Professor Eamonn Delahunt

School of Public Health, Physiotherapy and Sports Science
University College Dublin, Dublin, Ireland

EMAIL: eamonn.delahunt@ucd.ie
TWITTER: @EamonnDelahunt

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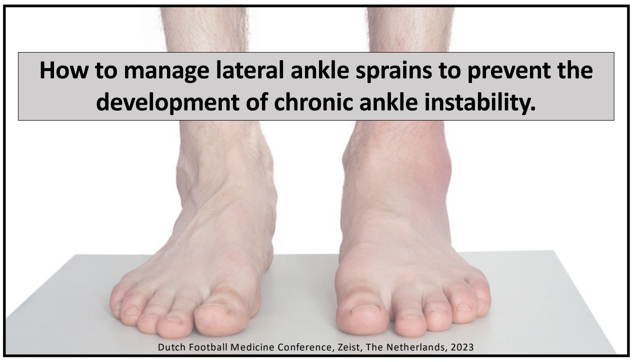

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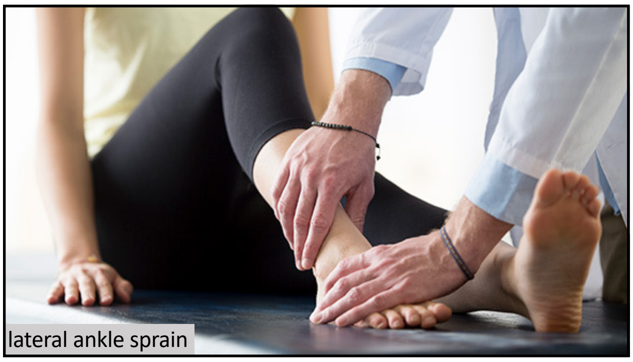

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High re-injury rate
14%
Ekstrand et al (2020)

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40% develop CAI
Doherty et al (2016)

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Link to OA
Valderrabano et al (2006)

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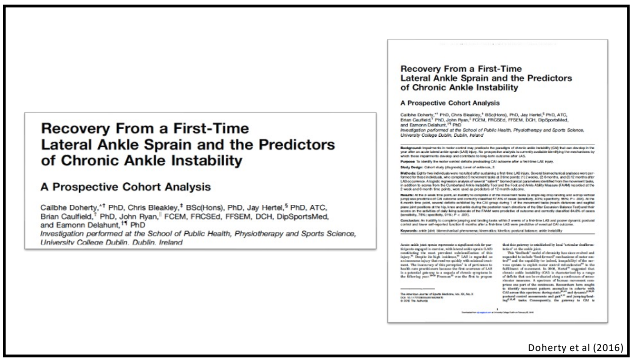
Recovery From a First-Time Lateral Ankle Sprain and the Predictors of Chronic Ankle Instability
A Prospective Cohort Analysis
Cailbhe Doherty, PhD, Chris Bleakley, BSc(Hons), PhD, Jay Hertel, PhD, ATC, Brian Caulfield, PhD, John Ryan, FCEM, FRCSEd, FFSEM, DCH, DipSportsMed, and Eamonn Delahunt, PhD
Investigation performed at the School of Public Health, Physiotherapy and Sports Science, University College Dublin, Dublin, Ireland
Doherty et al (2016)

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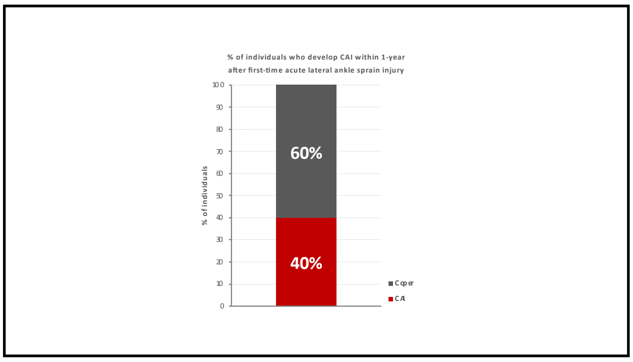
% of individuals who develop CAI within 1-year after first-time acute lateral ankle sprain injury
% of individuals
60%
40%

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Original Research
Lack of Medical Treatment From a Medical Professional After an Ankle Sprain
Tricia Hubbard-Turner, PhD, ATC, FACSM

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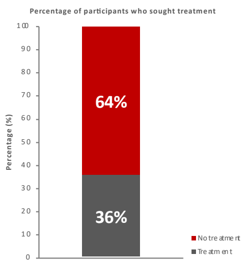

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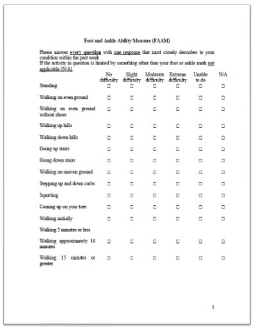

Foot and Ankle Ability Measure (FAAM)

Please answer every question with one response that most closely describes to your condition within the past week.
If the activity in question is limited by something other than your foot or ankle mark not applicable (N/A).

	No difficulty	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Standing	☐	☐	☐	☐	☐	☐
Walking on even ground	☐	☐	☐	☐	☐	☐
Walking on even ground without shoes	☐	☐	☐	☐	☐	☐
Walking up hills	☐	☐	☐	☐	☐	☐
Walking down hills	☐	☐	☐	☐	☐	☐
Going up stairs	☐	☐	☐	☐	☐	☐
Going down stairs	☐	☐	☐	☐	☐	☐
Walking on uneven ground	☐	☐	☐	☐	☐	☐
Stepping up and down curbs	☐	☐	☐	☐	☐	☐
Squatting	☐	☐	☐	☐	☐	☐
Coming up on your toes	☐	☐	☐	☐	☐	☐
Walking initially	☐	☐	☐	☐	☐	☐
Walking 5 minutes or less						
Walking approximately 10 minutes	☐	☐	☐	☐	☐	☐
Walking 15 minutes or greater	☐	☐	☐	☐	☐	☐

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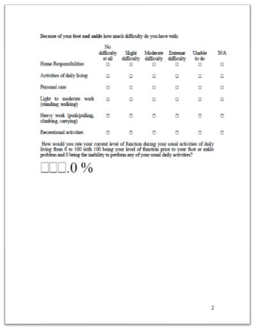

Because of your **foot and ankle** how much difficulty do you have with:

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Home Responsibilities	☐	☐	☐	☐	☐	☐
Activities of daily living	☐	☐	☐	☐	☐	☐
Personal care	☐	☐	☐	☐	☐	☐
Light to moderate work (standing, walking)	☐	☐	☐	☐	☐	☐
Heavy work (push/pulling, climbing, carrying)	☐	☐	☐	☐	☐	☐
Recreational activities	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during your usual activities of daily living from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?

☐☐☐.0 %

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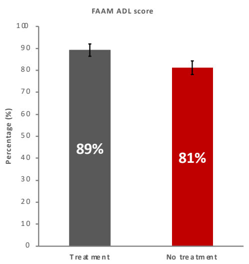

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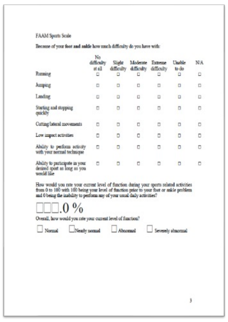

FAAM Sports Scale

Because of your **foot and ankle** how much difficulty do you have with:

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do	N/A
Running	☐	☐	☐	☐	☐	☐
Jumping	☐	☐	☐	☐	☐	☐
Landing	☐	☐	☐	☐	☐	☐
Starting and stopping quickly	☐	☐	☐	☐	☐	☐
Cutting/lateral movements	☐	☐	☐	☐	☐	☐
Low impact activities	☐	☐	☐	☐	☐	☐
Ability to perform activity with your normal technique	☐	☐	☐	☐	☐	☐
Ability to participate in your desired sport as long as you would like	☐	☐	☐	☐	☐	☐

How would you rate your current level of function during your sports related activities from 0 to 100 with 100 being your level of function prior to your foot or ankle problem and 0 being the inability to perform any of your usual daily activities?

☐☐☐.0 %

Overall, how would you rate your current level of function?

☐ Normal ☐ Nearly normal ☐ Abnormal ☐ Severely abnormal

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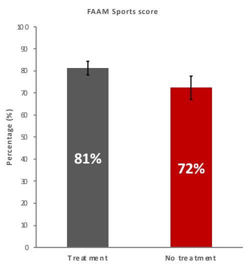

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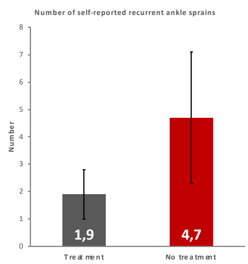

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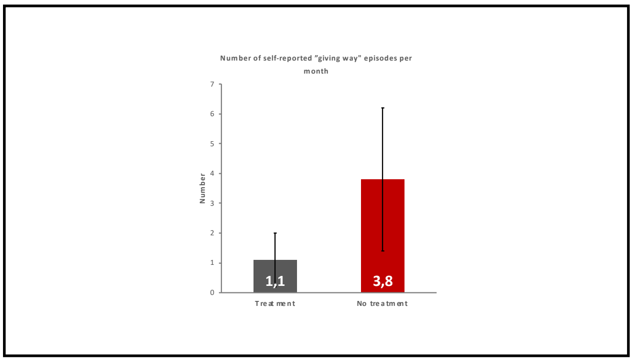

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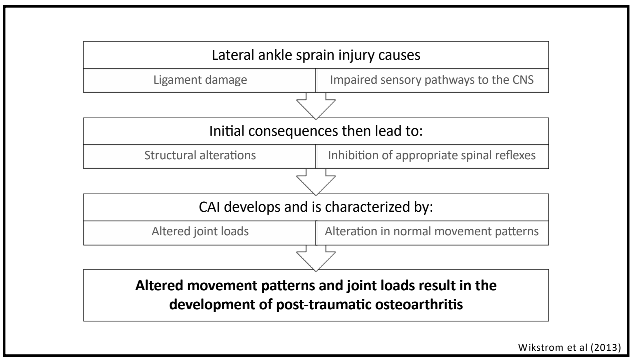

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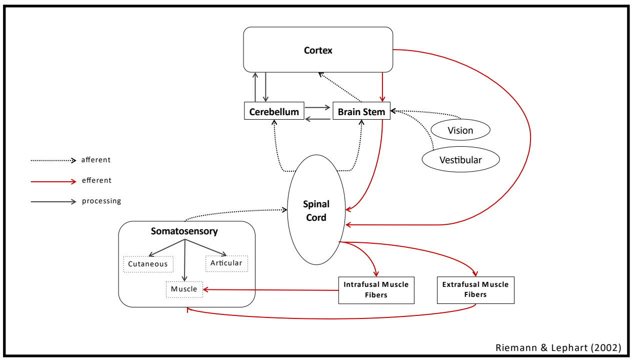

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Journal of Science and Medicine in Sport 17 (2014) 23–28

Journal of Science and Medicine in Sport

Original research

Return-to-play probabilities following new versus recurrent ankle sprains in high school athletes

Jennifer M. Medina McKeon, Heather M. Bush, Ashley Reed, Angela Whittington, Timothy L. Uhl, Patrick O. McKeon

Table 2
Return-to-play probabilities for new ($n = 163$) and recurrent ankle sprains ($n = 35$).

	Time point (day return)	N returned	Censored	Probability of RTP (%)	95% Confidence interval
New ankle sprains	Same-day return	41	0	25.2	18.7–31.9
	Next-day return	30	0	43.6	35.3–52.7
	3-Day return	50	1	74.8	64.9–82.5
	7-Day return	17	1	85.9	73.8–94.4
	10-Day return	14	0	94.5	78.1–98.9
	>22-Day return	6	3		
Recurrent ankle sprains	Same-day return	6	0	17.1	6.6–30.3
	Next-day return	12	0	51.4	32.5–67.5
	3-Day return	7	0	71.4	50.1–89.7
	7-Day return	5	0	85.7	55.5–97.5
	10-Day return	3	0	94.3	47.8–99.5
	>22-Day return	1	1		

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Original research

Time before return to play for the most common injuries in professional football: a 16-year follow-up of the UEFA Elite Club Injury Study

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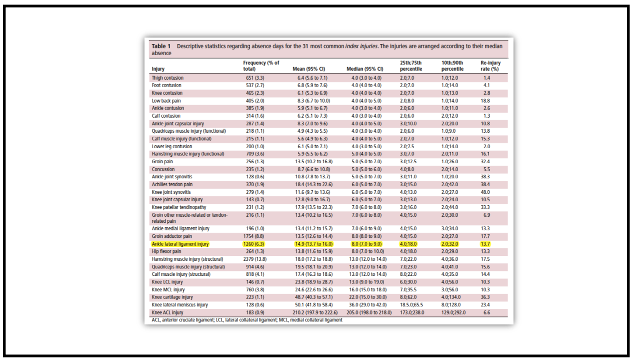

Table 1 Descriptive statistics regarding absence days for the 31 most common *index injuries*. The injuries are arranged according to their median absence

Injury	Frequency (% of total)	Mean (95% CI)	Median (95% CI)	25th;75th percentile	10th;90th percentile	Re-injury rate (%)
Thigh contusion	651 (3.3)	6.4 (5.6 to 7.1)	4.0 (3.0 to 4.0)	2.0;7.0	1.0;12.0	1.4
Foot contusion	537 (2.7)	6.8 (5.9 to 7.6)	4.0 (4.0 to 4.0)	2.0;7.0	1.0;14.0	4.1
Knee contusion	465 (2.3)	6.1 (5.3 to 6.9)	4.0 (4.0 to 4.0)	2.0;7.0	1.0;13.0	2.8
Low back pain	405 (2.0)	8.3 (6.7 to 10.0)	4.0 (4.0 to 5.0)	2.0;8.0	1.0;14.0	18.8
Ankle contusion	385 (1.9)	5.9 (5.1 to 6.7)	4.0 (3.0 to 4.0)	2.0;6.0	1.0;11.0	2.6
Calf contusion	314 (1.6)	6.2 (5.1 to 7.3)	4.0 (3.0 to 4.0)	2.0;6.0	2.0;12.0	1.3
Ankle joint capsular injury	287 (1.4)	8.3 (7.0 to 9.6)	4.0 (4.0 to 5.0)	3.0;10.0	2.0;20.0	10.8
Quadriceps muscle injury (functional)	218 (1.1)	4.9 (4.3 to 5.5)	4.0 (3.0 to 4.0)	2.0;6.0	1.0;9.0	13.8
Calf muscle injury (functional)	215 (1.1)	5.6 (4.9 to 6.3)	4.0 (4.0 to 5.0)	2.0;7.0	1.0;12.0	15.3
Lower leg contusion	200 (1.0)	6.1 (5.0 to 7.1)	4.0 (3.0 to 5.0)	2.0;7.5	1.0;14.0	2.0
Hamstring muscle injury (functional)	709 (3.6)	5.9 (5.5 to 6.2)	5.0 (4.0 to 5.0)	3.0;7.0	2.0;11.0	16.1
Groin pain	256 (1.3)	13.5 (10.2 to 16.8)	5.0 (5.0 to 7.0)	3.0;12.5	1.0;26.0	32.4
Concussion	235 (1.2)	8.7 (6.6 to 10.8)	5.0 (5.0 to 6.0)	4.0;8.0	2.0;14.0	5.5
Ankle joint synovitis	128 (0.6)	10.8 (7.8 to 13.7)	5.0 (5.0 to 7.0)	3.0;11.0	1.0;20.0	38.3
Achilles tendon pain	370 (1.9)	18.4 (14.3 to 22.6)	6.0 (5.0 to 7.0)	3.0;15.0	2.0;42.0	38.4
Knee joint synovitis	279 (1.4)	11.6 (9.7 to 13.6)	6.0 (5.0 to 7.0)	4.0;13.0	2.0;27.0	48.0
Knee joint capsular injury	143 (0.7)	12.8 (9.0 to 16.7)	6.0 (5.0 to 7.0)	3.0;13.0	2.0;24.0	10.5
Knee patellar tendinopathy	231 (1.2)	17.9 (13.5 to 22.3)	7.0 (6.0 to 8.0)	3.0;16.0	2.0;44.0	33.3
Groin other muscle-related or tendon-related pain	216 (1.1)	13.4 (10.2 to 16.5)	7.0 (6.0 to 8.0)	4.0;15.0	2.0;30.0	6.9
Ankle medial ligament injury	196 (1.0)	13.4 (11.2 to 15.7)	7.0 (6.0 to 9.0)	4.0;15.0	3.0;34.0	13.3
Groin adductor pain	1754 (8.8)	13.5 (12.6 to 14.4)	8.0 (8.0 to 9.0)	4.0;15.0	2.0;27.0	17.7
Ankle lateral ligament injury	1260 (6.3)	14.9 (13.7 to 16.0)	8.0 (7.0 to 9.0)	4.0;18.0	2.0;32.0	13.7
Hip flexor pain	264 (1.3)	13.8 (11.6 to 15.9)	8.0 (7.0 to 10.0)	4.0;18.0	2.0;29.0	13.3
Hamstring muscle injury (structural)	2379 (13.8)	18.0 (17.2 to 18.8)	13.0 (12.0 to 14.0)	7.0;22.0	4.0;36.0	17.5
Quadriceps muscle injury (structural)	914 (4.6)	19.5 (18.1 to 20.9)	13.0 (12.0 to 14.0)	7.0;23.0	4.0;41.0	15.6
Calf muscle injury (structural)	818 (4.1)	17.4 (16.3 to 18.6)	13.0 (12.0 to 14.0)	8.0;22.0	4.0;35.0	14.4
Knee LCL injury	146 (0.7)	23.8 (18.9 to 28.7)	13.0 (9.0 to 19.0)	6.0;30.0	4.0;56.0	10.3
Knee MCL injury	760 (3.8)	24.6 (22.6 to 26.6)	16.0 (15.0 to 18.0)	7.0;35.5	3.0;56.0	10.3
Knee cartilage injury	223 (1.1)	48.7 (40.3 to 57.1)	22.0 (15.0 to 30.0)	8.0;62.0	4.0;134.0	36.3
Knee lateral meniscus injury	128 (0.6)	50.1 (41.8 to 58.4)	36.0 (29.0 to 42.0)	18.5.0;65.5	8.0;128.0	23.4
Knee ACL injury	183 (0.9)	210.2 (197.9 to 222.6)	205.0 (198.0 to 218.0)	173.0;238.0	129.0;292.0	6.6

ACL, anterior cruciate ligament; LCL, lateral collateral ligament; MCL, medial collateral ligament

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Physiotherapists' Understanding of Functional and Mechanical Insufficiencies Contributing to Chronic Ankle Instability

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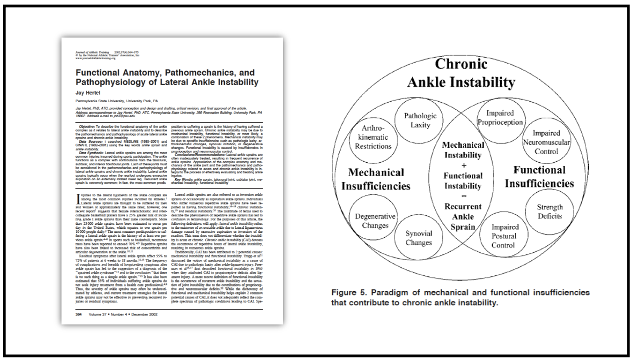

Functional Anatomy, Pathomechanics, and Pathophysiology of Lateral Ankle Instability

Jay Hertel

Figure 5. Paradigm of mechanical and functional insufficiencies that contribute to chronic ankle instability.

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If physiotherapists, in their role in managing CAI, are to adhere to the principals of evidence-based practice, it is important that they are fully aware of the insufficiencies that are associated with CAI.

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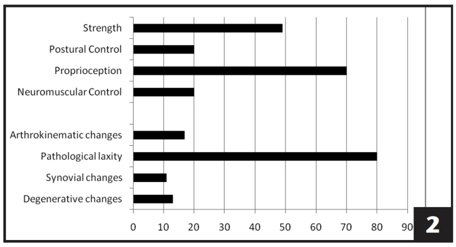

Figure 2. Identification of functional and mechanical insufficiencies. (Percent of participant responses.)

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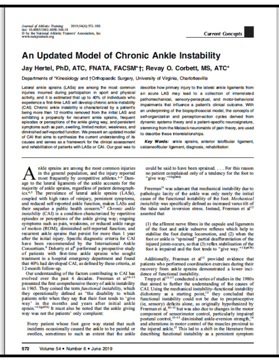

An Updated Model of Chronic Ankle Instability

Jay Hertel, PhD, ATC, FNATA, FACSM*†; Revay O. Corbett, MS, ATC*

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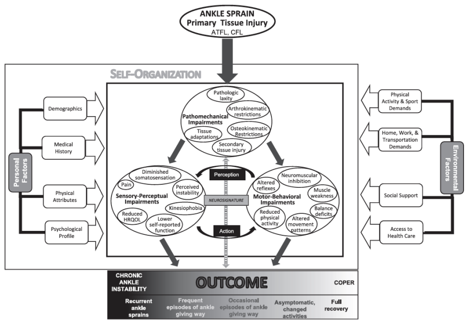

Figure 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

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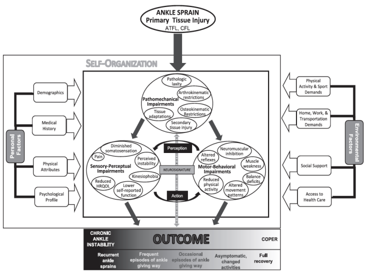

Figure 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

Pathologic Laxity
Loss of the structural integrity of the lateral ankle ligaments results in pathologic laxity of the talocrural joint and possibly the subtalar joint. This laxity represents the mechanical instability.

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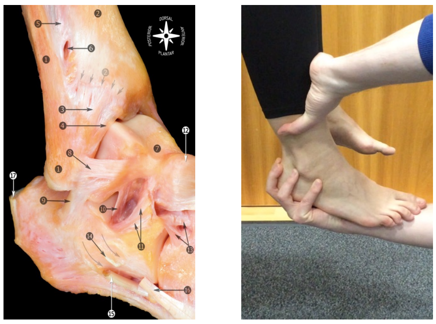
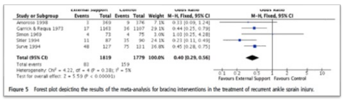


Golanó et al., 2010

36



There is strong evidence supporting the use of external support (in the form of taping or bracing) for reducing reinjury incidence and improving self-reported function.

There is moderate evidence suggesting bracing may be superior for self-reported function in comparison to taping.

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McDavid Ultralight 195 (McDavid Inc, Woodridge, Illinois)
McGuine et al, 2011

DonJoy Ankle Stabilizing Brace (DonJoy Inc, Vista, California)
McGuine et al, 2012

38

Wilkerson et al, 2005

39

Wilkerson et al, 2005

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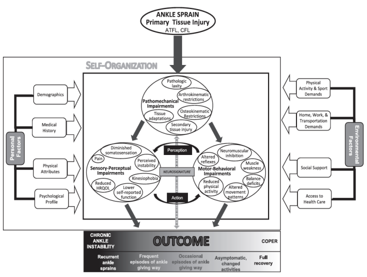

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Arthrokinematic Restrictions

In contrast to pathologic laxity, particular accessory joint motions may be limited after LAS or with CAI.

Anterior displaced talus
Anterior displaced fibula

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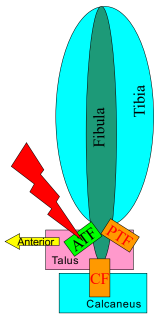

Hertel (2002)

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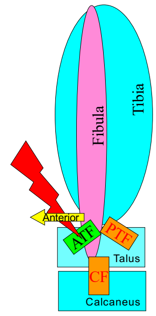

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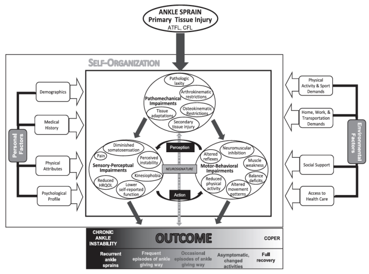

Figure 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

Osteokinematic Restrictions

Tight gastrocnemius
Tight soleus

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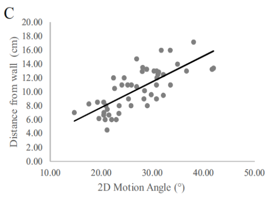

The weight-bearing lunge test may provide the best clinical assessment for evaluating dorsiflexion range of motion in patients with CAI.

Clinical integration of this measurement is further supported by strong evidence of validity and reliability.

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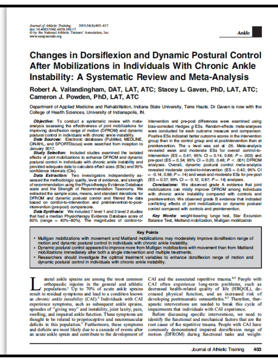

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Ankle

Changes in Dorsiflexion and Dynamic Postural Control After Mobilizations in Individuals With Chronic Ankle Instability: A Systematic Review and Meta-Analysis

Robert A. Vallandingham, DAT, LAT, ATC; Stacey L. Gaven, PhD, LAT, ATC; Cameron J. Powden, PhD, LAT, ATC

Department of Applied Medicine and Rehabilitation, Indiana State University, Terre Haute. Dr Gaven is now with the College of Health Sciences, University of Indianapolis, IN.

Objective: To conduct a systematic review with meta-analysis assessing the effectiveness of joint mobilizations for improving dorsiflexion range of motion (DFROM) and dynamic postural control in individuals with chronic ankle instability.

Data Sources: Electronic databases (PubMed, MEDLINE, CINAHL, and SPORTDiscus) were searched from inception to January 2017.

Study Selection: Included studies examined the isolated effects of joint mobilizations to enhance DFROM and dynamic postural control in individuals with chronic ankle instability and provided adequate data to calculate effect sizes (ESs) and 95% confidence intervals (CIs).

Data Extraction: Two investigators independently assessed the methodologic quality, level of evidence, and strength of recommendation using the Physiotherapy Evidence Database scale and the Strength of Recommendation Taxonomy. We extracted the sample sizes, means, and standard deviations for DFROM and dynamic postural control and filtered the data based on control-to-intervention and preintervention-to-postintervention (pre-post) comparisons.

Data Synthesis: We included 7 level 1 and 3 level 2 studies that had a median Physiotherapy Evidence Database score of 60% (range = 40%–80%). The magnitudes of control-to-intervention and pre-post differences were examined using bias-corrected Hedges g ESs. Random-effects meta-analyses were conducted for each outcome measure and comparison. Positive ESs indicated better outcome scores in the intervention group than in the control group and at postintervention than at preintervention. The α level was set at .05. Meta-analysis revealed weak and moderate ESs for overall control-to-intervention (ES = 0.41; 95% CI = 0.14, 0.68; P = .003) and pre-post (ES = 0.34; 95% CI = 0.20, 0.48; P < .001) DFROM analyses. Overall, dynamic postural control meta-analysis revealed moderate control-to-intervention (ES = 0.42; 95% CI = −0.14, 0.98; P = .14) and weak and moderate ESs for pre-post (ES = 0.37; 95% CI = −0.12, 0.87; P = .14) analyses.

Conclusions: We observed grade A evidence that joint mobilizations can mildly improve DFROM among individuals with chronic ankle instability compared with controls and preintervention. We observed grade B evidence that indicated conflicting effects of joint mobilizations on dynamic postural control compared with controls and preintervention.

Key Words: weight-bearing lunge test, Star Excursion Balance Test, Maitland mobilization, Mulligan mobilization

Key Points
- Mulligan mobilizations with movement and Maitland mobilizations may moderately improve dorsiflexion range of motion and dynamic postural control in individuals with chronic ankle instability.
- Dynamic postural control appeared to improve more from Mulligan mobilizations with movement than from Maitland mobilizations immediately after both a single intervention and multiple treatments.
- Researchers should investigate the optimal treatment variables to enhance dorsiflexion range of motion and dynamic postural control in individuals with chronic ankle instability.

Lateral ankle sprains are among the most common orthopaedic injuries in the general and athletic populations.[1] Up to 70% of acute ankle sprains result in residual symptoms and lead to a condition known as *chronic ankle instability* (CAI).[2] Individuals with CAI experience symptoms, such as subsequent ankle sprains, episodes of "giving way" and instability, joint laxity, pain, swelling, and impaired ankle function. These symptoms are thought to be related to proprioceptive and neuromuscular deficits in this population.[3] Furthermore, these symptoms and deficits are most likely due to a cascade of events after an acute ankle sprain and contribute to the development of CAI and the associated repetitive trauma.[4,5] People with CAI often experience long-term problems, such as decreased health-related quality of life (HRQOL), decreased physical function, and an increased risk of developing posttraumatic osteoarthritis.[6,7] Therefore, therapeutic interventions are needed to break this cycle of impairments that individuals with CAI experience.

Before discussing specific interventions, we need to identify the functional and mechanical factors that are the root cause of the repetitive trauma. People with CAI have commonly demonstrated impaired dorsiflexion range of motion (DFROM) during functional tasks and weight-

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Key Points
- Mulligan mobilizations with movement and Maitland mobilizations may moderately improve dorsiflexion range of motion and dynamic postural control in individuals with chronic ankle instability.
- Dynamic postural control appeared to improve more from Mulligan mobilizations with movement than from Maitland mobilizations immediately after both a single intervention and multiple treatments.
- Researchers should investigate the optimal treatment variables to enhance dorsiflexion range of motion and dynamic postural control in individuals with chronic ankle instability.

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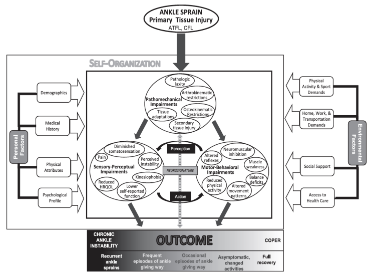


Figure 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

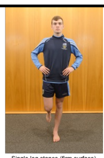
Balance Deficits

Static
Dynamic

48

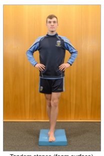
Double leg stance (firm surface)

Tandem stance (firm surface)

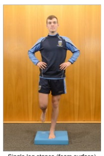


Single leg stance (firm surface)

Double leg stance (foam surface)



Tandem stance (foam surface)



Single leg stance (foam surface)

All tests are initiated and lasts for 20 seconds when the patients closes his/her eyes.

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Double leg stance (firm surface)

Errors

[1] Moving the hands off the hips
[2] Opening the eyes
[3] Step, stumble, or fall
[4] Abduction or flexion of the hip >30 degrees
[5] Lifting the forefoot or heel off the testing surface
[6] Remaining out of the proper test position for >5 seconds

50

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	Double leg stance (firm surface)	Tandem stance (firm surface)	Single leg stance (firm surface)	Double leg stance (foam surface)	Tandem stance (foam surface)	Single leg stance (foam surface)
Errors	0	2	5	2	5	10

Balance errors made by *Player A* as assessed via performance on the Balance Error Scoring System.

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No errors were made by *Player A* when completing the double leg stance (firm surface) task. Hence, this task will not challenge the sensorimotor system and its incorporation into a rehabilitation programme would be **redundant**.

Player A made 2 errors whilst completing the tandem stance (firm surface) task and the double leg stance (foam surface) task. This low number of errors would suggest that these tasks should only constitute **a minority component** (i.e., small percentage) of the total time devoted to postural balance exercises.

Player A made 5 errors whilst completing the single leg stance (firm surface) task and the tandem stance (foam surface) task. This is a substantial number of errors for each of these tasks and suggests that they are **appropriately challenging** the sensorimotor system; they are not so easy such that he can complete them with minimal errors, whilst they are not so difficult such that he cannot complete them at all. Therefore, it would be prudent to include these tasks as key exercises of the postural balance component of his rehabilitation programme.

Player A made 10 errors (i.e., the maximum number of errors) whilst completing the single leg stance (foam surface) task. This suggests that this task is **too challenging (at this time point)** for the sensorimotor system and should not be included as an initial exercise of the postural balance component of his rehabilitation programme.

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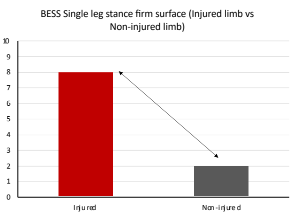

Concept of limb asymmetry

Applicable to:

[1] BESS Tandem stance (firm surface)

[2] BESS Single leg stance (firm surface)

[3] BESS Tandem stance (foam surface)

[4] BESS Single leg stance (foam surface)

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Clinical Tip #1:

Train the un-injured limb as well in the acute phase of injury


Clinical Biomechanics

Postural control strategies during single limb stance following acute lateral ankle sprain

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Clinical Tip #2:

'Unfreeze' the foot and ankle to help restore "ankle strategy"


Clinical Biomechanics

Postural control strategies during single limb stance following acute lateral ankle sprain

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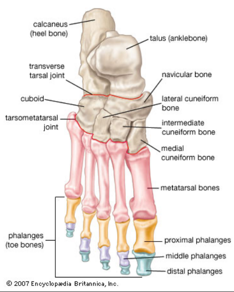
Rigid lever *vs.* mobile adapter



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Clinical Tip #3:

Ensure adequate hip strength


Lower Limb Interjoint Postural Coordination One Year after First-Time Lateral Ankle Sprain

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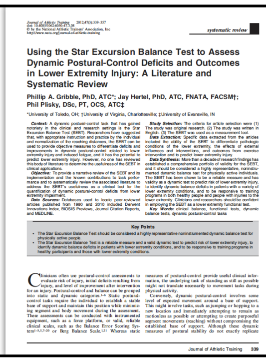
Using the Star Excursion Balance Test to Assess Dynamic Postural-Control Deficits and Outcomes in Lower Extremity Injury: A Literature and Systematic Review

Phillip A. Gribble, PhD, ATC*; Jay Hertel, PhD, ATC, FNATA, FACSM†; Phil Plisky, DSc, PT, OCS, ATC‡

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Start position | Anterior reach direction | Posterior-medial reach direction | Posterior-lateral reach direction

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Reach distance = $\left(\frac{distance\ reached\ (cm)}{leg\ length\ (cm)}\right) * 100$

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Composite reach distance = $\left(\frac{ANT\ distance\ reached\ (cm) + PM\ distance\ reached\ (cm) + PL\ distance\ reached\ (cm)}{3 * leg\ length\ (cm)}\right) * 100$

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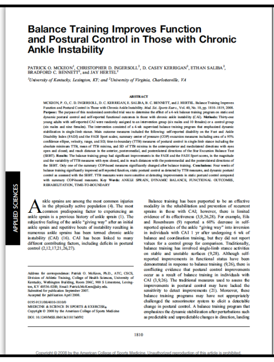

Balance Training Improves Function and Postural Control in Those with Chronic Ankle Instability

PATRICK O. MCKEON[1], CHRISTOPHER D. INGERSOLL[2], D. CASEY KERRIGAN[2], ETHAN SALIBA[2], BRADFORD C. BENNETT[2], and JAY HERTEL[2]

[1]University of Kentucky, Lexington, KY; and [2]University of Virginia, Charlottesville, VA

ABSTRACT

MCKEON, P. O., C. D. INGERSOLL, D. C. KERRIGAN, E. SALIBA, B. C. BENNETT, and J. HERTEL. Balance Training Improves Function and Postural Control in Those with Chronic Ankle Instability. *Med. Sci. Sports Exerc.*, Vol. 40, No. 10, pp. 1810–1819, 2008. **Purpose:** The purpose of this randomized controlled trial was to determine the effect of a 4-wk balance training program on static and dynamic postural control and self-reported functional outcomes in those with chronic ankle instability (CAI). **Methods:** Thirty-one young adults with self-reported CAI were randomly assigned to an intervention group (six males and 10 females) or a control group (six males and nine females). The intervention consisted of a 4-wk supervised balance training program that emphasized dynamic stabilization in single-limb stance. Main outcome measures included the following: self-reported disability on the Foot and Ankle Disability Index (FADI) and the FADI Sport scales; summary center of pressure (COP) excursion measures including area of a 95% confidence ellipse, velocity, range, and SD; time-to-boundary (TTB) measures of postural control in single-limb stance including the absolute minimum TTB, mean of TTB minima, and SD of TTB minima in the anteroposterior and mediolateral directions with eyes open and closed; and reach distance in the anterior, posteromedial, and posterolateral directions of the Star Excursion Balance Test (SEBT). **Results:** The balance training group had significant improvements in the FADI and the FADI Sport scores, in the magnitude and the variability of TTB measures with eyes closed, and in reach distances with the posteromedial and the posterolateral directions of the SEBT. Only one of the summary COP-based measures significantly changed after balance training. **Conclusions:** Four weeks of balance training significantly improved self-reported function, static postural control as detected by TTB measures, and dynamic postural control as assessed with the SEBT. TTB measures were more sensitive at detecting improvements in static postural control compared with summary COP-based measures. **Key Words:** ANKLE SPRAIN, DYNAMIC BALANCE, FUNCTIONAL OUTCOMES, REHABILITATION, TIME-TO-BOUNDARY

APPLIED SCIENCES

Ankle sprains are among the most common injuries in the physically active population (4). The most common predisposing factor to experiencing an ankle sprain is a previous history of ankle sprain (1). The subjective feeling of the ankle "giving way" after an initial ankle sprain and repetitive bouts of instability resulting in numerous ankle sprains has been termed chronic ankle instability (CAI) (16). CAI has been linked to many different contributing factors, including deficits in postural control (2,12,17,21,26,27).

Balance training has been purported to be an effective modality in the rehabilitation and prevention of recurrent sprains in those with CAI; however, there is limited evidence of its effectiveness (3,9,26,28). For example, Eils and Rosenbaum (9) reported a 60% decrease in self-reported episodes of the ankle "giving way" into inversion in individuals with CAI 1 yr after undergoing 6 wk of balance and coordination training, but they did not report values for a control group for comparison. Traditionally, balance training has involved single-limb stance activities on stable and unstable surfaces (9,28). Although self-reported improvements in functional status have been demonstrated in response to balance training (9,26), there is conflicting evidence that postural control improvements occur as a result of balance training in individuals with CAI (3,9,26). The traditional measures used to assess the improvements in postural control may have lacked the sensitivity to detect improvements (21). Moreover, these balance training programs may have not appropriately challenged the sensorimotor system to elicit a detectable change in postural control. A balance training program that emphasizes the dynamic stabilization after perturbations such as predictable and unpredictable changes in direction, landing

Address for correspondence: Patrick O. McKeon, Ph.D., ATC, CSCS, Division of Athletic Training, College of Health Sciences, University of Kentucky, Wethington Building, Room 206C, 900 S Limestone, Lexington, KY 40536-0200; Email: Patrick.McKeon@uky.edu.
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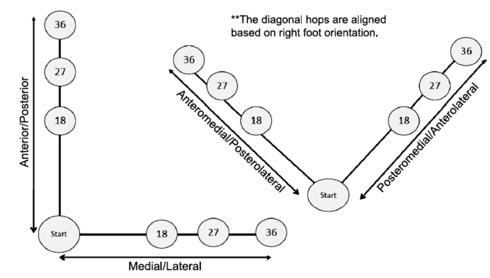

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Single-Limb Hops to Stabilization
(10 Repetitions per Direction)

Subject performed 10 hops in each direction. Each repetition consisted of a hop from the starting position to the target position (18, 27, or 36 inches). After stabilizing balance in a single-limb stance, participants hopped in the exact opposite direction back to the starting position and stabilized in the single-limb stance.

Four directions of hops: 1) anterior/posterior, 2) medial/lateral, 3) anterolateral/posteromedial, and 4) anteromedial/posterolateral.
Participants were not able to move to the next level in each category until they demonstrated 10 repetitions error-free.

Errors were determined on the basis of the following:
a. Touching down with opposite limb
b. Excessive trunk motion (>30 degree lateral flexion)
c. Removal of hands from hips during hands on hips activities
d. Bracing the non-stance limb against the stance limb
e. Missing the target

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Hop to Stabilization and Reach (Five Repetitions)

Combined with the mentioned exercises, however, after stabilization in the single-limb stance, participants had to reach back to the starting position. Repetitions were counted in the same manner mentioned previously. Participants hopped, stabilized, and reached back to the starting position. Then they hopped back to the starting position and reached to the target position.

Participants were not able to advance to the next level in each direction until they demonstrated five repetitions error-free.

Errors were determined on the basis of the following:
a. All errors associated with hop to stabilization
b. Using the reaching leg for a substantial amount of support during reaching component

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TABLE 1. Pretest and posttest scores on the FADI and the FADI Sport for the balance training and control groups.

	Balance Training Group		Control Group			
	Pretest	Posttest	Pretest	Posttest	Group Effect	Time Effect
FADI, %	85.5 ± 8.4	93.7 ± 7.4*,†	82.9 ± 7.4	81.40 ± 18.1	0.68	0.98
FADI Sport, %	69.9 ± 12.1	85.0 ± 14.4*,†	66.5 ± 9.8	66.3 ± 11.8	1.63	1.25

There was a significant group × time interaction for both instruments. There was no difference between groups at pretest, but there was a significant difference between posttest measures between groups and a significant difference in self-reported function at posttest for the balance training group, $P < 0.05$. Group effect sizes were calculated from posttest scores. Time effect sizes were calculated from the pretest and posttest measures of the balance training group.
* $P < 0.05$ for pretest to posttest comparisons within the balance training group.
†$P < 0.05$ for between-groups comparisons at posttest.

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TABLE 6. Pretest and posttest normalized reach distances on the SEBT.

	Balance Training Group		Control Group			
	Pretest	Posttest	Pretest	Posttest	Group Effect	Time Effect
Anterior reach	0.70 ± 0.10	0.67 ± 0.08	0.68 ± 0.06	0.67 ± 0.05	0	−0.38
PM reach	0.82 ± 0.14	0.91 ± 0.13*,†	0.81 ± 0.08	0.80 ± 0.06	1.83	0.64
PL reach	0.77 ± 0.15	0.87 ± 0.13*,†	0.76 ± 0.08	0.78 ± 0.09	1.0	0.67

There were significant group × time interactions for the PM and PL reaches. The balance training group reached significantly farther than their pretest measures and the posttest measures of the control group, $P < 0.05$. Group effect sizes were calculated from posttest scores. Time effect sizes were calculated from the pretest and posttest measures of the balance training group.
An effect size of zero was calculated when the comparison means were equal.
* $P < 0.05$ for pretest to posttest comparisons within the balance training group.
†$P < 0.05$ for between-groups comparisons at posttest.

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Diminished Somatosensation
Several domains of somatosensation have been noted to be impaired in patients with CAI.

Joint position sense
Threshold to movement detection
Force sense
Cutaneous sensation

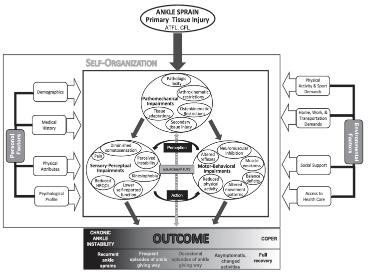

Figure 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

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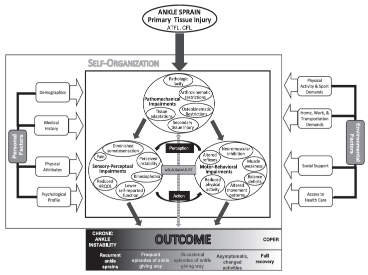

Figure 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

Altered Movement Patterns

Walking
Jogging
Running
Cutting
Landing

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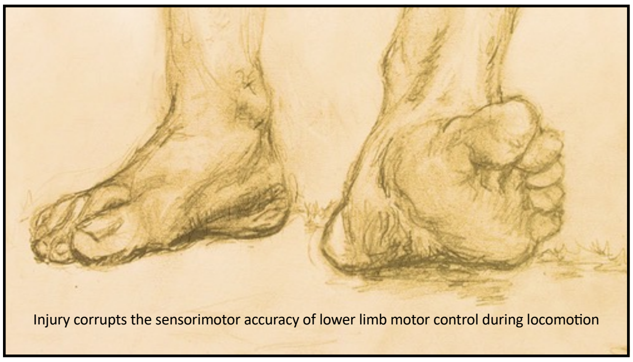

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Kinematics Analysis of Ankle Inversion Ligamentous Sprain Injuries in Sports

Five Cases From Televised Tennis Competitions

Daniel Tik-Pui Fong,*† PhD, Sophia Chui-Wai Ha,† MA, Kam-Ming Mok,† MPhil, Christie Wing-Long Chan,‡ and Kai-Ming Chan,† MBBS
Investigation performed at Department of Orthopaedics and Traumatology, Prince of Wales Hospital, Faculty of Medicine, The Chinese University of Hong Kong, China

Background: Ankle ligamentous sprain is common in sports. The most direct way to study the mechanism quantitatively is to study real injury cases; however, it is unethical and impractical to produce an injury in the laboratory. A recently developed, model-based image-matching motion analysis technique allows quantitative analysis of real injury incidents captured in televised events and gives important knowledge for the development of injury prevention protocols and equipment. To date, there have been only 4 reported cases, and there is a need to conduct more studies for a better understanding of the mechanism of ankle ligamentous sprain injury.
Purpose: This study presents 5 cases in tennis and a comparison with 4 previous cases for a better understanding of the mechanism of ankle ligamentous sprain injury.
Study Design: Case series; level of evidence, 4.
Methods: Five sets of videos showing ankle sprain injuries in televised tennis competition with 2 camera views were collected. The videos were transformed, synchronized, and rendered to a 3-dimensional animation software. The dimensions of the tennis court in each case were obtained to build a virtual environment, and a skeleton model scaled to the injured athlete's height was used for the skeleton matching. Foot strike was determined visually, and the profiles of the ankle joint kinematics were individually presented.
Results: There was a pattern of sudden inversion and internal rotation at the ankle joint, with the peak values ranging from 48°-126° and 35°-99°, respectively. In the sagittal plane, the ankle joint fluctuated between plantar flexion and dorsiflexion within the first 0.50 seconds after foot strike. The peak inversion velocity ranged from 509 to 1488 deg/sec.
Conclusion: Internal rotation at the ankle joint could be one of the causes of ankle inversion sprain injury, with a slightly inverted ankle joint orientation at landing as the inciting event. To prevent the foot from rolling over the edge to cause a sprain injury, tennis players who do lots of sideward cutting motions should try to land with a neutral ankle orientation and keep the center of pressure from shifting laterally.
Keywords: injury biomechanics; injury mechanism; sports trauma; ankle supination injury

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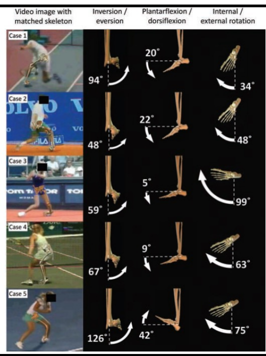

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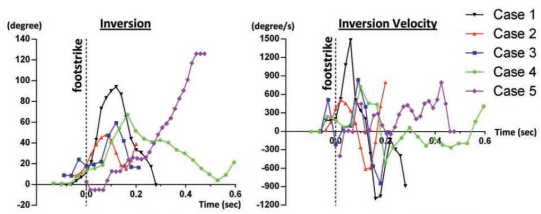

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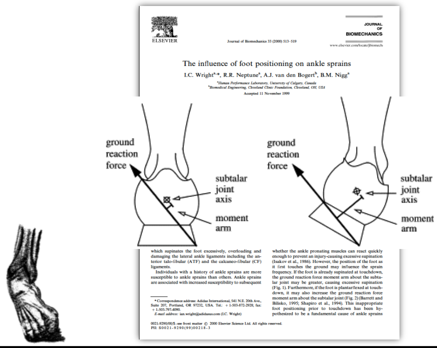

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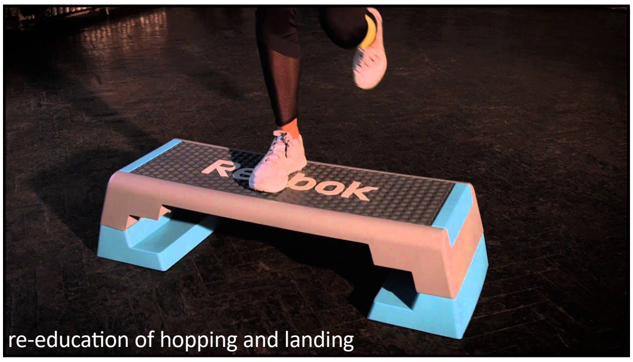

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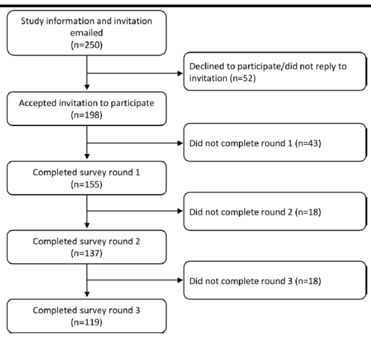

Figure 1 Participant flow through study.

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Table 2 Consensus on assessment items that should be included in the return to sport decision after an acute lateral ankle sprain, indicating the round of inclusion and level of agreement

Assessment item to be included	Round (1–3)	Agreement (%)
Sport-specific activities	1	98
Pain severity during sport participation	1	93
Ankle range of motion	1	90
Ankle muscle strength	1	87
Hopping	1	87
Agility	1	87
Completion of a full training session	3	87
Jumping	1	84
Pain severity over the last 24 hours	1	81
Perceived ankle reassurance/confidence	1	81
Proprioception	1	74
Perceived ankle stability	1	74
Psychological readiness	1	74
Ankle muscle endurance	1	73
Dynamic postural control/balance	1	73
Ankle (and lower limb) muscle power*	2	72

*Lower limb muscle power and ankle muscle power were initially presented to panellists as separate items, but 96% of panellists agreed that these items would be assessed together.

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Table 3 Consensus on assessment items that should not be included in the return to sport decision after an acute lateral ankle sprain, indicating the round of exclusion and level of agreement

Assessment item not to be included	Round (1–3)	Agreement (%)
Structural integrity of the ligaments on imaging	2	89
Pain severity over the last week	3	88
Pain severity on palpation	3	88
Health-related quality of life	2	85
Hip and knee muscle endurance	3	85
Ankle muscle length	3	85
The Functional Movement Screen	2	84
Aerobic fitness	3	84
Anaerobic fitness	3	82
Ligamentous laxity	2	81
Ankle joint arthrokinematics	3	78
Ankle muscle reaction time	3	76
Acute:chronic workload	3	76
Lower limb and/or trunk kinematics	2	75
Hip and knee muscle strength	3	74
Foot biomechanics	2	74
Straight-line running speed	3	72
Patient-reported foot and ankle function (using questionnaires such as the Foot and Ankle Ability Measure[34] or Foot and Ankle Outcome Score[35])	3	70

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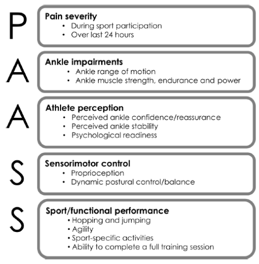

Figure 2 Return to sport domains (PAASS) and mapping of the agreed-upon return to sport items to domains (in nominal ordered list). Ability to complete a full training session reached consensus in round 3 and was not presented to panellists for their agreement on mapping. This placement was agreed on by the author group. Panellists agreed that ankle muscle strength would be assessed using tests of total lower limb muscle strength.

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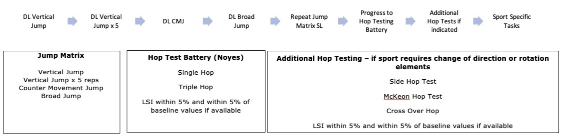

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Ankle Conditioning Circuit – linked to PAASS

	Exercise	Time	PAASS Framework
#1	Squat jumps in-and-out	20 seconds	Ankle Impairments
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#2	Single-leg stance on Airex Balance Pad	20 seconds	Sensorimotor Control
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#3	Switch lunges	20 seconds	Ankle Impairments
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#4	30cm lateral hops	20 seconds	Sport/functional Performance
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#5	Squat jumps single-leg land	20 seconds	Sensorimotor Control Sport/functional Performance
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#6	SEBT anterior reach	20 seconds	Sensorimotor Control
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#7	Skaters	20 seconds	Ankle Impairments
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#8	Reebok Step lateral hops	20 seconds	Sensorimotor Control Sport/functional Performance
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#9	Figure-8 hops	20 seconds	Sensorimotor Control
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?
#10	Reebok Step drop vertical jump with single-leg land	20 seconds	Sport/functional Performance
	REST	10 seconds	Pain?; Stability?; Confidence? Assurance?

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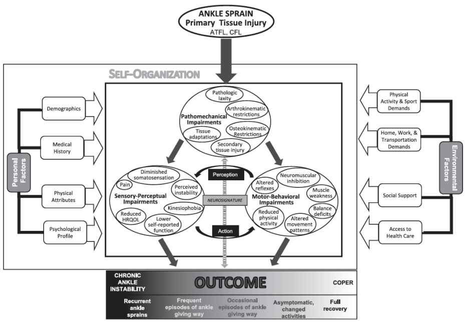

Figure 1. The updated model of chronic ankle instability (CAI). The outcome is determined at least 12 months after the initial ankle sprain. Abbreviations: ATFL, anterior talofibular ligament; CFL, calcaneofibular ligament; HRQOL, health-related quality of life.

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Professor Eamonn Delahunt

School of Public Health, Physiotherapy and Sports Science
University College Dublin, Dublin, Ireland

EMAIL: eamonn.delahunt@ucd.ie
TWITTER: @EamonnDelahunt

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