protocol.

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12 The DVJ protocol utilised for the current study has been described previously<sup>5</sup>. During the  
13 three DVJ trials, kinematic data were acquired at 250 Hz and kinetic data at 1000 Hz for each  
14 limb using three Codamotion cx1 units and two fully integrated AMTI (Watertown, MA)  
15 walkway embedded force-plates respectively. The CODA units were time synchronized with  
16 the force-plates. Kinetic and kinematic data were passed through a fourth-order zero phase  
17 Butterworth low-pass digital filter with 20Hz and 6-Hz cut-off frequencies respectively<sup>16</sup>.

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20 Kinematic and kinetic data were acquired and exported from the Codamotion software to  
21 Microsoft Excel file format for further analysis. 3-dimensional hip, knee and ankle angular  
22 displacements and sagittal plane hip, knee and ankle internal joint moments were calculated  
23 in time-averaged profiles, with subsequent calculation of group mean profiles. All moments  
24 were reported as internal joint moments derived from the ground reaction force (GRF) data  
25 created during contact with the force platforms. The number of output samples for kinematic  
26 and kinetic data was set at 100 + 1 per DVJ phase in the data-export option of the  
27 Codamotion software. All time-averaged profiles were plotted during the period from 200-ms  
28 pre-initial contact (IC) to 200-ms post-IC for the first and second phases of the DVJ.

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31 The RFD of the vertical GRF was calculated for each phase of the DVJ for each limb as the  
32 peak GRF normalised to bodyweight (BW) divided by the time from IC to peak vertical GRF  
33 <sup>17</sup>(BW/sec). The RFD was averaged accordingly and group mean profiles were calculated.

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3 Symmetry between temporal waveform data (angular displacement and moment-of-force  
4 profiles) was analysed using an eigenvector approach. The ‘trend symmetry’(TS) of  
5 waveform data was calculated to compare the time-normalised data for right and left limbs  
6 separately during phase 1 and phase 2 of the DVJ for the LAS and control groups as per  
7 previous research<sup>18</sup>. TS between two waveforms is expressed as a percentage value where  
8 0% indicates perfect symmetry between the two waveforms<sup>18</sup>. The TS of the relevant  
9 waveforms was determined using a sliding window approach, whereby data samples were  
10 analysed for symmetry sequentially in groups of 50 samples with a window overlap of 50%.  
11 This resulted in three separate TS windows to assess the preparatory<sup>8</sup> and reactive<sup>19</sup> activities  
12 of each landing event, in addition to IC; window 1 analysed from 200ms pre-IC to IC,  
13 window 2 analysed from 100ms pre-IC to 100ms post-IC and window 3 analysed from IC to  
14 200ms post IC. TS was calculated separately for each trial of the DVJ and averaged across  
15 the three trials for each participant. Group mean profiles were then calculated.

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32 A symmetry angle (SA) calculation<sup>20</sup> was utilised to evaluate the inter-limb RFD symmetry  
33 for each individual subject over each phase of a DVJ trial, with subsequent calculation of  
34 group means. A SA value of 0% between matched points indicates perfect symmetry, while  
35 100% indicates that the two values are equal and opposite<sup>20</sup>.

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41 Finally, the vertical jump height (m) achieved between phases 1 and 2 of the DVJ was  
42 calculated as a measure of task performance using the time of flight method<sup>21</sup> for LAS and  
43 control groups, with subsequent calculation of group mean profiles.

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47 The average of each subjects’ three trials for all variables was analysed (i.e. LAS vs control).  
48 For the LAS group, limbs were labelled as “involved” and “uninvolved” depending on  
49 which limb they injured at the time of recruitment; in all cases, the involved (injured) limb  
50 was compared to side-matched limbs in the control group, such that an equal proportion of  
51 right and left limbs were labelled as “involved” and “uninvolved” in each group.  
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3 A series of independent samples t-tests for each data point of the time-averaged 3D kinematic  
4 and sagittal plane kinetic profiles were undertaken to compare the movement and motor  
5 control patterns exhibited by the LAS and control groups during the DVJ task. The  
6 significance level for these analyses was set a priori at  $p < 0.05$ .  
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11 Next, independent samples t-tests for group (LAS vs control) RFD mean profiles for each  
12 phase of the DVJ for each limb were undertaken. The significance level for this analysis was  
13 set a priori at a bonferonni adjusted alpha level of  $p < 0.025$  (involved and uninvolved limbs).  
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16 To determine whether these coordination and motor control strategies would be contingent  
17 with disparities in inter-limb symmetry, independent samples t-tests were undertaken for  
18 group angular displacement and support moment profile TS windows for each phase of the  
19 DVJ. The significance level for these analyses were adjusted for multiple tests using the  
20 Benjamini-Hochberg method for false discovery rate ( $<5\%$ )<sup>22</sup> separately for kinetic and  
21 kinematic data, each with two levels (involved and uninvolved limbs). Independent samples  
22 t-tests for group (LAS vs control) RFD SA profiles for each phase of the DVJ were also  
23 undertaken. The significance level for this analysis was set a priori at  $p < 0.025$ .  
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27 Finally, to determine the potential presence of any discrepancies in task performance between  
28 LAS and control groups, an independent samples t-test comparing jump height achieved  
29 between phase 1 and phase 2 of the DVJ was undertaken. The significance level for this  
30 analysis was set a priori at a  $p < 0.025$ . All data were analyzed using Predictive Analytics  
31 Software (Version 18, SPSS Inc., Chicago, IL, USA).  
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## 36 RESULTS

37 Questionnaire scores for LAS and control participants are detailed in table 1.  
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40 Time-averaged 3-dimensional kinematic profiles revealed a number of between-groups  
41 differences for both phase 1 and phase 2 of the DVJ. Lower extremity sagittal plane and  
42 frontal plane ankle kinematic profiles for phases 1 and 2 of the DVJ are detailed in Figure 1.  
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3 Time-averaged sagittal plane moment-of-force profiles also revealed a number of between-  
4 groups differences for both phase 1 and phase 2 of the DVJ. Sagittal plane moment-of-force  
5 profiles for phases 1 and 2 of the DVJ are detailed in Figure 2.  
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10 There was no significant difference in RFD between LAS and control participants of the DVJ  
11 for phase 1 or phase 2 of the DVJ for either limb. RFD during both phases of the DVJ for  
12 LAS and control groups are detailed in Table 2.  
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16 TS analyses of kinematic and kinetic data revealed that the LAS group displayed greater  
17 inter-limb asymmetry in the hip moment of force profile during phase 1 of the DVJ in the  
18 third time window (from IC to 200ms post-IC). TS values for all kinetic data for LAS and  
19 control groups are detailed in Table 3. LAS participants displayed increased RFD asymmetry  
20 compared to control participants during both phase 1 and phase 2 of the DVJ (Table 2).  
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25 There was no significant difference in jump height scores between the LAS ( $0.16 \pm 0.5m$ )  
26 and control ( $0.18 \pm 0.9m$ ) groups ( $t(17.32) = -0.60, p = 0.56$ ).  
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## 29 30 31 **DISCUSSION**

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34 The novelty of this exploratory study is that we have identified movement patterns unique to  
35 individuals with a 6-month history of LAS and also revealed some potential consistencies in  
36 the coordination strategies adopted by this cohort and those exhibited by individuals with  
37 CAI performing similar tasks. Specifically, LAS participants in the current study displayed a  
38 reduction in ankle joint plantar-flexion on their involved limb during phase 2 of the DVJ and  
39 an increase in inter-limb asymmetries of RFD during both phase 1 and phase 2. Furthermore,  
40 they displayed increased moment of force profile asymmetries at the hip in the ground  
41 contact phase component of phase 1 of the DVJ. The increase in ankle inversion on their  
42 involved limb during phase 2 of the DVJ has previously been observed in the CAI literature  
43 during a stop-jump task<sup>2</sup>, a drop landing task<sup>23</sup> and a lateral hopping task<sup>24</sup>.  
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3 The potential for inversion laxity to coincide with damage to the calcaneofibular ligament in  
4 LAS participants, thus resulting in greater frontal plane motion, has repeatedly been  
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6 implicated in the greater tendency of these individuals towards inversion injury<sup>2</sup>. It has been  
7  
8 theorised that the introduction of uncontrollable frontal plane motion breaks the normal  
9  
10 boundaries of the “safe” window of ankle/foot positioning at IC<sup>25</sup>, thus leading to re-injury.  
11  
12 In contrast, the preparatory reduction in ankle plantar flexion could potentially be considered  
13  
14 an active, adaptive strategy to limit the placement of the ankle joint further into a position of  
15  
16 increased vulnerability. With increasing plantar flexion comes reduced bony congruity  
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18 between the superior aspect of the talus and the inferior aspect of the tibia<sup>26</sup>; by  
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20 approximating the ankle joint to a more dorsi-flexed, ‘closed pack’ position in preparation  
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22 for the landing events during phases 1 and 2 of the DVJ, LAS participants could have been  
23  
24 seeking to stabilise their ‘vulnerable’ ankle joint using this joint’s structural morphology.  
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26 Further proximally, the increase in knee flexion observed in the current study is in agreement  
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28 with the findings of Caulfield and Garrett in CAI participants during a single-leg hopping  
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30 task<sup>27</sup>. This again may be indicative of a reactive strategy designed exploit the knee in  
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32 making the motor apparatus of the LAS participant more flexible on landing, with greater  
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34 potential for minimising joint stiffness and excessive loading of static ligamentous  
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36 structures<sup>28</sup>. However, we urge caution in comparing the results of studies completed in  
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38 different research laboratories using different methodologies. The advantage of the current  
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40 study, in the context of the larger longitudinal analysis it forms part of, will be consistency  
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42 across individuals, the acquisition methods utilised and the task prescribed. The development  
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44 of a set of prediction rules for recovery based on the current literature is confounded by  
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46 inconsistencies in these areas, but particularly in the type of task prescribed<sup>3</sup>. Terminal  
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48 (landing) and non-terminal dynamic (jumping/hopping) movement tasks constrain  
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50 participants in contrasting ways<sup>4,9</sup>, and directly comparing the strategies used to complete  
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3 these tasks must be done with caution. This is evidenced by the fact that Gribble and  
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5 Robinson actually observed less knee flexion at IC during a jump-landing task<sup>29</sup>, which is in  
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7 contrast to our findings, yet they observed no differences in hip kinematics, in agreement  
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9 with our findings, but in contrast to the findings of Brown et al. during a stop-jump task<sup>30</sup>.  
10  
11 Importantly, none of the aforementioned studies of CAI populations evaluated movement  
12  
13 patterns on the uninvolved limb, making the bilateral nature of the adaptive movements  
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15 observed in the current study contextually unique. Bilateral deficits have previously been  
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17 shown to manifest following LAS injury during static and dynamic postural control tasks<sup>13,31</sup>.  
18  
19 Furthermore, evidence of centrally mediated changes of postural control in CAI populations  
20  
21 has been demonstrated in separate studies by Hale et al.<sup>32</sup> and Evans et al.<sup>31</sup>, suggesting that  
22  
23 this acute trauma may lead to impairment of spinal-level and/or supraspinal motor control  
24  
25 pathways<sup>33</sup>. Due to the tendency for many studies in the CAI literature to evaluate the  
26  
27 involved limb in isolation during dynamic movements<sup>2,23,24,29,30</sup>, the results of the current  
28  
29 study supplement the current dearth of evidence examining whether patients with a history of  
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31 ankle sprain exhibit bilateral deficits in postural control and dynamic balance<sup>33</sup>.  
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34 The moment of force profiles presented in the current analysis give an indication of the motor  
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36 control that caused the movement patterns observed. The LAS participants displayed greater  
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38 hip extensor dominance on both limbs during phase 1 of the DVJ. The profile for this joint  
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40 followed a sinusoidal waveform pattern; the flexor moment occurring  $\approx 75$ ms post-IC  
41  
42 transitioned to an extensor moment  $\approx 150$ ms post-IC, which was greater in the LAS group. The  
43  
44 flexor moment may have functioned in both LAS and control participants as a force  
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46 attenuation strategy adopted following IC<sup>28</sup>. That this then developed into greater extensor  
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48 dominance in the LAS group may indicate increased activity of the hamstrings and gluteals to  
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50 extend out of this flexed position during performance of the subsequent maximal vertical  
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52 jump, rather than depending on the distal activity of the ankle plantar-flexors to do so. As  
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3 there was no difference in the jump height achieved between the LAS and control groups,  
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5 neither this coping strategy nor the one displayed by controls can be interpreted as superior  
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7 for performance, based on the current results.  
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10 The greater temporal asymmetry of the hip moment of force profile of LAS participants  
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12 during phase 1 of the DVJ may be the expression of a strategy adopted in the acute phase of  
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14 injury to minimise loading to the non-injured limb, which has since become redundant. The  
15  
16 development of new motor control strategies will eventually determine these participants'  
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18 functional outcome <sup>12</sup>, but it is unclear based on the current dataset as to whether the motor  
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20 control asymmetries evident at the hip stand to obstruct this.  
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23 Ultimately, the truly anomalous movement patterns of this cohort which likely predict  
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25 procession to CAI or coped status can only be established at the 1-year time-point. This study  
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27 serves to identify which variables are most important in recovery. It is likely that some of  
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29 these movement patterns will emerge as conducive to 'coping', and others as maladaptive,  
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31 which lead to CAI. The limitation of this study is that in isolation, it does not elucidate the  
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33 main movement pattern or motor control predictors of recovery.  
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36 In consideration of the current results, clinicians must recognise the potential for persistence  
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38 of self-reported functional deficits and disability even 6-months following acute LAS. As part  
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40 of the rehabilitation protocol, the completion of unilateral and bilateral, dynamic balance  
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42 tasks which are both terminal and non-terminal in nature, may be required to establish new  
43  
44 'coping' motor control and coordination strategies following LAS injury. Future research is  
45  
46 required to confirm this speculation.  
47

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### 32 **Figure legends**

33  
34 **Figure 1.** Hip flexion-extension, knee flexion-extension, ankle inversion-eversion and  
35 dorsiflexion-plantarflexion angle during performance of phase 1 and phase 2 of the DVJ task  
36 from 200ms pre-IC to 200ms post-IC for the involved and uninvolved limbs of the LAS and  
37 control groups. Flexion, inversion and dorsiflexion are positive; extension, eversion and  
38 plantarflexion are negative. Black line with arrow = initial contact. Dashed lines = LAS  
39 group; continuous lines = control group; black lines = involved limb; grey lines = uninvolved  
40 limb. Bold abscissa axis indicates area of statistically significant greater trend asymmetry for  
41 the LAS group. Shaded area enclosed by black line = area of statistically significant between  
42 groups difference for the involved limb. Shaded area enclosed by grey line = area of  
43 statistically significant between groups difference for the uninvolved limb.  
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56 Abbreviations: IC = initial contact; DVJ = drop vertical jump; LAS = lateral ankle sprain.  
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3 **Figure 2.** Sagittal plane joint moment-of-force profiles for the involved and uninvolved hip,  
4 knee and ankle during performance of phase 1 and phase 2 of the DVJ task from 200ms pre-  
5 IC to 200ms post-IC for LAS and control groups. Extension and plantar-flexion moments are  
6 positive; flexion and dorsiflexion moments are negative. Black line with arrow = initial  
7 contact. Dashed lines = LAS group; continuous lines = control group; black lines = involved  
8 limb; grey lines = uninvolved limb. Bold abscissa axis indicates area of statistically  
9 significant greater trend asymmetry for the LAS group. Shaded area enclosed by black line =  
10 area of statistically significant between groups difference for the involved limb. Shaded area  
11 enclosed by grey line = area of statistically significant between groups difference for the  
12 uninvolved limb. Abbreviations: Mh = Hip moment; Mk = Knee Moment; Ma = Ankle  
13 moment; IC = initial contact; DVJ = drop vertical jump; LAS = lateral ankle sprain.  
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**Table 1.** Participant self-reported function and disability questionnaire scores [mean  $\pm$  SD] with associated confidence intervals (CIs) for the involved limb of LAS and control groups.

Group	CAIT (/30)	FAAMadl (%)	FAAMsport (%)
LAS	22.58 $\pm$ 5.53 [95%CI: 21.22 to 23.93]	95.91 $\pm$ 5.57 [95%CI: 94.54 to 97.27]	82.54 $\pm$ 18.33 [95%CI: 81.04 to 88.36]
Control	30 $\pm$ 0.00 [95%CI: 30 to 30]	100 $\pm$ 0.00 [95%CI: 100 to 100]	100 $\pm$ 0.00 [95%CI: 100 to 100]

LAS = lateral ankle sprain; FAAMadl = activities of daily living subscale of the Foot and Ankle Ability Measure; FAAMsport = sport subscale of the Foot and Ankle Ability Measure.

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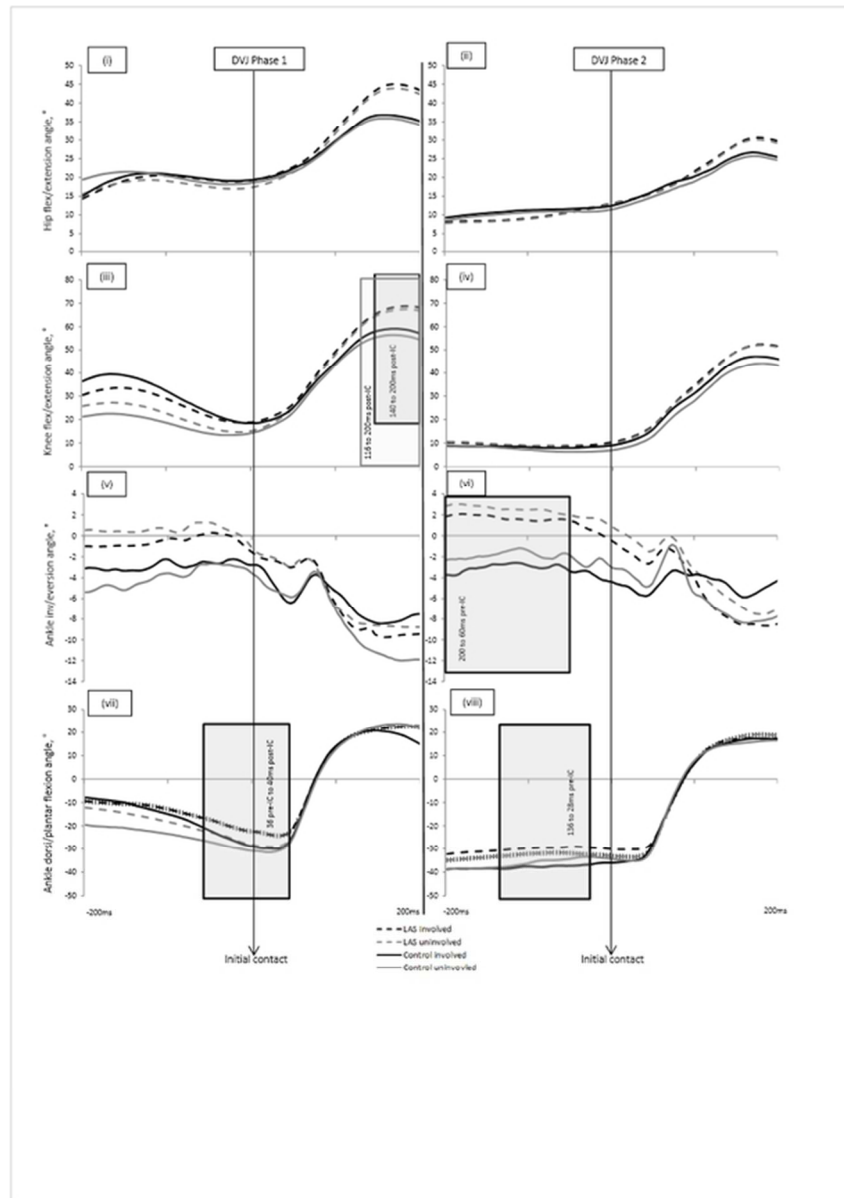
**Table 2.** Rate of force development (RFD) with corresponding inter-limb symmetry values for the phase 1 and phase 2 of the DVJ for the involved and uninvolved limbs of LAS and control groups. Abbreviations: BW = bodyweight; LAS = lateral ankle sprain; DVJ = drop vertical jump. \*indicates statistically significant between-groups difference.

DVJ phase	LAS		Control		P	$\eta^2$
Involved limb RFD (BW/sec)						
	Average	SD	Average	SD		
1	11.50	4.43	13.40	4.88	.160	0.03
2	13.12	3.28	14.60	3.20	.127	0.04
Uninvolved limb RFD (BW/sec)						
	Average	SD	Average	SD		
1	13.73	5.01	13.26	5.91	.761	0.00
2	14.39	4.22	15.02	3.45	.603	0.00
Limb symmetry (%)						
	Average	SD	Average	SD		
1	11.85	10.13	5.76	4.16	.001*	0.07
2	7.52	6.24	4.35	3.49	.016*	0.07

**Table 3.** Inter-limb trend symmetry data for LAS and control participants during phases 1 and 2 of the drop vertical jump task. Window 1 = 200ms pre-initial contact (IC) to IC; Window 2 = 100ms pre-IC to 100ms post-IC; Window 3 = IC to 200ms post-IC.

Variable	DVJ part	Trend symmetry						P-value		
		LAS			Control			LAS vs Control		
		1	2	3	1	2	3	1	2	3
Hip	1	18.58	25.89	25.41	16.53	16.92	11.48	0.628	0.149	0.005 <sup>a</sup>
Knee	1	4.74	5.25	1.42	6.17	2.26	0.71	0.397	0.036	0.140
Ankle	1	21.15	0.66	1.75	23.62	0.22	3.79	0.727	0.089	0.343
Hip	2	21.69	23.75	26.60	21.86	15.03	11.81	0.979	0.115	0.014
Knee	2	21.95	15.69	3.25	13.66	5.77	1.98	0.166	0.117	0.275
Ankle	2	27.50	0.63	3.15	25.35	0.34	1.39	0.878	0.450	0.305

<sup>a</sup>Denotes statistically significant between groups difference. Abbreviations: LAS = lateral ankle sprain; IC = initial contact.



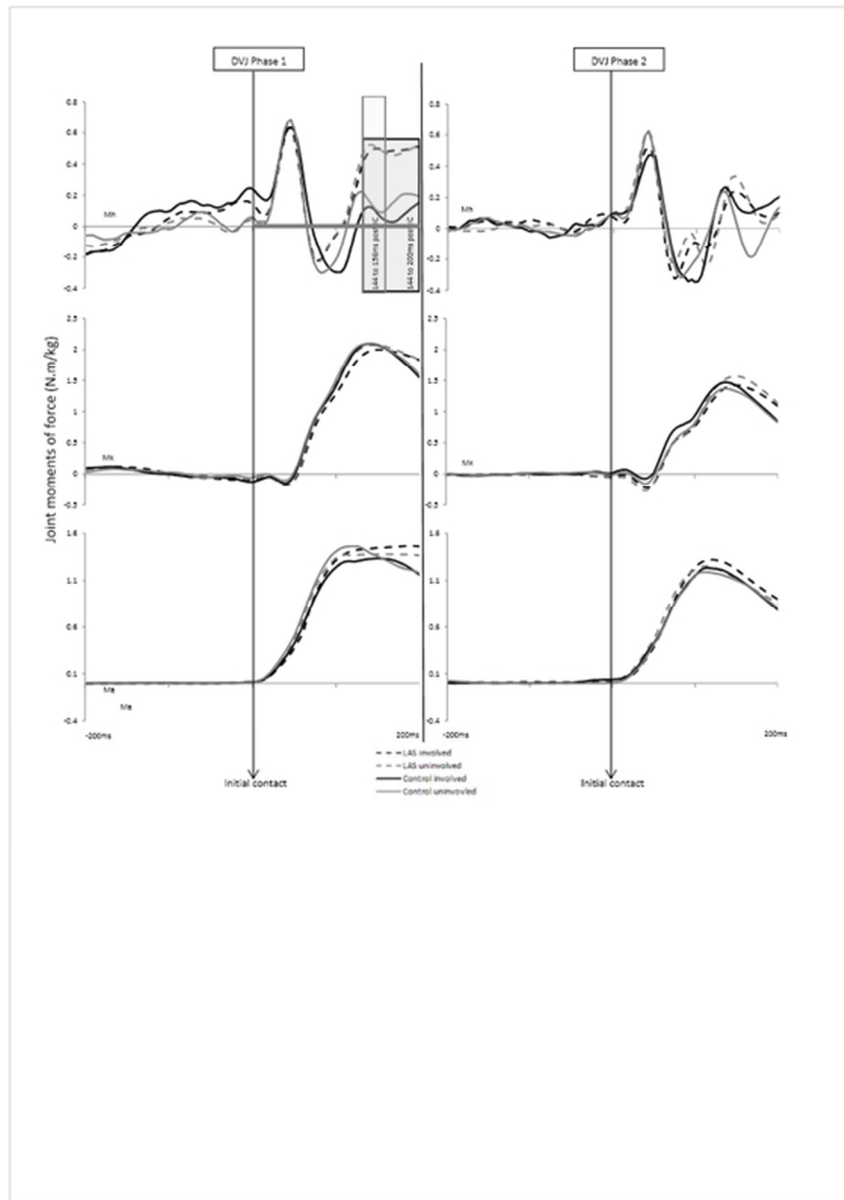
Hip flexion-extension, knee flexion-extension, ankle inversion-eversion and dorsiflexion-plantarflexion angle during performance of phase 1 and phase 2 of the DVJ task from 200ms pre-IC to 200ms post-IC for the involved and uninvolved limbs of the LAS and control groups. Flexion, inversion and dorsiflexion are positive; extension, eversion and plantarflexion are negative. Black line with arrow = initial contact. Dashed lines = LAS group; continuous lines = control group; black lines = involved limb; grey lines = uninvolved limb. Bold abscissa axis indicates area of statistically significant greater trend asymmetry for the LAS group.

Shaded area enclosed by black line = area of statistically significant between groups difference for the involved limb. Shaded area enclosed by grey line = area of statistically significant between groups difference for the uninvolved limb.

Abbreviations: IC = initial contact; DVJ = drop vertical jump; LAS = lateral ankle sprain.

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Sagittal plane joint moment-of-force profiles for the involved and uninvolved hip, knee and ankle during performance of phase 1 and phase 2 of the DVJ task from 200ms pre-IC to 200ms post-IC for LAS and control groups. Extension and plantar-flexion moments are positive; flexion and dorsiflexion moments are negative. Black line with arrow = initial contact. Dashed lines = LAS group; continuous lines = control group; black lines = involved limb; grey lines = uninvolved limb. Bold abscissa axis indicates area of statistically significant greater trend asymmetry for the LAS group. Shaded area enclosed by black line = area of statistically significant between groups difference for the involved limb. Shaded area enclosed by grey line = area of statistically significant between groups difference for the uninvolved limb. Abbreviations: Mh = Hip moment; Mk = Knee Moment; Ma = Ankle moment; IC = initial contact; DVJ = drop vertical jump; LAS = lateral ankle sprain.

47x67mm (300 x 300 DPI)