Lower Extremity Functional Testing: Is my Athlete Ready to Return to Sport?

Brittney Braegelmann, DPT
John Corbo, DPT, SCS, CSCS
Rob Himmerick, DPT, SCS

Objectives

• Identify the components of a functional test
• Discuss the current literature regarding lower extremity functional testing
• Discuss how functional testing fits into the decision to return an athlete to sport
• Identify specific functional tests to utilize in a clinic setting
• Be able to implement a functional test in a clinic setting
• Be able to perform, instruct, and critique each functional test

Decision-Making Scheme

Environmental
Physical
Emotional
Return to Sport

Return to Sport

• Subjective questionnaires
• Clinical Exam
  – Full ROM, no effusion, stability
• Isokinetic/Strength Testing
• Functional Testing

SD Barber-Westin and FR Noyes, 2011
Return to Sport

• Low correlations:
  – Subjective measures
  – Functional performance
  – Isokinetic testing

• Combination of subjective, clinical exam, and functional test


Imbalances and Re-Injury

• Biomechanical differences still exist
  – Drop vertical jump (Paterno et al 2010)
  – Single leg vertical hop (Myer et al 2012)
  – Single leg hop (Orishimo et al 2010)

• Strength differences still exist
  – Quadriceps strength (Schmitt et al 2012)
  – Hamstring strength (Braegelmann)
  – Isokinetic studies

What is a Functional Test?

• Mimics functional/sport movements
  – Strength
  – Agility
  – Power
  – Balance
  – Neuromuscular Control

• Assessment of the patient’s current functional status

Why Functional Tests?

• Objective, quantitative
• Clinicians gain confidence in their recommendations
• Decrease re-injury risk for athlete
Who Gets a Functional Test?

- s/p ACL ligamentous reconstruction (Noyes et al. 1991)
- s/p other knee surgeries
- s/p hip arthroscopies (Halcrow)
- Copers vs. non-copers (Fitzgerald et al. 2000)
- Patellofemoral Pain Syndrome (Loudon et al. 2002)
- Chronic ankle instability (Caffrey 2009)
- Normal, healthy athletes (Corbo, Monson)

Single Leg Hops Testing

Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture

Frank R. Noyes, MD, Sue D. Barber,* and Robert E. Mangine, MEd, LPT, ATC

From the Cincinnati Orthopaedic Center and the Deaconess Hospital, Cincinnati, Ohio

- 67 ACL-deficient subjects
- Single leg hop
- Triple hop
- Crossover hop
- 6-m timed hop
Limb Symmetry Index

- Distance hops:
  - \( \frac{\text{Mean Involved}}{\text{Mean Uninvolved}} \times 100\% = \text{LSI} \)
- Timed hop:
  - \( \frac{\text{Mean Uninvolved}}{\text{Mean Involved}} \times 100\% = \text{LSI} \)
- Per Noyes, abnormal LSI = < 85%

Reliability of Hops Testing in Normal Subjects

<table>
<thead>
<tr>
<th></th>
<th>ICC</th>
<th>SEM (+/-)</th>
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<tbody>
<tr>
<td>Single hop (cm)</td>
<td>0.96</td>
<td>4.56</td>
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<tr>
<td>Triple hop (cm)</td>
<td>0.95</td>
<td>15.44</td>
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<tr>
<td>Timed hop (seconds)</td>
<td>0.66</td>
<td>0.13</td>
</tr>
<tr>
<td>Cross-over hop (cm)</td>
<td>0.96</td>
<td>15.95</td>
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Reliability of Lower Extremity Functional Performance Tests

- 20 non-injured subjects (5 male, 15 female)
- Retested 48 hours later
Reliability of Hops Testing s/p ACLR

<table>
<thead>
<tr>
<th></th>
<th>ICC</th>
<th>SEM (+/-)</th>
<th>MDC (+/-)</th>
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<tbody>
<tr>
<td>Single hop</td>
<td>0.92</td>
<td>3.49</td>
<td>8.09</td>
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<tr>
<td>Timed hop</td>
<td>0.82</td>
<td>5.59</td>
<td>12.96</td>
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<td>Triple hop</td>
<td>0.88</td>
<td>4.32</td>
<td>10.02</td>
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<tr>
<td>Crossover hop</td>
<td>0.84</td>
<td>5.28</td>
<td>12.25</td>
</tr>
<tr>
<td>Overall</td>
<td>0.93</td>
<td>3.04</td>
<td>7.05</td>
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**RECOMMEND 90% LIMB SYMMETRY INDEX**

Necessity of Single Leg Assessment

- Double limb and modified double limb tests did not show any differences between groups
- 3 hopping tests sensitive enough to find limb asymmetries
  - Single leg hop for distance
  - Crossover hop for distance
  - Triple hop for distance
- Uninvolved limb may still mask deficits of involved limb during modified double limb tests
**Single-legged Hop Tests as Predictors of Self-reported Knee Function After Anterior Cruciate Ligament Reconstruction**

**The Delaware-Oslo ACL Cohort Study**

David Logersttoo, PT, PhD, MPT, SCS, Hogs Grindem, PT, MSc, Andrew Lynch, PT, PhD, DPT, Ingrid Etten, PT, PhD, Lars Engelbrechten, MD, PhD, May Arna Risberg, PT, PhD, Michael J. Axe, MD, and Linn Snyder-Mackler, PT, ScD, SCS, ATC, FAPTA. Investigation performed at University of Delaware Physical Therapy Clinic, Newark, Delaware, and Hjelp24 Norwegian Sports Medicine Clinic (Hjelp24 NMF), Ullevaal, Oslo, Norway

- 85 subjects s/p ACLR
- Participated in 10 pre-op rehab sessions, then did pre-op hops tests
- @ 6 months performed hops tests
- @ 1 year completed the IKDC 2000

**Hops Tests as Predictors of Function**

- Pre-op scores did not predict self-reported function @ 1 year
- Crossover hop and 6-m timed hop were strongest predictors of self-reported knee function
- Timed hop most indicative of below normal function
  - Specificity = 0.90
  - Cross-over most indicative of normal function
  - Sensitivity = 0.88

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>+ LR</th>
<th>- LR</th>
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<tr>
<td>Single hop</td>
<td>0.53</td>
<td>0.72</td>
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<td>Triple hop</td>
<td>0.77</td>
<td>0.46</td>
<td>1.41</td>
<td>0.52</td>
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<tr>
<td>6-m timed hop</td>
<td>0.53</td>
<td><strong>0.90</strong></td>
<td><strong>5.14</strong></td>
<td>0.53</td>
</tr>
</tbody>
</table>

**Hops Tests as Predictors of Function**

- Patients with knee function below normal ranges:
  - 5 times more likely of having a 6-m timed hop LSI < 88%
- Patients with knee function above normal ranges
  - 4 times more likely to have a crossover hop LSI > 95%
Step Tests

30 healthy subjects (19 M, 11 F)
19-58 years old
Surface EMG collected during 9 exercises
- Lateral step-up
  - VMO (85%)
  - Glute med (43%)
  - Glute max (29%)

40 male volunteers, > 18 years old
6 assessors
2 testing sessions, 5 weeks apart
Lateral step down
  - upright trunk, no rotation or lateral flexion
  - contralateral LE unsupported with hip slightly flexed and knee extended
Inter-rater reliability = 0.39
Intra-rater reliability = 0.49

Step-Down Assessment

4 point visual scale
- Excellent: no deviation from neutral alignment
- A small magnitude (single movement out of neutral alignment) or barely observable movement out of a neutral position and/or low frequency of segmental oscillation (multiple movements out of the neutral alignment)
- A moderate or marked movement out of a neutral position and/or moderate-frequency segmental oscillation
- Excessive or severe magnitude of movement out of a neutral position and/or high-frequency segmental oscillation

Chmielewski et al, 2007
Measures of Range of Motion and Strength Among Healthy Women With Differing Quality of Lower Extremity Movement During the Lateral Step-Down Test

- 29 healthy women
- Lateral step-down to 60 degree of knee flexion
- 5 consecutive reps performed
- 2 assessors

**Step-Down Assessment**

- Quality assessed by 6 point scale
  - Arm strategy: removal of hand off the waist – 1 point
  - Trunk alignment: leaning in any direction – 1 point
  - Pelvis plane: loss of horizontal plane – 1 point
  - Knee position: tibial tuberosity medial to second toe – 1 point. Tibial tuberosity medial to medial border of foot – 2 points
  - Steady stance: subject stepped down on non-tested limb, or foot wavered from side-to-side – 1 point
- 0-1 = “good”, 2-3 = “moderate”, 4-5 = “poor”

**Reliability of Step-Down**

- Inter-rater reliability = 0.59
- Percent agreement = 83%

**Strength and ROM Influences**

- Tested
  - Strength: hip ABD, ER
  - ROM: weightbearing ankle DF and prone DF
- Only significant finding = decreased ankle DF led to a moderate quality of movement

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Piva et al, 2006
Retro Step-up and Strength

- Holm J, EA Arendt, J Agel, unpublished 2009
- 156 functional tests and isokinetic tests compared in 131 patients s/p BTB ACLR

<table>
<thead>
<tr>
<th>deg/sec</th>
<th>120 quad</th>
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<th>240 quad</th>
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<td>0.43</td>
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<table>
<thead>
<tr>
<th>deg/sec</th>
<th>120 ham</th>
<th>180 ham</th>
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</thead>
<tbody>
<tr>
<td>Retro step</td>
<td>0.32</td>
<td>0.25</td>
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</table>

P < 0.01

Retro Step-up and Strength

- Low to moderate correlations between retro step-up and quadriceps/hamstring strength

Core Strength Testing

- 30 healthy subjects (19 M, 11 F)
- 19-58 years old
- Surface EMG collected during 9 exercises

Electromyographic Analysis of Core Trunk, Hip, and Thigh Muscles During 9 Rehabilitation Exercises

- 30 healthy subjects (19 M, 11 F)
- 19-58 years old
- Surface EMG collected during 9 exercises
Electromyographic Analysis of Transversus Abdominis and Lumbar Multifidus Using Wire Electrodes During Lumbar Stabilization Exercises

- 9 healthy men
- Fine-wire electrodes in TrA and lumbar multifidus
- Surface on rectus abdominus, external obliques and erector spinae

Muscle Activation in Core Strength Testing

- Prone plank: external obliques (47%), rectus abdominus (43%), TrA (15%)
- Side plank: glute med (74%), external obliques (69%), lumbar multifidus (42%), longissimus thoracis (40%), rectus abdominus (34%), external obliques (20-80%), TrA (15-35%)
- Single leg bridge: multifidus contralateral to stabilization (40-65%), erector spinae (30-45%), TrA contralateral to stabilization (20%)

Core Stability: Inter- and Intraobserver Reliability of 6 Clinical Tests

- 40 male volunteers, > 18 years old
- 6 assessors
- 2 testing sessions, 5 weeks apart
- Prone plank
  - prone, supported by underarms with arms directly under shoulder and toes under feet
  - Straight line from head to toe for 10 seconds
- Inter-rater reliability = 0.36, intra-rater reliability = 0.21

Core Strength and Sports Performance

- 40 male volunteers, > 18 years old
- 6 assessors
- 2 testing sessions, 5 weeks apart
- Prone plank
  - prone, supported by underarms with arms directly under shoulder and toes under feet
  - Straight line from head to toe for 10 seconds
- Inter-rater reliability = 0.36, intra-rater reliability = 0.21
Deficits in Neuromuscular Control of the Trunk Predict Knee Injury Risk

A Prospective Biomechanical-Epidemiologic Study

Bohdanna T. Zazulak,‡‡‡ DPT, MS, OCS, Timothy E. Hewett,§§§ PhD, FACSM, N. Peter Reeves,$ MSc, Barry Goldberg,⊥ MD, and Jacek Cholewicki,∥ PhD

• 277 collegiate athletes (137 M, 140 F)
• Prospective study of core proprioception
• Decreased core proprioception found in women with knee injuries and meniscal/ligamentous injuries
  — Sensitivity = 90%, Specificity = 56%

Core Strength and Performance

<table>
<thead>
<tr>
<th></th>
<th>R sided plank</th>
<th>L sided plank</th>
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<tr>
<td>Single leg squat</td>
<td>0.495</td>
<td>0.498</td>
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<tr>
<td>T-run</td>
<td>0.383</td>
<td>0.448</td>
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</table>

Relationship Between Core Stability, Functional Movement, and Performance

Tomoko Oida, Kellee C. Huxel, and Thomas W. Nesser
Exercise Physiology Laboratory, Athletic Training Department, Indiana State University, Terre Haute, Indiana

• 28 healthy individuals, recreational athletes
• Lateral plank held for endurance
• Compared to other performance tests
  — FMS
  — Single leg squat
  — T-run
  — BOMB

Does Core Strength Training Influence Running Kinetics, Lower-Extremity Stability, and 5000-M Performance in Runners?

Kimitake Sato and Monique Moreha
Department of Sport and Exercise Sciences, Barry University, Miami Shores, Florida

• 28 healthy adults competitive and recreational runners who were heel-strikers (10 M, 18 F)
• Randomized into control and core stability training groups
• Tests
  — SEBT (ant, lat, post)
  — 5000-m run on outdoor track
  — Core strength by Sahrmann test

This information is the property of B Braegelmann, J Corbo, and R Himmerick and should not be copied or otherwise used without express written permission of the author
Core Strength Training

• 5 exercises 4 times/week for 6 weeks
• Increasing sets and reps over the 6 week period
  – Abdominal crunch on stability ball
  – Back extension on stability ball
  – Supine alt UE/LE lift
  – Hip raise on stability ball
  – Russian twist on ball

Core Strength and Performance

• Core strength training group had faster 5000-m run
• No change in kinetics or SEBT scores

Proprioception and Dynamic Stability

• Dynamic stability of an athlete depends on accurate sensory input and appropriate motor responses, neuromuscular control, to meet the demands of rapid changes in trunk position during cutting, stopping, landing and response to internal and external forces

Proprioception and Dynamic Stability

• Proprioceptive deficits in the body’s core may contribute to decreased neuromuscular control of the lower extremity, which may lead to injury.
Deficits in Neuromuscular Control of the Trunk Predict Knee Injury Risk

A Prospective Biomechanical-Epidemiologic Study

Bohdanna T. Zazulak,PT, MS, OCS, Timothy E. Hewett,PhD, FACSM, N. Peter Reeves,MSc, Barry Goldberg,MD, and Jacek Cholewicki,PhD

• AJSM. 2007;35(7):1123-1130

Purpose

– To identify potential neuromuscular factors related to core stability that predispose athletes to knee injuries

Deficits in NM control

• Subjects sat in wooden apparatus
  – Restricted pelvic but not upper body movement
• Cable attached to harness and released
• Sensor at T5 recorded trunk motion

Deficits in NM control

• Cohort Study

• 277 collegiate athletes
  – 140 female
  – 137 male

• Prospectively tested for trunk displacement after a sudden force release

Results

– 25 athletes sustained knee injuries over 3-year period
  • 11 female, 14 male
– Trunk displacement greater in athletes with knee, ligament, and ACL injuries than uninjured athletes
– Logistic regression model
  • Trunk displacements, proprioception, and LBP
  • Predicted injury
    – All athletes = 91% sensitivity, 63% specificity
    – Females: 84%, 89%, and 91% accuracy
Assessed relationship between single leg balance, modified Balance Error Scoring System, and modified Star Excursion Balance Test

Postural Control

• Results
  – Significant Associations
    • SLB and mBESS
    • mBESS and mSEBT
  – SLB and mSEBT
    • Variability in one not explained by the other
  – Reliability
    • SEBT has excellent test-retest and intertester

Star Excursion Balance Test

• Used to challenge and assess dynamic balance and postural control as a subject balances on one limb and performs a series of reaching tasks with the opposite limb

SEBT Performance

• SEBT Grid consists of 8 lines extending out at 45 deg angles from each other
SEBT Performance

- Single leg stance in middle of Grid
  - Test limb
- Reach with opposite leg along each line

SEBT Reliability

  - High Intratester and Intertester Reliability
  - Range
    - 0.85 to 0.96

Simplifying the Star Excursion Balance Test: Analyses of Subjects With and Without Chronic Ankle Instability

Original research
Between-session reliability of the star excursion balance test
Allan G. Munro\(^1\), Lee C. Herrington

Physical Therapy in Sport (2010)
- Test-retest reliability = 0.84 – 0.92
- Standard error or measurement = 2.21 – 2.94%
- Smallest detectable difference = 6.13 – 8.15%
SEBT and CAI

- 48 subjects with CAI
  - Unilateral CAI
- 39 controls
- Results
  - Subjects with CAI reached significantly less on the anteromedial, medial, and posteromedial when balancing on involved limb compared to uninvolved limbs and side matched controls

SEBT and ACL injury

- 25 ACLD patients
  - 17 male, 8 female
  - 17 right, 8 left
- 25 matched controls
- ACLD patients
  - All non-contact injuries
  - 5 months to 2 years post injury
  - Injury confirmed
    - Clinical exam
    - MRI or arthroscopic examination
    - No concurrent ligament or meniscal injuries

A comparison of Star Excursion Balance Test reach distances between ACL deficient patients and asymptomatic controls
Lee Herrington, Julian Hatcher, Alison Hatcher, Michael Mcnicholas

- Purpose:
  - To determine if decrements in SEBT reach distance is associated with ACL deficiency
- Results
  - No significant difference between the ACLD limb and the uninjured limb of the patients for all directions (p>.05)
  - Significant Differences between ACLD and controls
    - Control group and ACLD limb
      - Anterior (p=.0032)
      - Lateral (p = .005)
      - Posteromedial (p=.0024)
      - Medial (p=.001)
    - Controls and uninjured limb of ACLD group
      - Medial (p=.001)
      - Lateral (p=.001)
SEBT and ACL injury

• Conclusion
  – Dynamic postural control seems to be affected by ACL injury
  – There may be a predisposing factor of poor postural control which may lead to ACL injury.

Rehab and SEBT

• Subjects = 20 uninjured female soccer players
  – 13 experimental
  – 7 control

• Methods:
  – Experimental group went through a neuromuscular training program
  – Controls = normal activity
  – SEBT was administered to all subjects prior and following

NMTP

• Biweekly for 8 weeks
  – Nonconsecutive days
• Subject to therapist ratio of 4:1
• 5 min warm-up on agility ladder
• 2 - 45 min increments of LE strengthening and core stability training
• 5 min cool-down of static and dynamic stretches
NMTP

- Exercise progressions were gradual
  - Progressed by adding exercises that increased lateral trunk perturbations
- Low volume initially for high intensity exercises until correct form was attained
- Volume increased when athlete could perform exercises with proper form
- Progressed from stable to unstable surfaces
- External perturbations and unanticipated movement to the base of support

Results

- Pre-training composite scores
  - No significant side to side difference within subjects or between groups
- Post-training
  - Significant increase (103%) in the composite scores of the training group (p<.05)
  - No change in the control group.

SEBT as Injury Predictor

- Subjects
  - 235 athletes
    - 130 male
    - 105 female
- Tested SEBT in Preseason
- Coach and ATC recorded injuries during the season

Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High School Basketball Players

- Prospective Cohort Study
- 2004 Basketball season
SEBT as Injury Predictor

• Results
  – Reliability
    • SEBT = 0.82–0.87
    • Limb Length = .99
  – Injury Prediction
    • Players with an anterior right/left reach distance difference of greater than 4 cm were 2.5 times more likely to sustain a LE injury
    • Females with a composite reach distance less than 94% of their limb length had a 6.5 times greater risk for injury

Agility

• Ability to move and change direction and position of the body quickly and effectively while under control
• Important for successful sports performance and return to sport
• Limited data and current practical clinical use for return to sport is limited

Reliability and Factorial Validity of Agility Tests for Soccer Players

Goran Sporis, Igor Jurec, Luka Milanovic, and Vlatko Vucetic
Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia

• Methods
  – 150 elite male junior soccer players
  – Specific testing protocol
  – 6 agility tests

Agility T-Test

Figure 1. Layout of the T-test (TT)
Slalom Test

Sprint 4 x 5 m (S4 x 5)

Sprint with 90° turns (S90°)

Sprint 93639
- Fwd/bwd (SFB)
- 180° turns (S180°)
Agility

• Results
  – All 6 demonstrated acceptable between and within subject reliability
    • ICC values 0.928-0.992
  – SBF, TT, S180 are most reliable and valid
• Positions
  • Attackers/fwds: S4 x 5
  • Midfielders: S180° and SFB
  • Defenseman: TT
• Limitations

Agility

• Normative values

Between-Session Reliability of Four Hop Tests and the Agility T-Test
Allan G. Munro and Lee C. Herrington

• T-test
  – Methods
    • 22 subjects without LE injury
    • Recreationally active (Tegner Level 5 or greater)
    • Tested on 3 separate occasions 1 week apart
  – Results
    • ICC values 0.82-0.96

A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction

• Methods
  – n=9 male, 6 female
  – n=30 ACL injury, 33 ACL-R
  – 5 jumps tests
    • 3 jumps tests
    • 2 agility jump tests
Agility

• Square hop
  – 40 x 40 cm square
  – Count the number of hops in 30 sec
  – If touch the line >25% of hops, 3 min rest and repeat a 2nd trial
  – R LE CW, L LE CCW

Results

• Square hop
  – No significant side to side differences in subjects with ACL injury
  – ICC 0.55-0.89
  – Lowest specificity and accuracy

• Side hop
  – Significant difference between injured/uninjured LEs
  – ICC 0.72-0.95
  – Combined with vertical jump and hop for distance
    • 54% ACL-R subjects obtained abnormal LSI
    • 9% had normal LSI
    • Sensitivity=87% ACL injury, 91% ACL-R

• Methods
  – n=30 FAI, 30 control subjects
  – Completed 4 hopping tests

A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction

The Ability of 4 Single-Limb Hopping Tests to Detect Functional Performance Deficits in Individuals With Functional Ankle Instability
Agility

• Results
  – Significant difference in side hop and figure-of-8 hop
    • p=0.05 and 0.06 respectively
    • Differences were small
  – FAI giving way (GW) vs FAI not giving way (NGW)
    • Largest, significant side-side deficits
  – Multiple plane, timed tests identified differences

Agility Summary

• T-test
  – Commonly used, valid and reliable
  – Recommend 1 practice attempt
  – Does not determine LSI
    • Myer JOSPT 2011
• 6 agility tests
  – Valid and reliable
  – Only tested on soccer players
  – Not research for return to sport

Agility Summary

• Side hop demonstrated greater ability to detect side-side deficits than other hops tests
• Agility tests should include multiple directions and be timed
Squat

• Squat = foundational movement
• Importance of maintaining proper alignment/mechanics
• Single leg squat is a common screening tool used in clinic

Single Leg Squat

• Criteria

Performance on the Single-Leg Squat Task Indicates Hip Abductor Muscle Function

Kay M. Crossley,11 PhD, Wan-Jie Zhang,3 MBBS, Anthony G. Schache,1 PhD, Adam Bryant,3 PhD, and Sally M. Cowan,7 PhD

• Methods
  – 34 healthy adults
  – Single leg squat task
    • 8 inch box
    • Perform 5 reps
  – Video analysis and EMG
  – Handheld dynamometer for hip and trunk strength
  – Graded as good, fair, poor

• Results
  – Reliability
    • Interrater
      – Experienced raters κ= 0.70-0.80
      – Inexperienced raters κ=0.60
    • Intrarater κ=0.61-0.80
  – Strength
    • EMG onset timing of glute med
    • Hip abd
    • WB side bridge force
    • No difference in ER
The Effect of Cam FAI on Hip and Pelvic Motion during Maximum Squat

Methods
- n=32 (16 control, 16 Cam FAI)

Results
- FAI group decreased sagittal pelvic ROM
- Squat depth reduced in FAI
- 33% of FAI group able to reach full attainable depth

Squat Summary
- Single leg squat assessment is a reliable tool for assessing LE mechanics
- May indicate hip weakness or other impairments
- Use of maximum squat may also be a useful screen for hip impingement
- Fairview functional test
  - Single leg depth squat

Endurance
- The ability for a muscle group to perform repeated muscle contractions against a low to moderate load over a period of time
- Limited research for return to sport

Fatigue alters lower extremity kinematics during a single-leg stop-jump task

Methods
- n=30 healthy subjects
- Video analysis pre and post exhaustive exercise

Results
- Less knee flexion angles when fatigued
**Effects of Fatigue and Recovery on Knee Mechanics during Side-Step Cutting**

Liang-Ching Tsa1, Susan M. Siguard1, Christine D. Pollard1, Mark J. Fletcher2, and Christopher M. Powers1

- **Methods**
  - n=15 recreational female athletes
  - Run-cut task performed pre and 3 x post fatigue
- **Results**
  - Significant difference for all 3 post fatigue trials in knee valgus and knee IR angles

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**Endurance Research**

- Validation of single leg endurance squat test in individuals with and without lower extremity pathology (Corbo, 2011)

- **Purpose**

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**Endurance Research**

- **Control**: n=15 (10 female, 5 male)
  - Age range: 23-43 (26.8 avg)
- **Post-operative**: n=9 (1 female, 8 males)
  - Age range: 18-41 (26.5 avg)
  - 5 ACL reconstruction
  - 1 MPFL reconstruction
  - 1 Tibial tubercle transfer
  - 1 patellar facetectomy
  - 1 trochlear groove microfracture
  - Average of 7.7 months after surgery (range: 4-13 months)

- **Results**
  - No difference between LE in healthy subjects
  - No difference between LE in s/p subjects
    - Limitations
    - Anecdotal evidence vs research results

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**Endurance Research**

- **Limitations**
- Anecdotal evidence vs research results
Endurance Summary

- Endurance leads to impaired mechanics
- Biomechanical flaws increase risk of knee injuries
- Important component of sport
- Endurance testing should be a component of RTS testing
- Further research needed

Established Functional Assessment Tools

Tuck Jump Assessment

- **Purpose**
  - Clinical assessment to identify landing flaws
- **Instructions**
  - Athlete performs repeated tuck jumps for 10 seconds
  - Use checklist to tally score
  - Scores of 6 or lack of improvement need further technique training
Does an In-Season Only Neuromuscular Training Protocol Reduce Deficits Quantified by the Tuck Jump Assessment?

Madelyn F. Klugman1,2, Jensen L. Brent1, Gregory D. Myer1,3,4, Kevin R. Ford1,3, and Timothy E. Hewett1,2,4

- Methods
  - n=49 (15 subjects, 34 controls)
  - Pre and post TJA
  - Subjects performed an in-season ACL injury prevention program
- Results
  - No significant difference between groups
  - TJA score improved for both groups
  - Dose-response relationship
- Conclusion
  - Easy to administer tool
  - Further research needed

The Landing Error Scoring System (LESS) Is a Valid and Reliable Clinical Assessment Tool of Jump-Landing Biomechanics

The JUMP-ACL Study

Darin A. Paudue,1,7 PhD, ATC, Stephen W. Marshall,18 PhD, Michelle C. Boling,9 PhD, ATC, Charles A. Thigpen,7 PhD, ATC, William E. Garrett Jr,4 MD, PhD, and Anthony I. Beutler,7 MD

- Purpose
  - Identify and quantify high risk movements
  - Establish easy to use clinical assessment tool
- Methods
  - N=2691; incoming freshman military academy
  - 3 jump landing trials assessed

Drop Vertical Jump

- 12 inch box
- Jump forward and up

Drop Vertical Jump

- Scoring
  - Excellent ≤4
  - Good 5
  - Moderate 6
  - Poor >6

This information is the property of B Braegelmann, J Corbo, and R Himmerick and should not be copied or otherwise used without express written permission of the author
Results

- Reliability
  - Intra, inter ICC 0.91 and 0.84 respectively
  - Significant differences between gender
- Prospective study Smith et al AJSM 2010
  - Did not predict ACL injury

Vail Sport Test™

- Return to sport assessment
- 4 tests
  - Single leg squat for 3 minutes
  - Lateral bounding for 3 minutes
  - Forward jogging for 2 minutes
  - Backward jogging for 2 minutes
- Patients are qualitatively scored

Videos

Methods

- n=30 s/pACL-r
- Average 5.5 months Tegner Level 5
- Video analysis involving 3 PTs
**Vail Sport Test™**

- **Results**
  - Average score: 45 (+/-10.2) / 54
  - Intra-rater reliability 0.95-1 ICC
  - Inter-rater reliability 0.97 ICC
- **Limitations**
  - Only ACL-r
  - Score has not been validated

**Functional Movement Screen**

- Developed by Grey Cook and Lee Burton in 1995
- **Purpose**
  - Identify deficiencies, asymmetries and imbalances, in order to decrease injury risk
  - Faulty movement patterns due to learned compensatory strategies/behaviors
  - Grading system that documents movement patterns in functional movement

**Functional Movement Screen**

- **Tests**
  - Deep squat, hurdle step, in-line lunge, shoulder mobility, active SLR, trunk stability push-up, rotary stability
  - Not appropriate for painful athletes
- **Can make recommendations for participation, identify weaknesses and work on improving these, setting goals**

**Examples**
Functional Movement Screen

• Outcomes
  – Average score 15.7 ± 1.9 (Schneiders et al 2011)
  – ICC 0.91 – 1.00 (Hickey et al 2010, Schneiders et al 2011)
  – Score < 14 increases injury risk (Kiesel (Pro football players) et al 2008 and Chorbo (collegiate female athletes) et al 2010)

• Limitations
  – Not discussing this in depth

Predictors of Reinjury

• Incidence rate
  – Paterno, CJSM 2012
    • 15 x greater after ACL-R
    • 16 x greater in females s/p ACL-R
    • Females 4 x more likely to retear, 6 x more likely to injure contralateral than males
  – Hewett, AJSM 2012
    • 5 year f/u in female had 44% 2nd ACL injury
    • Soccer player cohort
      – 2 year f/u: 6% reinjury rate
      – 7 year f/u: 12% reinjury rate
  – Pinczewski et al. AJSM
    • 1 in 3.7 individuals had 2nd injury

Injury Risk Factors

• Factors
  – Hewett NAJSPT 2010
    • Primary: neuromuscular control
      – Leg dominance
      – Ligament dominance
      – Quadriceps dominance
      – Trunk dominance
  – Hewett AJSM 2012
    • Younger athletes
      – <17 years, 17% sustained 2nd ACL injury
      – >25 years, 4% reinjury
      – Shelbourne AJSM 2009
    • Neuromuscular control
      – Majority of 2nd injuries are non-contact injuries
### Biomechanical Measures During Landing and Postural Stability Predict Second Anterior Cruciate Ligament Injury After Anterior Cruciate Ligament Reconstruction and Return to Sport

- 4 predictive factors identified (Paterno AJSM 2010)
  - Contralateral hip internal rotation
  - Increased sagittal plane knee moment
    - Knee extensor of contralateral limb
    - Knee flexor moment of involved limb
  - Postural stability deficits
- Sensitivity = 0.92 and specificity = 0.88
- Graft type and A-P knee laxity were not predictors

### Return to Sport Predictors

- Evidence lacking
  - There is no single return to play formula
  - There are no universally accepted functional guidelines for objectively determining
  - Area of most research is following ACL-R
  - In a SR 2011 only 35 of 264 (13%) articles reviewed included some measurable objective criteria for RTS
    - Barber-Westin and Noyes 2011

### Return to Sport

- No Association of Time From Surgery With Functional Deficits in Athletes After Anterior Cruciate Ligament Reconstruction

- Evidence for Objective Return-to-Sport Criteria

- Timeframe RTS v. Criterion-Based RTS
  - 11 months s/p ACL-R and after release to sport; LE asymmetries are found
  - Asymmetries are independent of time
- Emphasize Criterion-Based RTS
Time Line for Noncopers to Pass Return-to-Sports Criteria After Anterior Cruciate Ligament Reconstruction

- **Return to sport criteria**
  - 90% quadriceps strength index
  - 90% LSI on 4 hops tests (single, triple, triple crossover, 6-m timed)
    - Who can hop?
      - >12 week postoperative
      - <1+ knee effusion
      - >80% quad strength index
      - Full knee ROM
      - Pain-free hopping
      - Normal gait
  - 90% on Knee Outcome Survey-ADLs
  - 90% Global rating scale

Return to Sport

- **RTS Percentage**
  - 5% at 3 months
  - 48% at 6 months
  - 78% passed RTS criteria at 12 months
    - 6/8 has impaired quadriceps strength

- **Conclusion**
  - Emphasize criterion-based vs. time based

**Return to Sport**

- **Who returns to sport?**
  - Less than 50% RTS (MOON, 2010)
  - MOON AJSM 2012
    - High school and college football players
    - 63% and 69%, respectively
    - Factors for not RTS
      - Other interests
      - Fear (kinesiophobia)
      - Physical symptoms
      - Advice
      - Loss of speed or strength
  - Soccer players
    - Older athletes
    - Females
FAIRVIEW FUNCTIONAL TESTS

Lower Extremity Physical Performance Test

- **Level I**
  - Modified stand and reach
  - SEBT
  - Single leg balance
  - Single leg squat
  - Retro Step-up
  - Prone and Side planks
  - Single leg bridge

- **Level II**
  - Single leg squat for endurance
  - Single leg hop

- **Level III**
  - 6 meter timed hop
  - Single leg crossover hop

Modified Stand and Reach

- Modified from STAR Excursion Balance Test
- 90° “V” on floor
- Reach with contralateral UE
- Lightly touch tape and distance recorded
- Performed in anteromedial and anterolateral directions
- Best of 3 trials
- Failure
  - Loss of balance
  - Using UE for support

Single Leg Balance

- Unilateral stance
- Hands on hips
- Eyes open or closed
- Measure time to failure (max 60 seconds)
- Best of 3 trials
- Failure:
  - Stance foot shifts
  - Opposite foot touches down
  - Arms wave off hips
Single Leg Squat for Depth
- Unilateral stance
- Squats down to maximal depth
- Returns to standing
- Opposite leg must not touch stance leg or ground
- Best of 3 trials
- Measure maximal knee flexion

Retro Step-Up
- Place test leg back on step
- Heel of front leg is the only contact with the ground
- Raise up and slowly lower down
- Box height 2 – 20”
- Record highest successful box height
- 3 attempts
- Failure:
  - Loss of balance
  - Compensation

Retro Step-Up Video

Prone Plank
- Bilateral forearm and flexed toe support
- Basic includes knee support
- Maintain neutral alignment
- Allow one verbal cueing for form correction
- Time to failure
- Maximum 60 seconds
- Perceived exertion (0-5 scale)
Side Plank

- Bilateral forearm and stacked feet support
- Basic includes knee support
- Maintain neutral alignment
- Allow one verbal cueing for form correction
- Time to failure
- Maximum 60 seconds
- Perceived exertion (0-5 scale)
- Perform on both sides

Single Leg Bridge

- Knees flexed to 100°
- Measuring stick fixated at maximal bridge height
- Opposite leg held in vertical position
- Arms crossed over chest
- 1 bridge / 2 seconds
- Maintain neutral alignment and reach maximal height
- Allowed one verbal cue for form correction
- Reps to failure
- Maximum 20 reps
- Perceived exertion (0-5 scale)

Single Leg Bridge Video

SEBT

- Set up 3 tape measures forming a “Y” with the posterior limbs forming a 90° angle
- Stand on one leg at center of “Y” (test leg is stance limb)
- Squat and reach toes of opposite LE as far as possible along grid
- 3 attempts in each direction (anterior, posteromedial, posterolateral), with the best of 3 attempts recorded.
- Failure: 1) Losing balance and touching opposite LE on ground 2) Transferring body weight to reaching leg, 3) Heel of stance leg comes off ground, 4) Reaching leg does not fully return to the starting position
Single Leg Squat Endurance

- Repeated single leg squat to 60° knee flexion, controlled with fixated bar at 60°
- 1 squat / 2 seconds
- Squat down and lightly touch bar with buttock
- Return to upright position
- Maintain normal LE and trunk alignment
- ≤ 3/10 pain
- Allowed 2 verbal cues for form correction—faulty squats not included in total
- Reps to failure or cramping
- Maximum 60 reps
- Perceived exertion (0-5 scale)

Single Leg Hop for Distance

- Stands on one leg and leaps forward
- Must stick landing and maintain balance
- Best of 3 trials
- Maximal distance recorded

Single Leg Squat Endurance Video

Single Leg Hop Video
6 Meter Timed Hop

- Stands on one leg
- Hops as quickly as possible on one leg through the 6 meter finish line
- Best of 3 trials
- Fastest time recorded

Single Leg Crossover Hop

- Stand on one leg
- 3 consecutive hops crossing a center line
- “Jump, jump, stick”
- “Zig, zag, stick”
- Must stick landing and maintain balance
- Best of 3 trials
- Maximal distance recorded
How to Improve Functional Test Scores?

Recommended exercises for LE performance test deficiencies

**Modified Stand and Reach**
- T-reach
- Apple-picking
- Hip airplane

**Squat for Depth**
- Leg Press
- Single leg kick stand squat
- Lunges

**Retro Step**
- Donkey Kick
- Butt-back squat
- Isometric retro step hold
SEBT
- T-reach
- Step back
- Slide outs

Balance
- Unstable surfaces
- Eyes closed

Prone Plank
- Crunches
- Sit-ups
- Sahrmann progression

Side Plank
- Clamshell
- Fire hydrant
- Spider kick
**Bridge**
- Donkey kick
- Bridge Progression

**Squat for Endurance**
- Donkey kicks
- Leg press
- Kick stand squat
  - Holds → Reps

**HOPS**
- Double limb → single limb
- Stationary → transitory
- Bounding

**HOPS Videos**
Thank You/Questions

Contact Information

• bbraege1@fairview.org
• jcorbo1@fairview.org
• rhimmer1@fairview.org