[RESEARCH REPORT]

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Dynamic Balance Deficits 6 Months Following First-Time Acute Lateral Ankle Sprain: A Laboratory Analysis

The incidence and prevalence of ankle sprain injury in active populations[16] are compounded by an array of chronic, long-term sequelae throughout the recovery process.[2,30] *Chronic ankle instability* (CAI) is the term used to describe this continuum of residual symptoms that persist for a minimum of 1 year following the initial ankle sprain, and includes feelings of instability or "giving way" at the ankle joint, as well as recurrent ankle sprain incidents.[9]

In contrast, certain individuals, described as "copers," may sustain an ankle sprain without developing subsequent instability, giving way, or recurrent sprains in the year following the acute incident.[37]

The manifestation of ankle joint in-

stability during daily, recreational, and sporting activity in patients with CAI has stimulated research to quantify performance ability in this population by objective measures of dynamic balance. The Star Excursion Balance Test (SEBT) is one such objective measure that is commonly utilized by clinicians[33] and researchers[20] to evaluate dynamic balance in participants with a history of ankle sprain. The SEBT requires an individual to transition from a position of bilateral stance to unilateral stance and perform a maximum-reach excursion with the nonstance limb in 1 of 8 reach directions.[19] In a clinical setting, the magnitude of this reach distance may be used to assess CAI-associated dynamic balance impairment and the effectiveness of a given rehabilitation protocol. In the laboratory setting, analysis of SEBT task performance has been used to elucidate the coordination strategies underlying reach-distance limitations in persons with CAI.[22] Specifically, biomechanical analyses of SEBT task performance have enabled researchers to determine that the primary reason participants with CAI achieve lower scores during the various reach directions of the SEBT is reduced sagittal plane hip and knee flexion of the stance limb.[20,21]

● **STUDY DESIGN:** Controlled laboratory study.

● **OBJECTIVE:** To utilize kinematic and stabilometric measures to compare dynamic balance during performance of the Star Excursion Balance Test between persons 6 months following first-time lateral ankle sprain (LAS) and a noninjured control group.

● **BACKGROUND:** Biomechanical evaluation of dynamic balance in persons following first-time LAS during performance of the Star Excursion Balance Test could provide insight into the mechanisms by which individuals proceed to recover fully or develop chronic ankle instability.

● **METHODS:** Sagittal plane kinematics of the lower extremity and the center-of-pressure path during the performance of the anterior, posterolateral, and posteromedial reach directions of the Star Excursion Balance Test were obtained from 69 participants 6 months following first-time acute

LAS and from a control group of 20 noninjured participants.

● **RESULTS:** Compared to the control group, the LAS group displayed lower normalized reach distances in all 3 reach directions on the injured and noninjured limbs, with the largest observed effect size in the posterolateral direction ($P = .001$, $\eta_p^2 = 0.07$). The performance impairment was associated with less hip and knee flexion and ankle dorsiflexion at the point of maximum reach ($P<.02$), and coincided with less complexity of the center-of-pressure path ($P<.05$).

● **CONCLUSION:** Participants with a 6-month history of LAS exhibit a persistence of deficits previously established in the acute phase of injury. *J Orthop Sports Phys Ther 2015;45(8):626-633. Epub 24 Jun 2015. doi:10.2519/jospt.2015.5653*

● **KEY WORDS:** *ankle joint, biomechanical phenomena, kinematics, kinetics, postural balance*

A recent analysis completed in our laboratory has revealed that participants in the acute phase of lateral ankle sprain (LAS) injury, who report significantly greater disability and impaired functional ability based on the Cumberland Ankle Instability Tool (CAIT)[26] and subscales of the Foot and Ankle Ability Measure (FAAM),[5] display movement patterns similar to those of their chronically impaired counterparts.[15] Specifically, these participants exhibited significantly less sagittal plane range of motion at joints proximal to the injured ankle, manifesting in SEBT performance decrement.[15] The fact that these deficits were exhibited bilaterally is in agreement with a previous study,[17] and may indicate that acute LAS injury has the capacity to cause impairment of centrally mediated motor control pathways.[29] The kinematic analysis in this investigation[15] utilized platform stabilometry as a measure to conceptualize the way in which the body exploited its supporting environment in maintaining balance. Specifically, the fractal dimension (FD) of the center-of-pressure (COP) path was calculated to describe its complexity.[15] The finding of a lower FD of the stance-limb COP path trajectory in participants with acute LAS during performance of specific reach directions of the SEBT[15] may indicate the impaired ability of these participants to effectively utilize their available base of support.[13,14]

While a number of studies have evaluated the movement performance characteristics of individuals with CAI[10,20,21] and acute LAS,[14] in addition to the copers previously described,[7] an ambiguity persists in this area of research in relation to the postacute phase (greater than 2 weeks) and the prechronicity/recovery period (less than 1 year). Specifically, recovery and functional status of these individuals have not been clearly defined within the time frame between postacute (after 2 weeks) and prechronic (less than 1 year). Tracking function and performance in a group of persons who experience a first-time LAS within this time frame

(postacute to prechronic) would advance current understanding of how individuals with this injury progress toward CAI. It has previously been hypothesized that restoring functional ability following ankle sprain injury may depend on the emergence of appropriate postinjury movement strategies.[4,11] In light of the high likelihood of individuals to return to their activity of interest within 2 weeks of an acute LAS,[31] the potential identification of persistent deficits in the postacute (greater than 2 weeks) and prechronic (less than 1 year) phases of this injury would appear to be pertinent for clinicians.

The current study is part of a longitudinal analysis of recovery following first-time acute LAS injury and is a continuation of a previous study that evaluated participants in the acute phase of LAS injury.[15] In the present study, dynamic balance was evaluated in participants 6 months after sustaining a first-time acute LAS injury using the same kinematic and stabilometric measures during performance of selected reach directions of the SEBT. We hypothesized that the group with a 6-month history of LAS would report greater disability and impaired function following the acute injury, exhibit movement patterns conducive to poorer performance of the SEBT (lower sagittal plane flexion positions at the knee and hip), and demonstrate a lower complexity of the stance-limb COP path in their performance of the SEBT, as determined by a measure of FD.

METHODS

Participants

SIXTY-NINE PARTICIPANTS (44 MALE, 25 female; mean ± SD age, 22.78 ± 4.12 years; height, 1.72 ± 0.09 m; body mass, 76.6 ± 13.6 kg) were recruited from a university-affiliated hospital emergency department within 2 weeks of sustaining a first-time acute LAS injury. An additional 20 participants (15 male, 5 female; mean ± SD age, 22.6 ± 1.7 years; height, 1.73 ± 0.1 m; body mass, 71.4 ± 11.29 kg) with no prior history of

LAS were recruited from the community population surrounding the hospital using posters and flyers. The participants with LAS included in the current study were from a cohort in a prospective longitudinal study. This manuscript pertains to the data collected 6 months following recruitment. All participants with LAS were provided with basic advice on applying ice and compression on discharge from the hospital and were encouraged to bear weight and walk within the limits of pain. Activities of daily living were encouraged. Whether participants sought additional formal medical health care services or rehabilitation was recorded (yes or no) on arrival to the testing laboratory but was not controlled as part of the current study.

None of the subjects had a history of severe lower extremity injury (excluding the recently sustained LAS for the injured group), vestibular conditions, or any other pathology that would impair their motor performance (including recent concussion). The study protocol was approved by the Human Research Ethics Committee of University College Dublin, and informed written consent was acquired from each participant prior to testing.

Protocol

Collection methods for this study have been previously documented.[15] Briefly, all participants were required to complete the CAIT[26] in addition to the activities of daily living and sports subscales of the FAAM.[5] Prior to each biomechanical assessment, ankle dorsiflexion (DF) range of motion (ROM) was evaluated using the knee-to-wall test, as described by Denegar et al.[12] To determine the DF ROM, the mean value of 2 measures was calculated separately for each limb.

Each participant was then instrumented with the Codamotion bilateral lower-limb gait setup[32] (Charnwood Dynamics Ltd, Rothley, UK) and asked to perform specified reach directions of the SEBT (anterior [ANT], posterolateral [PL], and posteromedial [PM]) on

both limbs (**FIGURE**) while standing on 2 adjacent force plates. The SEBT was performed based on the recommendations of Gribble et al[22] and as described by Doherty et al.[15] The order of testing for limb and SEBT direction was randomized using a random-number generator. The onset and end of each trial were determined using a 10-N threshold of the vertical component of the ground reaction force of the reaching (nonstance) limb.[15] Reach distances were divided by limb length (as measured from the anterior superior iliac spine to the ipsilateral medial malleolus) and multiplied by 100 to calculate a dependent variable that represented reach distance as a percentage of limb length.[22]

Kinematic (angular displacement) and stabilometric (FD of the COP path) data were acquired for the stance limb during each reach trial using 3 Codamotion CX1 camera units and 2 AMTI (Advanced Mechanical Technology, Inc, Watertown, MA) walkway-embedded force plates. Center-of-pressure data acquired from trials of the SEBT were used to compute the FD of the combined anterior/posterior and medial/lateral COP path.[28] The output of the FD calculation is a discrete value between 1 and 2 that describes the complexity of the COP path, wherein a larger value denotes higher path complexity.[35] Fractal dimension was calculated based on the full duration of the unilateral stance during the SEBT reach attempt. The anterior/posterior and medial/lateral time series were passed through a fourth-order, zero-phase, Butterworth low-pass digital filter with a 5-Hz cutoff frequency. For each participant, a mean of 3 trials in each reach direction was calculated for each dependent variable during the SEBT (reach distance, discrete sagittal plane lower extremity joint angular position at the point of maximum reach, and the FD of the COP path).

Data Analysis

For the LAS group, the injured limb was labeled as "involved" and the noninjured
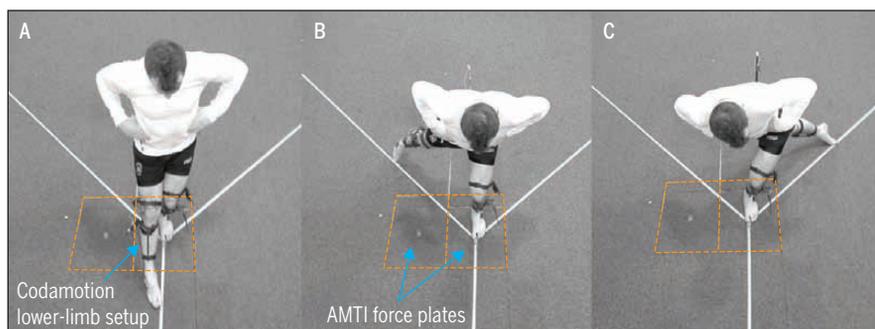

FIGURE. Laboratory setup for the (A) anterior, (B) posteromedial, and (C) posterolateral reach directions of the Star Excursion Balance Test.

TABLE 1	PARTICIPANT SELF-REPORTED FUNCTION AND DISABILITY QUESTIONNAIRE SCORES IN THE INVOLVED LIMB OF THE LAS AND CONTROL GROUPS*		
Group	**CAIT (0-30)**	**FAAM-ADL, %**	**FAAM-sports, %**
LAS	21.6 ± 5.8†	95.8 ± 5.8†	87.1 ± 17.7†
Control	30 ± 0.0	100 ± 0.0	100 ± 0.0

Abbreviations: CAIT, Cumberland Ankle Instability Tool; FAAM-ADL, Foot and Ankle Ability Measure activities of daily living subscale; FAAM-sports, Foot and Ankle Ability Measure sports subscale; LAS, lateral ankle sprain.
*Values are mean ± SD.
†Significantly different from control group.

limb as "uninvolved." In all cases, the limbs in the control group were randomly matched to the limbs in the injured group. For each control subject, one limb was assigned as involved and the other 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 Participant characteristics were compared between the LAS and control groups using multivariate analysis of variance. The dependent variables were age, body mass, sex, and height. The independent variable was group (LAS versus control). The significance level for this analysis was set a priori at $P<.05$.[34]

Questionnaires To determine whether the LAS group reported lower scores on the CAIT and on the subscales of the FAAM compared to the control group, a multivariate analysis of variance was undertaken. The independent variable was

group (LAS versus control). The dependent variables were CAIT score, FAAM activities of daily living subscale score, and FAAM sports subscale score for the involved limb. The significance level for this analysis was set a priori at $P<.05$.[34]

Ankle DF ROM An independent-samples t test was performed to compare ankle DF ROM between LAS and control groups (LAS involved versus control involved; LAS uninvolved versus control uninvolved). The significance level for this analysis was set a priori with a Bonferroni-adjusted alpha level of $P<.025$.[34]

Reach Distances A 2-way, between-group analysis of variance was conducted for each reach direction of the SEBT to determine whether the LAS group demonstrated lower reach distances during the SEBT compared to the control group on matched limbs. The independent variables were group (LAS and control) and limb (involved and uninvolved). The dependent variable was reach distance. As the 3 com-

TABLE 2	ANKLE DORSIFLEXION RANGE OF MOTION AS DETERMINED USING THE KNEE-TO-WALL TEST FOR THE INVOLVED AND UNINVOLVED LIMBS OF THE LAS AND CONTROL GROUPS				
	LAS*	Control*	Mean Difference†	P Value	η^2
Involved	100.8 ± 44.8	113.4 ± 28.2	−12.7 (−37.8, 12.4)	.32	0.01
Uninvolved	118.1 ± 36.4	112.8 ± 27.2	5.3 (−15.6, 26.1)	.61	0.00

Abbreviation: LAS, lateral ankle sprain.
*Values are mean ± SD mm.
†Values in parentheses are 95% confidence interval.

TABLE 3	SPECIFIED STAR EXCURSION BALANCE TEST REACH DIRECTION SCORES FOR THE INVOLVED AND UNINVOLVED LIMBS OF LAS AND CONTROL GROUPS*	
	LAS	Control
Involved		
ANT	60.6 ± 9.3	65.5 ± 6.5
PL	90.8 ± 16.2	101.1 ± 8.2
PM	98.3 ± 19.7	107.3 ± 5.9
Uninvolved		
ANT	60.4 ± 12.2	65.3 ± 5.4
PL	91.2 ± 19.9	102.4 ± 8.3
PM	98.0 ± 19.2	106.7 ± 5.6

Abbreviations: ANT, anterior reach direction; LAS, lateral ankle sprain; PL, posterolateral reach direction; PM, posteromedial reach direction.
*Values are mean ± SD percent leg length.

ponents of the SEBT were considered to represent separate tasks (ANT, PL, PM), the significance level for this analysis was not adjusted and was set a priori at P<.05.
Kinematics To test the hypothesis that the LAS group would exhibit altered kinematics during the SEBT compared to the control group, a 2-way, between-group multivariate analysis of variance was performed for each reach direction to compare joint position at the point of maximum reach between the LAS and control groups. Three dependent variables were used: sagittal plane hip, knee, and ankle joint positions. The independent variables were group (LAS versus control) and limb (involved and uninvolved). Preliminary assumption testing

was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. An alpha level of P<.05 was used to determine significant differences for this analysis.[34] Significant effects were evaluated post hoc via 2-tailed, independent-samples t tests where appropriate. Statistical significance for post hoc analyses was established a priori, with a false discovery rate of less than 5%.[3]
Kinetics (**FD**) To test the hypothesis that the LAS group would exhibit altered COP paths compared to the control group, a 2-way, between-group analysis of variance was conducted for each reach direction.

The independent variables were group (LAS and control) and limb (involved and uninvolved). The dependent variable was FD of the COP path. The significance level for this analysis was set a priori at P<.05.

Associated effect sizes (eta squared) were calculated for all discrete variables, with 0.01 considered a small effect size, 0.06 a medium effect size, and 0.14 a large effect size.[6] All statistical analyses were performed with IBM SPSS Statistics 20 (IBM Corporation, Armonk, NY).

RESULTS

Participant Characteristics and Questionnaire Results

THERE WAS NO STATISTICALLY SIGnificant difference between the LAS and control groups with respect to age, body mass, sex, and height ($F_{4,72}$ = 1.51, P = .21, Wilks' λ = 0.923). Regarding function, there was a statistically significant main effect for the combined dependent variables ($F_{3,72}$ = 14.81, P<.01, Wilks' λ = 0.62, η_p^2 = 0.38), with the LAS group exhibiting lower scores on the CAIT and on the subscales of the FAAM (**TABLE 1**). Forty-six percent of participants with LAS reported having attended formal medical counsel/rehabilitation services for their LAS injury.

Ankle DF ROM

There was no significant difference in ankle DF ROM between the LAS and control groups for either limb (**TABLE 2**).

Reach-Distance Scores

There was a statistically significant main effect for group (no interaction) in the ANT ($F_{1,165}$ = 7.37, P = .007, η_p^2 = 0.04), PL ($F_{1,165}$ = 13.17, P<.001, η_p^2 = 0.07), and PM ($F_{1,165}$ = 8.08, P = .005, η_p^2 = 0.05) reach directions. On average, the LAS group exhibited lower scores in all 3 directions for both limbs compared to the control group (**TABLE 3**).

Kinematics

There was a statistically significant main effect for group (no interaction) in the PL

TABLE 4	Discrete Kinematic Variable Values for the Hip, Knee, and Ankle at the Point of Maximum Reach in the Involved and Uninvolved Limbs of the LAS and Control Groups for 3 Reach Directions of the Star Excursion Balance Test*							
	Involved				**Uninvolved**			
Reach Direction/Kinematic Variable	**LAS**	**Control**	**P Value**	η^2	**LAS**	**Control**	**P Value**	η^2
Anterior								
Hip flexion/extension†	9.7 ± 14.5‡	21.0 ± 10.5	<.01	0.25	11.3 ± 18.1	15.6 ± 19.7	.38	0.01
Knee flexion/extension†	45.5 ± 20.2‡	56.7 ± 11.0	<.01	0.15	45.9 ± 27.6	51.5 ± 18.8	.41	0.01
Ankle dorsiflexion/plantar flexion§	26.9 ± 8.8‡	33.7 ± 16.0	.02	0.07	27.2 ± 11.0	25.5 ± 18.3	.61	0.00
Posterolateral								
Hip flexion/extension†	57.3 ± 19.4‡	73.0 ± 15.5	<.01	0.12	63.2 ± 23.8	71.6 ± 16.4	.16	0.02
Knee flexion/extension†	40.0 ± 15.9‡	50.4 ± 12.9	.01	0.08	45.3 ± 18.5‡	57.1 ± 9.7	<.01	0.19
Ankle dorsiflexion/plantar flexion§	20.1 ± 8.9	24.8 ± 7.4	.04	0.05	21.1 ± 15.1‡	32.3 ± 25.6	.02	0.06
Posteromedial								
Hip flexion/extension†	58.6 ± 20.1‡	71.7 ± 13.5	.01	0.09	61.2 ± 20.9	71.2 ± 11.7	.04	0.05
Knee flexion/extension†	55.9 ± 17.8‡	66.9 ± 11.6	.01	0.07	59.2 ± 11.3‡	67.3 ± 7.9	<.01	0.10
Ankle dorsiflexion/plantar flexion§	22.8 ± 7.3‡	28.6 ± 9.5	.01	0.09	22.3 ± 9.3‡	28.0 ± 9.6	.02	0.06

Abbreviation: LAS, lateral ankle sprain.
*Values are mean ± SD degrees unless otherwise indicated.
†Flexion is positive, extension is negative.
‡Significantly different from control group.
§Dorsiflexion is positive, plantar flexion is negative.

($F_{3,163}$ = 5.722, P = .001, Wilks' λ = 0.9) and PM ($F_{3,163}$ = 5.858, P = .001, Wilks' λ = 0.896) reach directions. There was, however, a significant group-by-limb interaction in the ANT reach direction ($F_{3,163}$ = 2.891, P = .037, Wilks' λ = 0.949). Post hoc analyses revealed that in the involved limb, the LAS group exhibited a less-flexed position of the hip and knee in all 3 directions, and a less-dorsiflexed position at the ankle in the ANT and PM directions, compared to the control group (**TABLE 4**). On the uninvolved limb, the LAS group displayed less knee flexion and ankle DF in the PL and PM directions compared to the control group (**TABLE 4**).

Center-of-Pressure FD

There was a statistically significant main effect for group (no interaction) in the ANT ($F_{1,165}$ = 5.03, P = .026, η_p^2 = 0.03), PL ($F_{1,165}$ = 11.151, P = .001, η_p^2 = 0.06), and PM ($F_{1,165}$ = 5.23, P = .023, η_p^2 = 0.03)

reach directions. On average, the LAS group exhibited a lower FD of the COP path on both limbs compared to the control group (**TABLE 5**).

DISCUSSION

THE OBJECTIVE OF THIS STUDY WAS TO evaluate dynamic balance in a group of participants with a 6-month history of first-time LAS injury. As such, we sought to identify the persistence of impairments previously recognized in this cohort in the acute phase of their ankle sprain.[15] In the current study, the evaluation of dynamic balance was completed following the acute phase of LAS injury, thus allowing for factors such as swelling and pain[15] to resolve, and prior to the establishment of long-term (greater than 1 year) deficits. The questionnaires (the CAIT and subscales of the FAAM) were utilized to differentiate the groups and to quantify self-reported function and

disability in the LAS group. The values reported by the LAS participants provide an indication of recovery trajectory following a first-time acute LAS and could be used as a reference value for clinicians in this 6-month time frame.

The experimental hypotheses for this investigation were confirmed. Specifically, participants with LAS reported significantly poorer ankle joint function and greater disability. These individuals performed poorer during specified reach directions of the SEBT, and this performance impairment was consistent with a limitation in the primary kinematic determinants of test outcome (namely, lower-limb sagittal plane flexion and DF positions). Finally, these findings coincided with less complexity of the test-limb COP path, as evidenced by a reduction in FD.

A previous study conducted on the same cohort during the acute phase of their LAS indicated a bilateral impair-

TABLE 5	FRACTAL DIMENSION SCORES FOR THE INVOLVED AND UNINVOLVED LIMBS OF LAS AND CONTROL GROUPS FOR 3 REACH DIRECTIONS OF THE STAR EXCURSION BALANCE TEST*	

Limb/Reach Direction	LAS	Control
Involved		
Anterior	1.4 ± 0.2	1.5 ± 0.1
Posterolateral	1.7 ± 0.3	1.9 ± 0.2
Posteromedial	1.7 ± 0.3	1.8 ± 0.3
Uninvolved		
Anterior	1.5 ± 0.1	1.5 ± 0.1
Posterolateral	1.6 ± 0.5	1.9 ± 0.3
Posteromedial	1.7 ± 0.2	1.8 ± 0.2

Abbreviation: LAS, lateral ankle sprain.
*Values are mean ± SD.

ment in these same performance determinants.[15] With regard to the current analysis, the significant main effect observed for group in the a priori statistical model for analyzing reach-distance performance likely indicates a similar bilateral impairment during the 3 specified SEBT reach directions. The bilateral manifestation of performance deficits also was evident in the coinciding COP patterns, as assessed by FD analysis, whereby a group main effect also was observed for each reach direction. Again, group mean profiles revealed that participants with LAS displayed less complexity of the stance-limb COP path, as determined by a reduction in FD, suggesting that participants with LAS were less effective in their utilization of the available base of support for all reach directions on both limbs. This finding was consistent with the acute data.[15]

It previously has been reported that the PM reach direction is most representative of the kinematic requirements for better performance of the SEBT in CAI groups.[24] However, the current LAS cohort with a 6-month history of first-time LAS actually exhibited impaired capacity to fulfill the same kinematic requirements in all 3 of the specified reach directions. Another laboratory analysis

evaluating the primary kinematic determinants of SEBT task outcome in a noninjured cohort revealed that hip and knee flexion positions of the stance limb were the greatest predictors of reach distance.[36] This was attributed to the mechanical advantage afforded by these joints' morphology, including an extensive range of supporting musculature suited to controlling both motion and stability during dynamic balance tasks such as the SEBT.[1,22] The fact that persons with CAI have been shown to have a reduced capacity to exploit the available ROM of the lower extremity joints during the SEBT on their involved limb[20,21] is reflected in individuals with a 6-month history of first-time LAS included in the present study. Specifically, the a priori analysis for the discrete kinematic data revealed a significant main effect for group in the PL and PM reach directions and a significant effect for the interaction between group and limb in the ANT direction. Post hoc analyses also identified a reduction in the involved-limb flexion/DF positions at the hip, knee, and ankle in the ANT and PM reach directions, and at the hip and knee in the PL reach direction. Deficits also were observed in knee and ankle joint position at the point of maximum reach in the PL and PM reach

directions in the uninvolved limb. Thus, the main effect for group in the posterior reach directions likely resulted from bilateral deficits in the LAS group. Because deficits only were present on the involved limb in the LAS group in the ANT direction, no group main effect emerged. However, we believe this to have been exposed by the significant interaction between group and limb.

The same kinematic deficits also were present in this cohort of participants when they were tested in the acute phase of injury.[15] The fact that bilateral differences in both COP patterns and reach distances in all 3 of the specified reach directions did not manifest in the kinematic data for the ANT direction (where ROM deficits were only present on the involved limb) may be explained by motor control "redirection," whereby kinematic strategies not evaluated in the current analysis (eg, frontal and transverse ROM) were more effectively exploited by controls but not by participants with LAS, thus manifesting in poorer performance in this direction in the LAS group.[8] While impaired performance in the ANT direction has been reported in CAI populations, with regression analysis revealing reduced sagittal plane ankle ROM as a primary contributing factor to this impairment,[27] kinematic redirection might have limited the power of the statistical analyses in the current investigation by masking between-group differences. Although a reduction in DF ROM was evident in the posterior directions of the SEBT, in light of the results presented by Hoch et al,[27] it is likely that this was merely a function of less knee flexion and did not contribute to the decrease in reach distance of the LAS group at either the 2-week or 6-month time point. These hypotheses are further supported by the fact that there was no difference in ankle DF ROM, as determined using the knee-to-wall test, between the LAS and control groups in the current study. Thus, the bilateral reduction in reach distances achieved by the LAS group may

be primarily attributed but not exclusive to the observed decrease in hip and knee flexion.

The presence of bilateral deficits following unilateral injury is not a novel finding in persons following LAS injury,[13,14,15,17] and a number of researchers have previously suggested that alterations may occur at the spinal or supraspinal level after LAS.[17,25,29] These deficits are likely the result of motor control anomalies in the pathways of the central nervous system following acute injury, but whether these anomalies caused or were the result of the ankle sprain is a contentious issue that cannot be determined with the current study design. An additional limitation of the current study design is that it was unable to show whether the deficits displayed by the LAS cohort dictated their recovery outcome (CAI versus coper). However, this study is part of a series of observational investigations that will culminate in a prospective study designed to address this question. Furthermore, as it would have been unethical to control the choice of participants with LAS to seek professional rehabilitation advice for their injury, this variable could be an important covariate not considered as part of the current study.

The immediate clinical implications of this study are 2-fold. First, because individuals often return to activity participation within 2 weeks of sustaining an acute LAS,[18,31] the results of the current study and of that completed in the same cohort in the acute phase of their injury[15] highlight the potential risk of a premature return to activity following LAS injury. The current findings illustrate the potential capacity for unilateral ankle sprain to either be preceded by deficits in centrally mediated motor control mechanisms or to alter them, manifesting in the observed bilateral balance impairments. Clinicians should ensure that self-reported function has resolved at least to preinjury levels in LAS cohorts. This may coincide with a restoration of dynamic balance before a return to activity is permitted. Second, balance

training programs need to be designed to address deficits on both the involved and uninvolved limbs, and proximal to the injured joint. Finally, in light of recently published evidence that training the uninvolved limb of participants with LAS results in improvements in the involved limb,[23] clinicians may consider the value of implementing balance training in the acute phase of injury on the uninvolved limb and progressing on the involved limb as the patient is able.

CONCLUSION

PARTICIPANTS WITH A 6-MONTH HIStory of LAS present with bilateral and proximally manifesting deficits in an assessment of dynamic balance. These deficits coincided with an alteration in the stance-limb kinematic profile and COP behavior during performance of the task. ◉

■ KEY POINTS

FINDINGS: Individuals with a 6-month history of first-time acute LAS injury exhibit dynamic balance deficits on both their previously injured and noninjured limbs during performance on selected reach directions of the SEBT.

IMPLICATIONS: Clinicians should consider that acute balance impairments may persist following LAS injury and that these impairments may contribute to long-term chronicity.

CAUTION: It is still unclear as to whether the deficits exhibited by the LAS group in the current study preceded those participants' initial injury.

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