Lateral ankle sprains corrupt the sensorimotor accuracy of lower limb movement strategies: re-educating hopping and landing

Professor Eamonn Delahunt

Injury corrupts the sensorimotor accuracy of lower limb motor control during locomotion

Kinematics Analysis of Ankle Inversion Ligamentous Sprain Injuries in Sports

Five Cases From Televised Tennis Competitions

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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

Ankle ligamentous sprain is the most common injury in sports, and the majority clinically and qualitatively present with an inversion or supination mechanism.[9] Understanding the injury mechanism, preferably with biomechanics quantities, is a key component required for the development of injury prevention protocols and the design of protective equipment.[2] With the advance of sport biomechanics technique, numerous approaches have emerged for the quantitative understanding of injury mechanism.[13] Among different methods, the most direct way is to investigate real injury incidents; however, it is unethical and practically impossible to perform experiments in which test subjects are purposefully injured. In rare cases, accidents have unexpectedly occurred in a biomechanics laboratory with calibrated motion analysis equipment. Recently, there were 2 such reports on ankle inversion sprain injury with reported kinematics data.[10,12] In each study, the subject participated in a biomechanics test with a sideward cutting motion and accidentally sustained an inversion ankle sprain injury.

There are far more real injury incidents unintentionally captured during televised sports events than in the biomechanics laboratory; however, the environments of the sports venues are less calibrated or even not calibrated. The first ever real injury analysis during a sports event was published in 1977, which reported a human patellar

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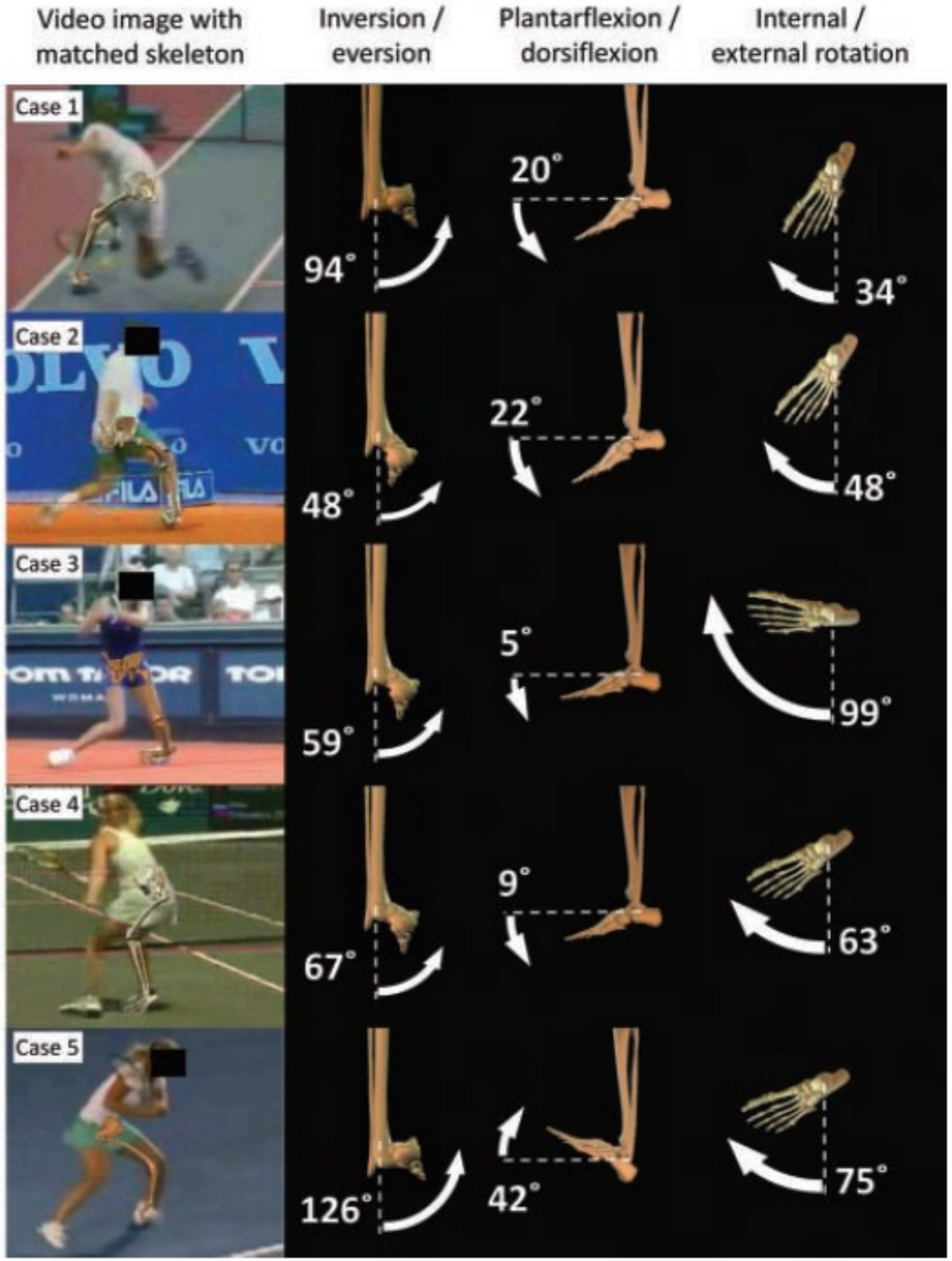
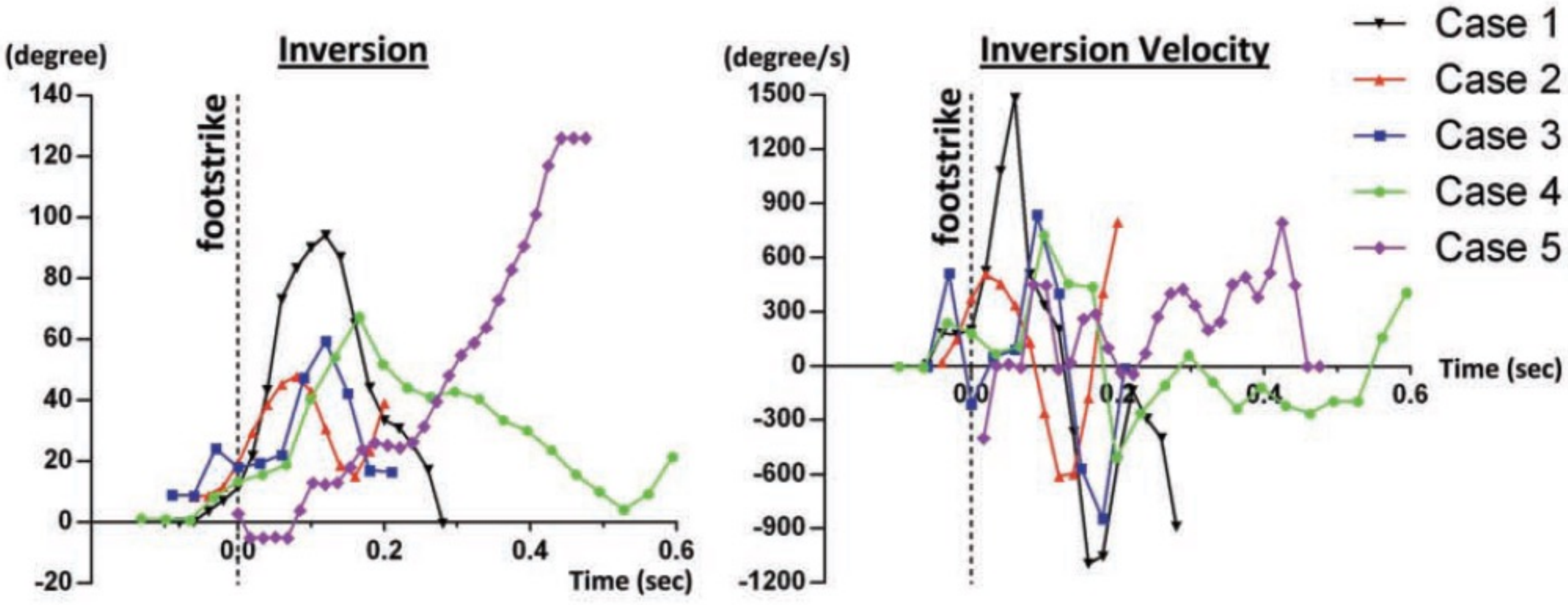

Video image with matched skeleton
Inversion / eversion
Plantarflexion / dorsiflexion
Internal / external rotation
Case 1
94°
20°
34°
Case 2
48°
22°
48°
Case 3
59°
5°
99°
Case 4
67°
9°
63°
Case 5
126°
42°
75°



Inversion
(degree)
140
120
100
80
60
40
20
0
-20
footstrike
0.0
0.2
0.4
0.6
Time (sec)
Inversion Velocity
(degree/s)
1500
1200
900
600
300
0
-300
-600
-900
-1200
footstrike
0.0
0.2
0.4
0.6
Time (sec)
Case 1
Case 2
Case 3
Case 4
Case 5

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The influence of foot positioning on ankle sprains

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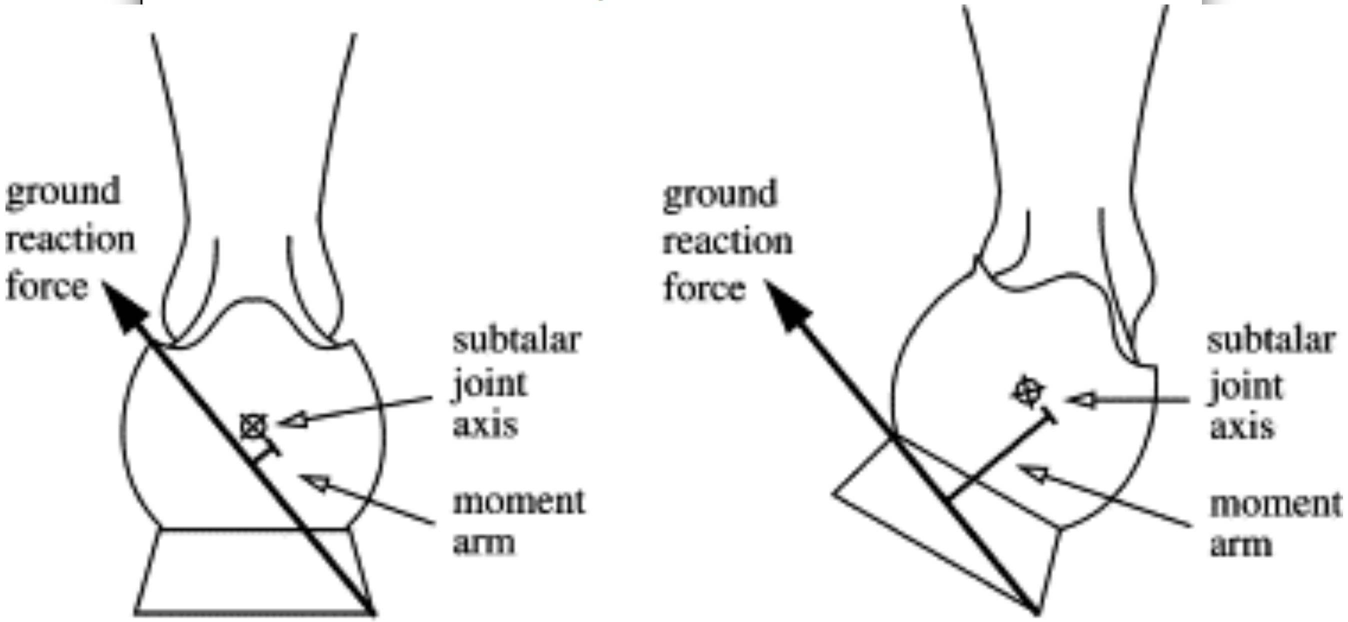

which supinates the foot excessively, overloading and damaging the lateral ankle ligaments including the anterior talo-fibular (ATF) and the calcaneo-fibular (CF) ligaments.

Individuals with a history of ankle sprains are more susceptible to ankle sprains than others. Ankle sprains are associated with increased susceptibility to subsequent

whether the ankle pronating muscles can react quickly enough to prevent an injury-causing excessive supination (Isakov et al., 1986). However, the position of the foot as it first touches the ground may influence the sprain frequency. If the foot is already supinated at touchdown, the ground reaction force moment arm about the subtalar joint may be greater, causing excessive supination (Fig. 1). Furthermore, if the foot is plantarflexed at touchdown, it may also increase the ground reaction force moment arm about the subtalar joint (Fig. 2) (Barrett and Bilisko, 1995; Shapiro et al., 1994). This inappropriate foot positioning prior to touchdown has been hypothesized to be a fundamental cause of ankle sprains

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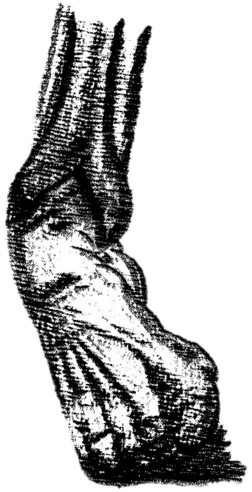
PII: S0021-9290(99)00218-3



Load Acceptance

This requires continuous monitoring to understand the ability of the ankle to manage with increasing load and movement complexity. Use of the ankle joint monitoring tools would be appropriate in conjunction with subjective athlete reporting and POMS.

QASL can be utilised at all phases if apparent deficits in neuromuscular control

Use of 3D Motion Capture has been verified for analysis of these movement qualities utilising inverse dynamics to calculate internal joint moments (Doherty et al, 2016).

Joint working with S&C to utilise ForeDecks and Optojump to quantify findings would be best practice

Load Acceptance tasks should be completed on an appropriate surface to the requirements of sport and in sport specific footwear as appropriate

Loading Progressions - Complexity of Task and Force Demands

DL Vertical Jump → DL Vertical Jump x 5 → DL CMJ → DL Broad Jump → Repeat Jump Matrix SL → Progress to Hop Testing Battery → Additional Hop Tests if indicated → Sport Specific Tasks

Jump Matrix

Vertical Jump
Vertical Jump x 5 reps
Counter Movement Jump
Broad Jump

Hop Test Battery (Noyes)

Single Hop

Triple Hop

LSI within 5% and within 5% of baseline values if available

Additional Hop Testing – if sport requires change of direction or rotation elements

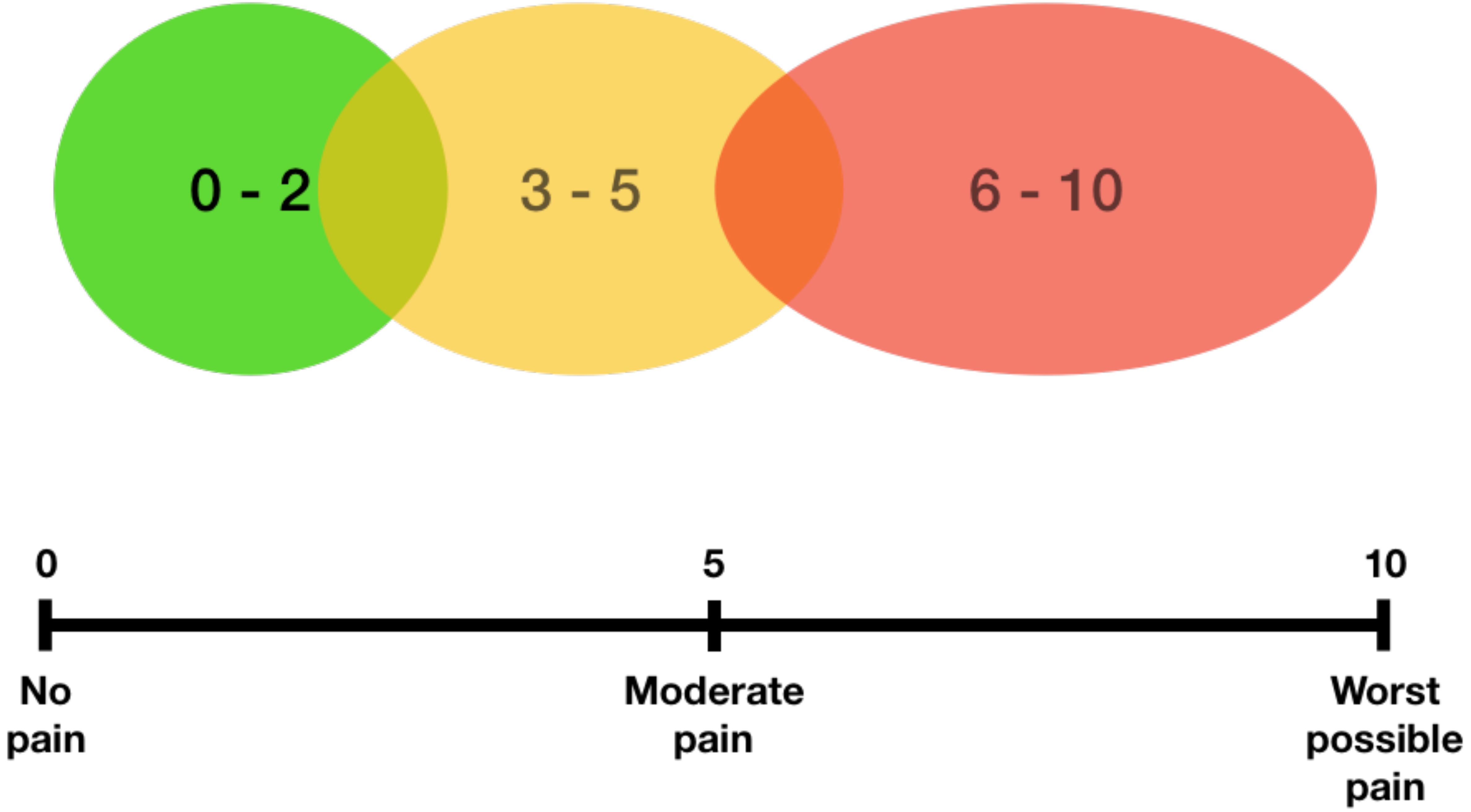
Side Hop Test

McKeon Hop Test

Cross Over Hop

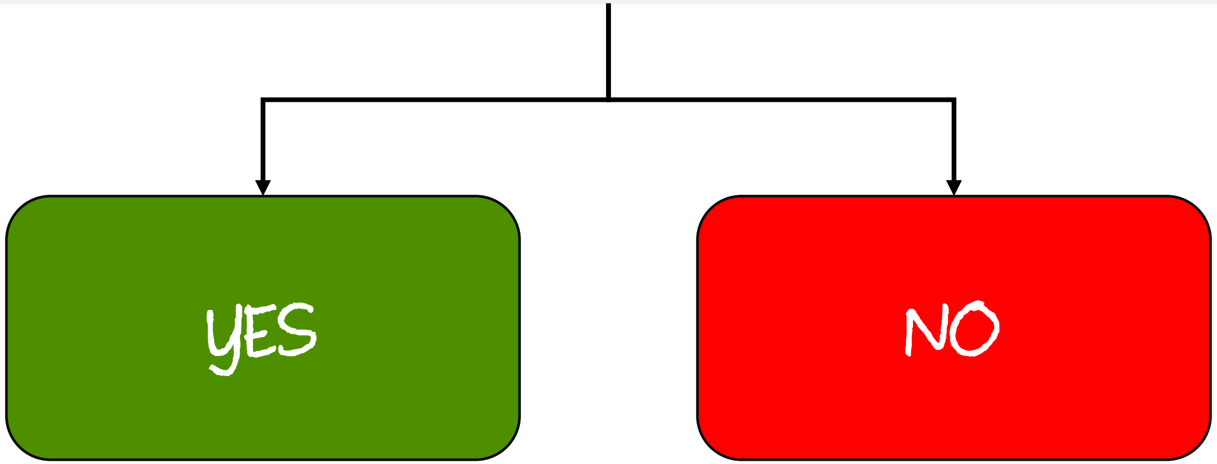
LSI within 5% and within 5% of baseline values if available

Figure 1



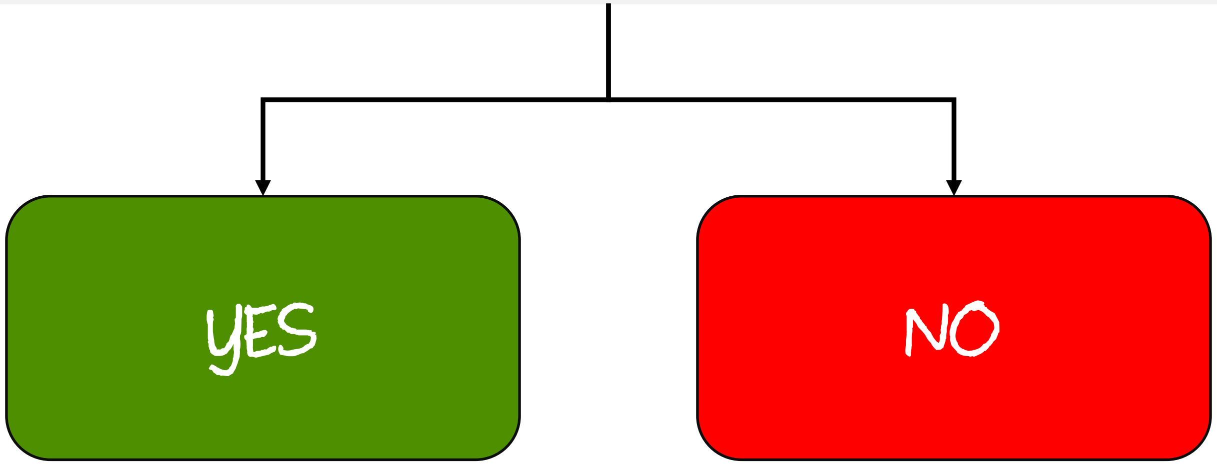
STABILITY

Did your ankle 'feel' steady and controlled during the performance of the activity/test?



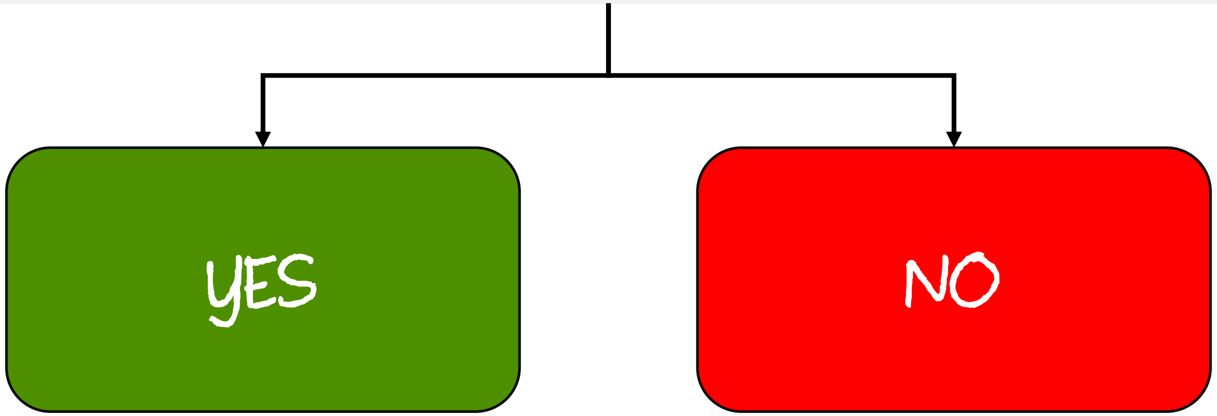
CONFIDENCE

Could you perform the test/activity to your expected level?



ASSURANCE

During the performance of the test/activity, did you think you were at risk of spraining your ankle?



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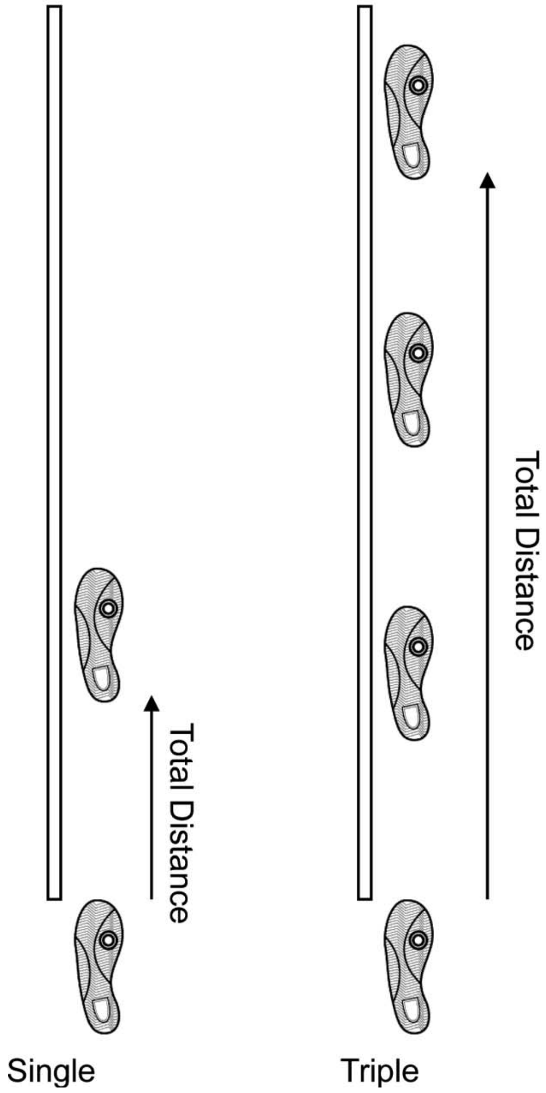
Side Hop Test

McKeon Hop Test

Cross Over Hop

LSI within 5% and within 5% of baseline values if available



Testing Procedure (Please inform subject of information below prior to testing)

- No warm-up
- Complete 4 trials of each hop test on each leg
- Up to 30 seconds rest between trials and 2 minutes between tests
- No restrictions to arm movement
- Each test starts with first toe of testing leg on start line
- Distance measured to rear of foot on final landing
- Landing position to be maintained for minimum of 3 seconds – **Advise participants of this**
- Unsuccessful hop = loss of balance, extra hop on landing or touching down either contralateral lower or upper extremity
- Calculate Limb Symmetry Index based on results

Single Hop

Instruction: *Hop forwards as far as possible along the line and land on the same leg*

Triple Hop

Instruction: *Hop forwards 3 times as far as possible along the line and land on the same leg*

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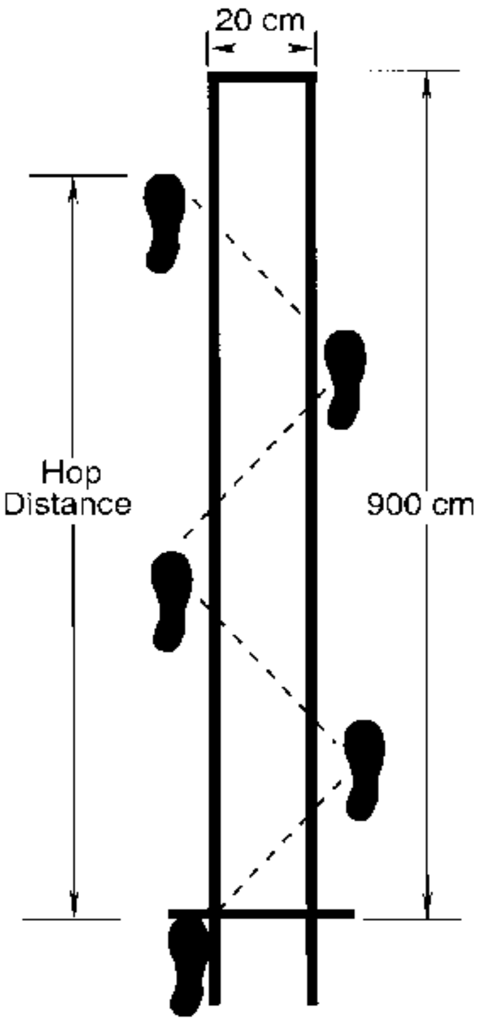


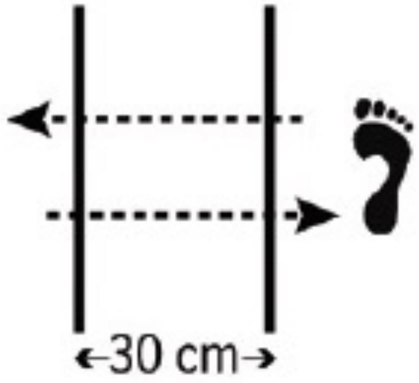
Equipment Required:
Tape Measure
Tape to mark floor
Recording Sheet

Surface: level non-slip surface could also be sport specific (e.g., on pitch)

Subject Footwear: Normal training footwear

Using the grid (two parallel lines 20cm apart extending at least 5m) the subject undertakes four consecutive hops without pause crossing the grid lines each time.

Cross Over Hop
Instruction: *Hop forwards and across the line 4 times as far as possible* (clarify with demo if required)



Equipment Required:
Tape Measure
Tape to mark floor
Recording Sheet
Stopwatch

Surface: level non-slip surface could also be sport specific (e.g., on pitch)

Subject Footwear: Normal training footwear

Testing Procedure:
From start point athlete hops laterally and back to start point. This equals 1 repetition.
Test requires 10 repetitions as quickly as possible
Time recorded and compared to baseline and contralateral limb
Suggest max of 2 trials

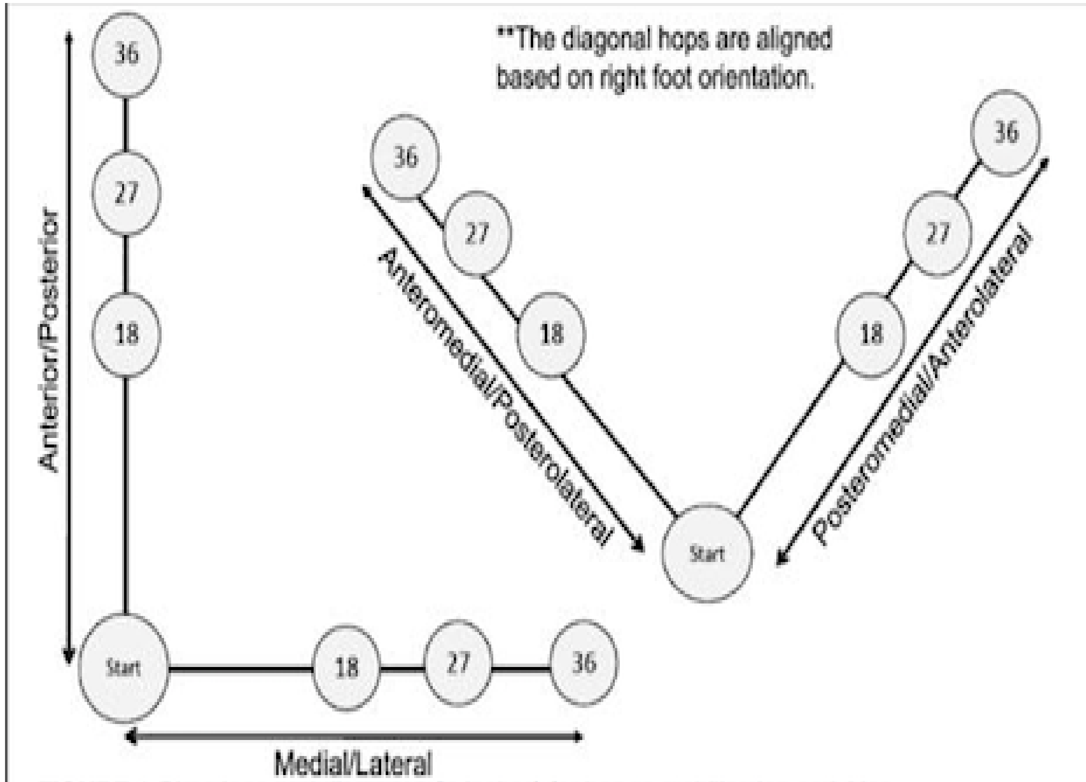


FIGURE 1-Directions and distances (in inches) for hop to stabilization activities.

Equipment Required:
Tape Measure
Tape to mark floor
Recording Sheet

Surface: level non-slip surface could also be sport specific (e.g.,) on pitch

Subject Footwear: Normal training footwear

Testing Procedure:
From start point hops to 18-inch marker and stabilize landing for minimum of 2 seconds
Must be able to complete 10 repetitions without error to progress to next level of difficulty
Completes testing in all 4 directions – as per diagram

QASL	Task: Single leg squat; Single leg step down; Single leg hop for distance	Left	Right
Arm strategy	Excessive arm movement to balance		
Trunk alignment	Leaning in any direction		
Pelvic plane	Loss of neutral pelvis position		
Single Leg Landing	Excessive noise-stiff leg landing		
Thigh motion	WB thigh moves into hip adduction		
	NWB thigh not held in neutral		
Knee position	Patella pointing towards 2nd toe (noticeable valgus)		
	Patella pointing past inside of foot (significant valgus)		
Steady stance	Touches down with NWB foot		
	Stance leg wobbles noticeably		
	Total		