Safe to Run?
Physiologic Assessments for the Lower Quarter

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Objectives

- Explain factors contributing to running-related injuries
- Summarize the roles of training load and physiologic capacity in injury risk and the limitations of basic assessments
- Utilize evidence-based assessments for key deficiencies
- Apply targeted assessments to identify strength, endurance, power, and motor control deficits in runners
- Make data-driven decisions for treatment progress and determine safe timelines for returning to running

Session Format:

- This 45-minute session will include interactive lecture components
- You will need a laptop and your cell phone

Epidemiology

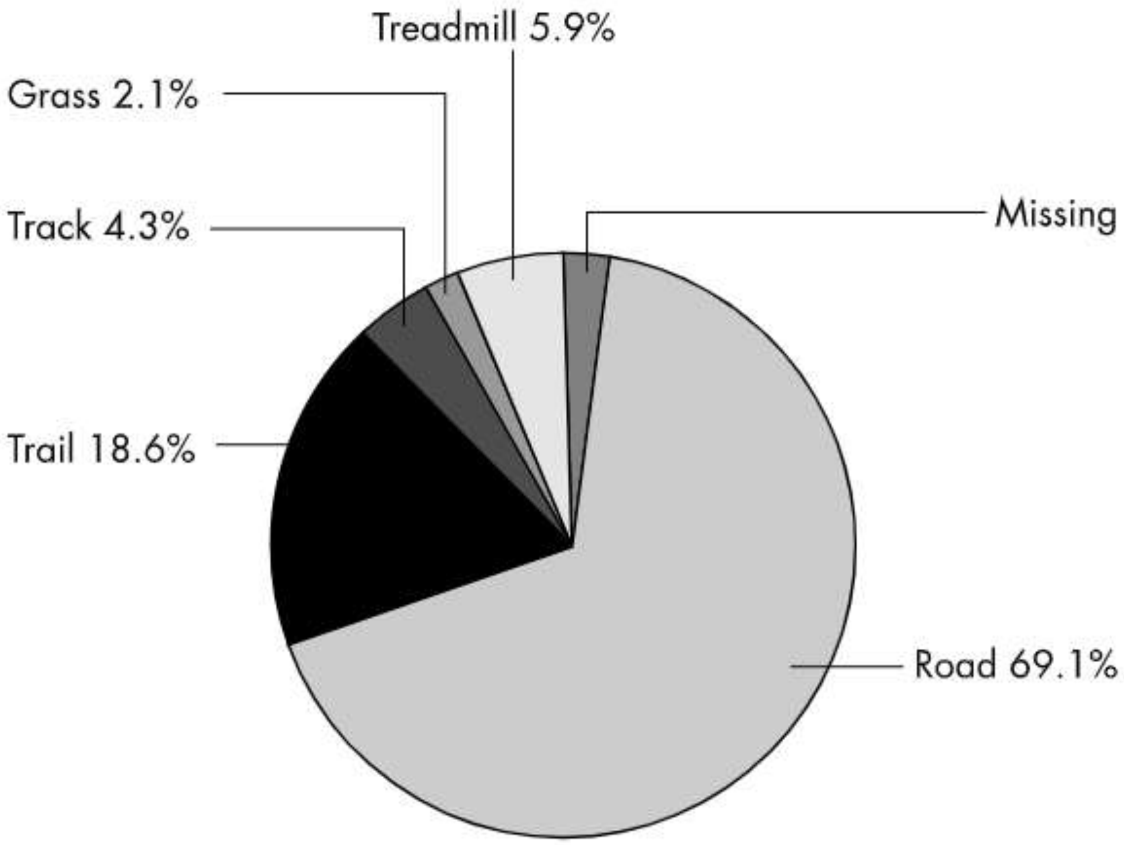


Figure 1 Breakdown of running surfaces.

Table 2 Running frequency

	No	%
1 day/week	49	5.8
2 days/week	244	29.0
3 days/week	501	59.6
4 days/week	36	4.3
5 days/week	9	1.1

Data were not provided in five cases.

Table 3 Distribution of injuries by anatomical site

Location	Men	Women
Knee	21 (36)	62 (32)
Shin	10 (17)	28 (15)
Foot	8 (14)	25 (13)
Achilles/calf	5 (8)	20 (10)
Ankle	6 (10)	20 (10)
Hip/pelvis	4 (7)	19 (10)
Low back	4 (7)	10 (5)
Hamstring	0 (0)	6 (3)
Thigh	0 (0)	2 (1)

Values are numbers with percentages in parentheses. Certain subjects indicated multiple injury locations.

Taunton JE, Ryan MB, Clement DB, McKenzie DC, Lloyd-Smith DR, Zumbo BD. A prospective study of running injuries: the Vancouver Sun Run "In Training" clinics. Br J Sports Med. 2003 Jun;37(3):239-44. doi: 10.1136/bjsm.37.3.239. PMID: 12782549; PMCID: PMC1724633.

The Running Injury Equation

$$\frac{\text{Training Load}}{\text{Physiologic Capacity}} = \text{Injury Risk}$$

- Running injuries occur when training load exceeds physiologic capacity
- Statistics on running injury prevalence (50-75% annual injury rate among runners)

Malisoux L, Nielsen RO, Urhausen A, et al. Training load and injury risk in runners: a systematic review. Sports Med. 2020;50(8):1613-1628.

Souza RB, Powers CM. Differences in hip kinematics, muscle strength, and muscle activation between subjects with and without patellofemoral pain. J Orthop Sports Phys Ther. 2009;39(1):12-19.

What is the Problem?

Load (What you want to do)	**Capacity** (What you can do)
• Volume • Intensity • Frequency • Mindset	• Recovery • Running economy • Cardiovascular fitness • Musculoskeletal health • BMI

Limitations of Basic Assessment Techniques

Evidence on Flexibility and Running Injury Risk

- The relationship between flexibility and running injuries is not straightforward, with conflicting evidence in the literature
- Traditional assumptions that increased flexibility reduces injury risk have been challenged by recent research
- Witvrouw et al. (2004) found limited support for stretching in preventing running injuries
- A meta-analysis by Lauersen et al. (2014) concluded that stretching programs alone did not significantly reduce sports injury risk (RR = 0.96, 95% CI: 0.85-1.08)

Witvrouw E, Mahieu N, Danneels L, McNair P. Stretching and injury prevention: An obscure relationship. *Sports Med*. 2004;34(7):443-449.

Lauersen JB, Bertelsen DM, Andersen LB. The effectiveness of exercise interventions to prevent sports injuries: a systematic review and meta-analysis of randomised controlled trials. *Br J Sports Med*. 2014;48(11):871-877.

Limitations of Basic Assessment Techniques

There is evidence that once injury occurs there may be flexibility impairments

- Plantar fasciitis: Limited ankle dorsiflexion (particularly with the knee extended) associated with 2.1x higher risk[1]
- Patellofemoral pain: Reduced quadriceps and hamstring flexibility correlated with increased risk[2]
- Iliotibial band syndrome, No clear relationship with flexibility measures[3]
- Achilles tendinopathy Both excessive flexibility and stiffness showed associations with injury development[4]

1. Pohl MB, Hamill J, Davis I. Biomechanical and anatomic factors associated with a history of plantar fasciitis in female runners. *Clin J Sport Med*. 2009;19:372-376.
2. Witvrouw E, Lysens R, Bellemans J, Cambier D, Vanderstraeten G. Intrinsic risk factors for the development of anterior knee pain in an athletic population. A two-year prospective study. *Am J Sports Med*. 2000;28(4):480-489.
3. Aderem J, Louw QA. Biomechanical risk factors associated with iliotibial band syndrome in runners: a systematic review. *BMC Musculoskelet Disord*. 2015;16:356.
4. O'Neill S, Watson PJ, Barry S. A Delphi study of risk factors for Achilles tendinopathy- opinions of world tendon experts. *Int J Sports Phys Ther*. 2016;11(5):684-697.
5. Witvrouw E, Mahieu N, Danneels L, McNair P. Stretching and injury prevention: An obscure relationship. *Sports Med*. 2004;34(7):443-449.

Limitations of Basic Assessment Techniques

Validity Concerns for MMT related to running related Injures

- **Functional Correlation:** Poor relationship to athletic function
  - MMT grades 4-5 fail to correlate with functional performance in running tasks[1]
  - Static strength measured via MMT showed weak correlation (r = 0.31-0.48) with dynamic strength[2]
- **Sensitivity Issues:** Limited ability to detect deficits in athletes
  - **Ceiling effect:** Most runners score 4-5/5 despite measurable strength differences on instrumented testing[3]
  - Failure to detect bilateral deficits common in runners[4]
  - Small but clinically relevant strength deficits undetectable via MMT[5]

Specific Limitations for Runners

- **Inability to Assess Strength Endurance:**
  - Single maximal contraction fails to assess fatigue resistance crucial for running[6]
  - Running injuries often manifest under fatigue conditions not captured by MMT[7]

1. Hickey JT, Hickey PF, Maniar N, et al. A novel apparatus to measure knee flexor strength during various hamstring exercises: A reliability and retrospective injury study. *J Orthop Sports Phys Ther*. 2018;48(2):72-80.
2. Schmitt LC, Paterno MV, Hewett TE. The impact of quadriceps femoris strength asymmetry on functional performance at return to sport following anterior cruciate ligament reconstruction. *J Orthop Sports Phys Ther*. 2012;42(9):750-759.
3. Jackson SM, Cheng MS, Smith AR Jr, Kolber MJ. Intrarater reliability of hand held dynamometry in measuring lower extremity isometric strength using a portable stabilization device. *Musculoskelet Sci Pract*. 2017;27:137-141.
4. Mattock J, Steele JR, Mickle KJ. Lower leg muscle structure and function are altered in long-distance runners with medial tibial stress syndrome: a case control study. *J Foot Ankle Res*. 2021;14(1):47.
5. Bohannon RW. Manual muscle testing: does it meet the standards of an adequate screening test? *Clin Rehabil*. 2005;19(6):662-667.
6. Bazett-Jones DM, Cobb SC, Huddleston WE, O'Connor KM, Armstrong BS, Earl-Boehm JE. Effect of patellofemoral pain on strength and mechanics after an exhaustive run. *Medicine & Science in Sports & Exercise*. 2013;45(7):1331-1339.
7. Hayes PR, French DN, Thomas K. The effect of muscular endurance on running economy. *J Strength Cond Res*. 2011;25(9):2464-2469.

Assessment Framework

Identify pertinent impairments for rehab and prevention of running related Injuries

Esculier JF, Bouyer LJ, Dubois B. Validity and reliability of lower limb assessment tools used in research on runners with knee pain. J Athl Train. 2020;55(2):169-175.


VO@ MAX
RUNNING ECONOMY
MOTOR CONTROL
FLEXIBILITY
STRENGTH
POWER


Quick Movement Screens

- Arms Forward Squat
- Weight Bearing Lunge Test
- Single-Leg Balance
- Single-Leg Squat
- Piva Step-down Test

Overhead Squat Test

Procedure: Feet shoulder-width apart, squat with arms extended overhead

Observations: Ankle dorsiflexion, knee alignment, hip mobility, trunk position

Evidence:

- Moderate inter-rater reliability (κ = 0.74-0.87) for identifying movement patterns
- Limited predictive validity for running injuries as standalone test (sensitivity = 0.58)
- Better for assessing global movement patterns and thoracic mobility

Clinical applications:

- Identifies restrictions that may affect running economy and mechanics
- More sensitive to upper quarter dysfunction than lower extremity issues

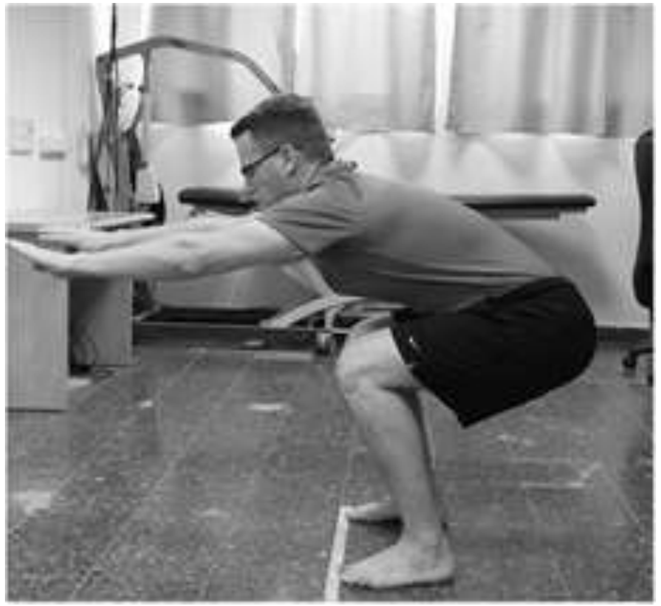
Butler RJ, Plisky PJ, Southers C, et al. Biomechanical analysis of the different classifications of the Functional Movement Screen deep squat test. Sports Biomech. 2010;9(4):270-279.

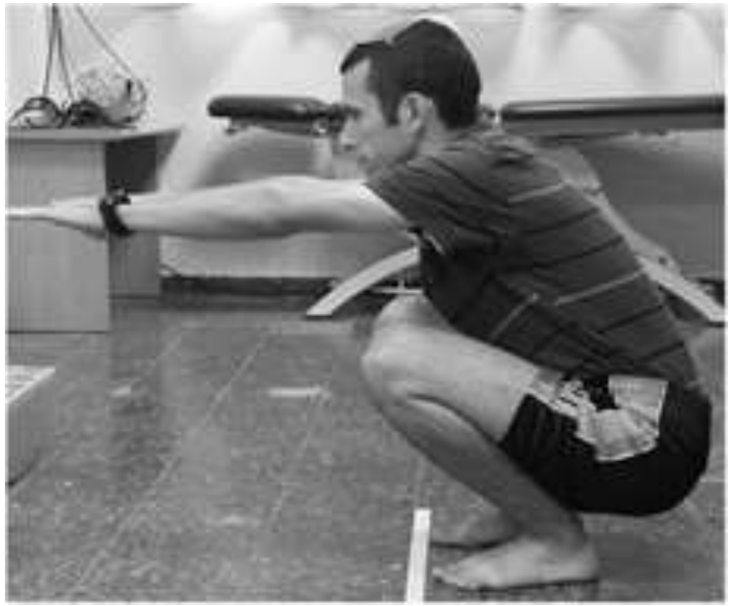
Kiesel K, Butler R, Plisky P. Prediction of injury by limited and asymmetrical fundamental movement patterns in American football players. J Sport Rehabil. 2014;23(2):88-94.

Moran RW, Schneiders AG, Major KM, et al. How reliable are Functional Movement Screening scores? A systematic review of rater reliability.
Br J Sports Med. 2016;50(9):527-536.

Arms Forward Squat Test

Participants were instructed to squat as far as possible while maintaining both heels in contact with the floor, and both arms reaching forward (shoulders flexed 90 and the elbows extended)





Rabin A, Kozol Z. Utility of the Overhead Squat and Forward Arm Squat in Screening for Limited Ankle Dorsiflexion. J Strength Cond Res. 2017 May;31(5):1251-1258. doi: 10.1519/JSC.0000000000001580. PMID: 27465627.

Arms Forward Squat Test

Procedure: Barefoot, Feet shoulder-width apart, squat with arms extended forward

Evidence:

- Better isolation of lower extremity mechanics[1]
- Higher completion rates in clinical populations
- Comparable lower extremity kinematics to overhead squat[2]
- Reduced compensatory patterns from upper body restrictions

1. Myer GD, Kushner AM, Brent JL, et al. The back squat: a proposed assessment of functional deficits and technical factors that limit performance. Strength Cond J. 2014;36(6):4-27.
2. Pantoja PD, Venâncio PEM, Ribas LR, et al. Correlation between biomechanical variables and morphological adaptations in the lower limbs of runners. JSHS. 2016;5(1):213-216.
3. Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. J Strength Cond Res. 2010;24(12):3497-3506.
4. Rabin A, Kozol Z. Utility of the Overhead Squat and Forward Arm Squat in Screening for Limited Ankle Dorsiflexion. Journal of Strength and Conditioning Research. 2017; 31 (5): 1251-1258. doi: 10.1519/JSC.0000000000001580.

Arms Forward Squat Test

Clinical applications for runners:

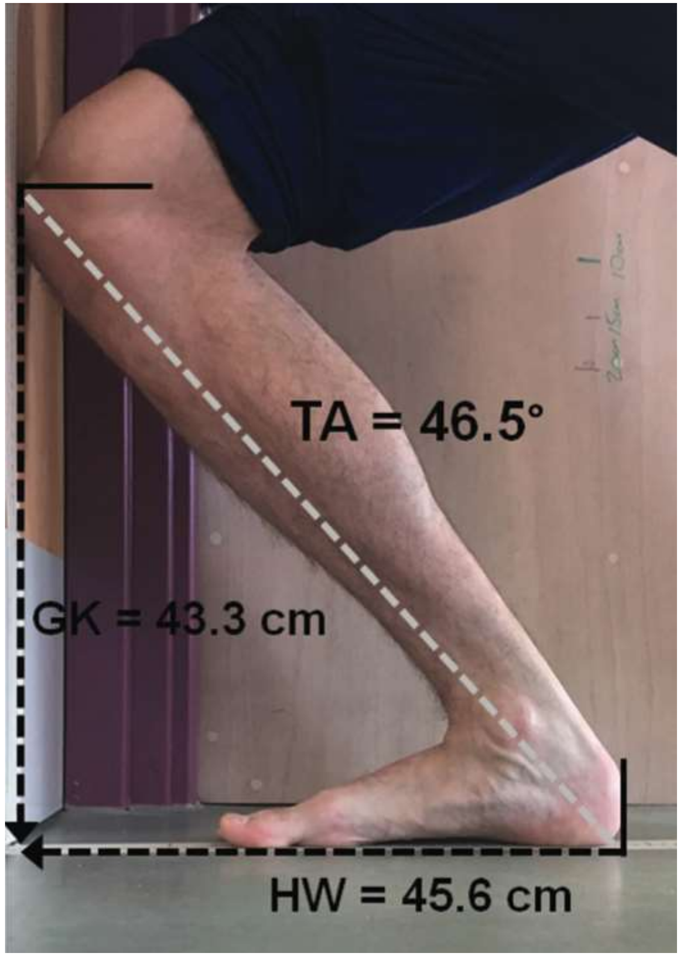
- More specific assessment of lower quarter function relevant to running
- Recommended as initial screening before progressing to overhead squat
- Better differentiation of ankle vs. hip mobility restrictions

Comparative Value:

- Use both tests to determine if limitations are primarily in lower or upper kinetic chain
- Arms forward position has better evidence for clearing lower extremity function

1. Myer GD, Kushner AM, Brent JL, et al. The back squat: a proposed assessment of functional deficits and technical factors that limit performance. Strength Cond J. 2014;36(6):4-27.
2. Pantoja PD, Venâncio PEM, Ribas LR, et al. Correlation between biomechanical variables and morphological adaptations in the lower limbs of runners. JSHS. 2016;5(1):213-216.
3. Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. J Strength Cond Res. 2010;24(12):3497-3506.
4. Rabin A, Kozol Z. Utility of the Overhead Squat and Forward Arm Squat in Screening for Limited Ankle Dorsiflexion. Journal of Strength and Conditioning Research. 2017; 31 (5): 1251-1258. doi: 10.1519/JSC.0000000000001580.

Weight-Bearing Lunge Test



Procedure: measuring ankle dorsiflexion ROM

- **Normative values:** ≥ 40° or 10cm tibia-to-wall distance
- **Limb symmetry index (LSI):** >94% between limbs considered normal

Clinical relevance:

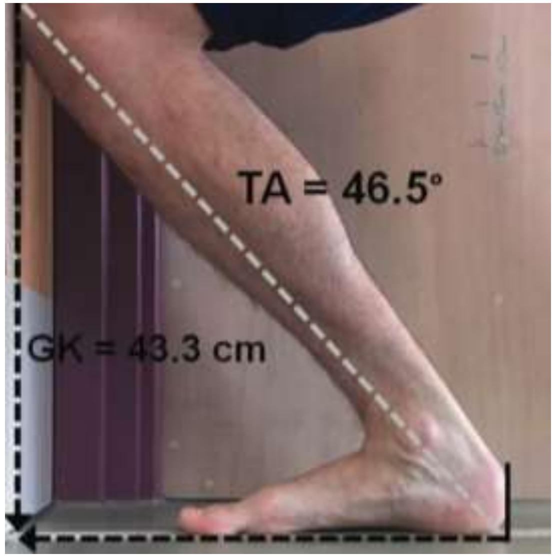
- Values < 35° associated with 2.5x increased injury risk in runners
- LSI < 90% associated with altered landing mechanics and increased medial knee displacement
- Minimum detectable change (MDC): 1.9cm
- Positive Test > 2 cm side to side difference distance from tip of hallux to wall while heel contacts the floor

Howe LP, Bampouras TM, North JS, Waldron M. Within-session reliability for inter-limb asymmetries in ankle dorsiflexion range of motion measured during the weight-bearing lunge test. Int J Sports Phys Ther. 2020 Feb;15(1):64-73. PMID: 32089959; PMCID: PMC7015029.

Weight Bearing Lunge Test (Ankle Df)

WARNING: there is a fair amount of procedure variability in the literature

Modified = Degrees



Kneeling/standard = distance

Howe LP, Bampouras TM, North JS, Waldron M. Within-session reliability for inter-limb asymmetries in ankle dorsiflexion range of motion measured during the weight-bearing lunge test. Int J Sports Phys Ther. 2020 Feb;15(1):64-73. PMID: 32089959; PMCID: PMC7015029.

Cejudo A, Sainz de Baranda P, Ayala F, Santonja F. A simplified version of the weight-bearing ankle lunge test: Description and test–retest reliability. Man Ther. 2014;19(4):355-359.

Bennell KL, Talbot RC, Wajswelner H, Techovanich W, Kelly DH, Hall AJ. Intra-rater and inter-rater reliability of a weight-bearing lunge measure of ankle dorsiflexion.Aust J Physiother. 1998;44(3):175-180.

Rabin A, Kozol Z, Finestone AS. Limited ankle dorsiflexion increases the risk for mid-portion Achilles tendinopathy in infantry recruits: a prospective cohort study. J Foot Ankle Res. 2014;7(1):48.

Malliaras P, Cook JL, Kent P. Reduced ankle dorsiflexion range may increase the risk of patellar tendinopathy in volleyball players. J Sci Med Sport. 2015;18(4):494-498.

Hoch MC, McKeon PO. Normative range of weight-bearing lunge test performance asymmetry in healthy adults. Man Ther. 2011;16(5):516-519.

Powden CJ, Hoch JM, Hoch MC. Reliability and minimal detectable change of the weight-bearing lunge test: a systematic review. Man Ther. 2015;20(4):524-532.

Single-Leg Stance Test

Procedure:
Timed stance with
eyes closed & eyes open

Normative values:
>30 seconds for healthy adults

Clinical significance:
<10 eyes closed or open increased risk LAS

Was pain reproduced?

Trojian TH, McKeag DB. Single leg balance test to identify risk of ankle sprains. Br J Sports Med. 2006;40(7):610-613

Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. J Orthop Sports Phys Ther. 2009;36(12):911-919

McGuine TA, Greene JJ, Best T, Leverson G. Balance as a predictor of ankle injuries in high school basketball players. Clin J Sport Med. 2000;10(4):239-244.

Hrysomallis C. Relationship between balance ability, training and sports injury risk. Sports Med. 2007;37(6):547-556

Emery CA, Cassidy JD, Klassen TP, Rosychuk RJ, Rowe BH. Effectiveness of a home-based balance-training program in reducing sports-related injuries among healthy adolescents: a cluster randomized controlled trial. CMAJ. 2005;172(6):749-754

Single-Leg Squat for Dynamic Foot Control

Procedure:

- Single-leg stance with hands on hips
- Controlled descent to 60° knee flexion
- 3-5 repetitions with observation of foot/ankle mechanics

Key observations:

- Mediolateral stability of the foot
- Maintenance of arch during loading
- Forefoot-rearfoot relationship
- Weight distribution through the foot

Carroll, Lindsay & Kivlan, Benjamin & Martin, Robroy & Phelps, Amy & Carcia, Christopher. (2021). The Single Leg Squat Test: A "Top-Down" or "Bottom-Up" Functional Performance Test?. International Journal of Sports Physical Therapy. 16. 10.26603/001c.21317.

Kim HY, Sakuma J, Sorci E, et al. Relationship between foot posture and medial tibial stress syndrome: a prospective study. J Foot Ankle Res. 2017;10(1):56.

Crossley KM, Zhang WJ, Schache AG, et al. Performance on the single-leg squat task indicates hip abductor muscle function. Am J Sports Med. 2011;39(4):866-873.

Dingenen B, Malliaras P, Janssen T, et al. Two-dimensional video analysis can discriminate differences in running kinematics between recreational runners with and without running-related knee injury. Phys Ther Sport. 2019;38:184-191.

Single-Leg Squat for Dynamic Foot Control

Rating scale:

0 = No deviation (excellent foot control)

1 = Small deviation (good foot control)

2 = Moderate deviation (fair foot control)

3 = Large deviation (poor foot control)

Clinical significance:

- Stronger correlation with running mechanics than static measures
- Excessive midfoot pronation during test present in 78% of runners with PFP vs. 32% of controls
- Poor foot control associated with 2.7x risk of medial tibial stress syndrome

Carroll, Lindsay & Kivlan, Benjamin & Martin, Robroy & Phelps, Amy & Carcia, Christopher. (2021). The Single Leg Squat Test: A "Top-Down" or "Bottom-Up" Functional Performance Test?. International Journal of Sports Physical Therapy. 16. 10.26603/001c.21317.

Kim HY, Sakuma J, Sorci E, et al. Relationship between foot posture and medial tibial stress syndrome: a prospective study. J Foot Ankle Res. 2017;10(1):56.

Crossley KM, Zhang WJ, Schache AG, et al. Performance on the single-leg squat task indicates hip abductor muscle function. Am J Sports Med. 2011;39(4):866-873.

Dingenen B, Malliaras P, Janssen T, et al. Two-dimensional video analysis can discriminate differences in running kinematics between recreational runners with and without running-related knee injury. Phys Ther Sport. 2019;38:184-191.

Lateral Step-Down Test (Piva Protocol)

Procedure: Quality rating based on five criteria during step-down task from 20cm step (7.87 inches)

- Arm strategy
- Trunk alignment
- Pelvis plane
- Knee position
- Steady stance
- Scoring: 0-1 (good), 2 (fair), ≥3 (poor)

Psychometric properties:

- Inter-rater reliability: kappa = 0.67[1]
- Intra-rater reliability: ICC = 0.80-0.85[2]
- Inter- and intra-rater reliability: Kappa = 0.04 – 0.65

1. Piva SR, Fitzgerald K, Irrgang JJ, et al. Reliability of measures of impairments associated with patellofemoral pain syndrome. BMC Musculoskelet Disord. 2006;7(1):33.
2. Rabin A, Kozol Z, Moran U, Efergan A, Geffen Y, Finestone AS. Factors associated with visually assessed quality of movement during a lateral step-down test among individuals with patellofemoral pain. *J Orthop Sports Phys Ther*. 2014;44(12):937-946.
3. Mansfield C, Spech C, Rethman K, et al. Moderate reliability of the lateral step down test amongst experienced and novice physical therapists. Physiotherapy Theory and Practice. 2022;38(12):2029-2037. doi: 10.1080/09593985.2021.1923097Schreiber C, Becker J. Performance on the Single-Legged Step Down and Running Mechanics. *J Athl Train*. 2020;55(12):1277-1284.

https://wikism.org/Lateral_Step_Down_Test

Lateral Step-Down Test (Piva Protocol)

Clinical significance:

- Scores ≥3 associated with 2.3x increased risk of knee pain in runners
- Performance correlates with hip strength ($r = 0.67$-0.74), particularly external rotators
- Test performance reflects neuromuscular control patterns used during running stance phase
- More sensitive for detecting knee control issues than general stability tests

Piva SR, Fitzgerald K, Irrgang JJ, et al. Reliability of measures of impairments associated with patellofemoral pain syndrome. BMC Musculoskelet Disord. 2006;7(1):33.

Noehren B, Hamill J, Davis I. Prospective evidence for a hip etiology in patellofemoral pain. Med Sci Sports Exerc. 2013;45(6):1120-1124.

Dingenen B, Malfait B, Vanrenterghem J, et al. The reliability and validity of the measurement of lateral trunk motion in two-dimensional video analysis during unipodal functional screening tests in elite female athletes. Phys Ther Sport. 2013;14(2):94-101.

Lateral Step-Down Scoring

1 point per fault

- 0-1=GOOD
- 2-3=MEDIUM
- >4=POOR

Total each side & compare, ICC=0.94

	LEFT	RIGHT
Arm Strategy		
Trunk Strategy		
Pelvic Strategy		
Knee Medial 2nd Toe		
Knee Medial MLA		
Unsteadiness		
TOTAL		

Strength Tests

- Handheld dynamometry
- Single-leg wall squat test
- McGill side plank test
- Single-leg heel raise test

Handheld Dynamometry

Procedure for key muscle groups: hip abductors, external rotators, extensors, knee extensors

- Normative values (adjusted for body weight)
- Limb symmetry index (LSI): <90% indicates deficit

Tramer, Joseph & Khalil, Lafi & Jildeh, Toufic & Abbas, Muhammad & McGee, Anna & Lau, Michael & Moutzouros, Vasilios & Okoroha, Kelechi. (2022). Blood Flow Restriction Therapy For Two Weeks Prior to Anterior Cruciate Ligament Reconstruction Did Not Impact Quadriceps Strength Compared to Standard Therapy. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 39. 10.1016/j.arthro.2022.06.027.

Mucha MD, Caldwell W, Schlueter EL, et al. Hip abductor strength measurement and hip abductor muscle size assessment: reliability and correlation. Int J Sports Phys Ther. 2017;12(6):924-932.

Martins J, da Silva JR, da Silva MRB, Bevilaqua-Grossi D. Reliability and validity of the belt-stabilized handheld dynamometer in hip- and knee-strength tests. J Athl Train. 2017;52(9):809-819.

Deasy M, Leahy E, Semciw AI. Hip strength deficits in people with symptomatic knee osteoarthritis: a systematic review with meta-analysis. J Orthop Sports Phys Ther. 2016;46(8):629-639.

Katoh M, Yamasaki H. Comparison of reliability of isometric leg muscle strength measurements using a hand-held dynamometer with and without a restraining belt. J Phys Ther Sci. 2011;41(1):9-16.This is your primary reference in the presentation

Single-Leg Wall Squat Test

Procedure: time to failure maintaining 60° knee flexion

- **Clinical threshold of <45 seconds**
- Found mean wall squat hold times of 45.3 seconds in healthy controls
- Patients with PFP averaged 28.7 seconds
- **Consider LSI**

Dierks TA, Manal KT, Hamill J, Davis IS. Lower extremity kinematics in runners with patellofemoral pain during a prolonged run. Med Sci Sports Exerc. 2011;43(4):693-700.

Earl JE, Hoch AZ. A proximal strengthening program improves pain, function, and biomechanics in women with patellofemoral pain syndrome. Am J Sports Med. 2011;39(1):154-163.

McGill Core Endurance Tests

Side Plank Test: Gold standard assessment

- Procedure: Standard side plank position, maximal hold time
- Normative values for runners (Evans 2007)
  - Elite: 95-120s (males), 75-95s (females)
  - Recreational: 65-85s (males), 55-75s (females)
- The original normative values from McGill et al. (1999)
  - 75-95 seconds for men, 50-75 seconds for women
- Clinical significance: Deficits suggest weakness core, hip ABD and ER
- Reliability: Excellent test-retest reliability (ICC = 0.91-0.96)

McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. Arch Phys Med Rehabil. 1999;80(8):941-944.

Leetun DT, Ireland ML, Willson JD, et al. Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc. 2004;36(6):926-934.

Evans K, Refshauge KM, Adams R. Trunk muscle endurance tests: reliability, and gender differences in athletes. J Sci Med Sport. 2007;10(6):447-455.

Brumitt J, Matheson JW, Meira EP. Core stabilization exercise prescription, part I: current concepts in assessment and intervention. Sports Health. 2013;5(6):504-509.

Core Strength Test Norms

MEAN ENDURANCE	TIMES RATIOS
Flex/Extend Ratio	0.77 sec
RSB/LSB Ratio	0.96 sec
RSB/Extend Ratio	0.48 sec
LSB/Extend Ratio	0.50 sec

McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. Arch Phys Med Rehabil. 1999;80(8):941-944.

McGill S. *Low Back Disorders: Evidence-Based Prevention and Rehabilitation*. Human Kinetics; 2007.

McGill Core Endurance Tests

Runner-Specific Modifications:

- Active hip abduction during side plank (better assesses stance phase stability)
- Alternating arm/leg raises from plank (challenges rotational control)
- Progressive loading protocol (better reflects functional demands than single maximum test)

Core Endurance Ratio:

- Calculate ratio of side plank : roughly 1:1
- Imbalanced ratios may be more predictive of running injuries than absolute times

McGill SM, Childs A, Liebenson C. Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. Arch Phys Med Rehabil. 1999;80(8):941-944.

Leetun DT, Ireland ML, Willson JD, et al. Core stability measures as risk factors for lower extremity injury in athletes. Med Sci Sports Exerc. 2004;36(6):926-934.

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Brumitt J, Matheson JW, Meira EP. Core stabilization exercise prescription, part I: current concepts in assessment and intervention. Sports Health. 2013;5(6):504-509.

Core Strength Tests

Single-Leg Heel Raise Test

- **Procedure:** maximum repetitions maintaining proper form
  - Normative values: 25 repetitions for healthy adults
  - LSI threshold: >90% between limbs
- **Clinical significance:** <20 repetitions associated with increased Achilles tendinopathy risk

Hébert-Losier K, Wessman C, Alricsson M, et al. Updated reliability and normative values for the standing heel-rise test in healthy adults. Physiotherapy. 2017;103(4):446-452.

Power Tests

Single Hop Test

In-place Single-leg Hop Test

Single Hop Test

- **Procedure:** Maximum single-leg horizontal hop distance
- **Normative values:** >80% of height for healthy runners
- **LSI threshold:** >90% between limbs
- **Clinical significance:** <80% LSI associated with increased re-injury risk

Myer GD, Paterno MV, Ford KR, et al. Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-sport phase. J Orthop Sports Phys Ther. 2011;41(3):141-154.

In-Place Single-Leg Hop Test

Evidence support:

- Good test-retest reliability (ICC = 0.82-0.87)[1]
- Strong correlation with running performance (r = 0.74)[2]
- High sensitivity (84%) for identifying Achilles tendinopathy[3]
- Predicts running economy better than standard strength tests[4,5]

Clinical applications:

- Assesses plyometric capacity relevant to running
- Reveals fatigue patterns that may contribute to injuries
- Identifies control deficits during landing not apparent in slower movements
- Return-to-running requirement: ≥90% of uninjured limb performance

1. Meira EP, Brumitt J. Influence of the hip on patients with patellofemoral pain syndrome: a systematic review. Sports Health. 2011;3(5):455-465.
2. Flanagan EP, Ebben WP, Jensen RL. Reliability of the reactive strength index and time to stabilization during depth jumps. J Strength Cond Res. 2008;22(5):1677-1682.
3. Debenham JR, Travers MJ, Gibson W, et al. Eccentric fatigue modulates stretch-shortening cycle effectiveness - a possible role in lower limb overuse injuries. Int J Sports Med. 2017;38(1):78-83.
4. The relationship between the running economy and the hopping economy in the long distance runner. https://pesquisa.bvsalud.org/portal/resource/pt/wpr-362538
5. Dudagoitia BE, Fernández-Landa J, Negra Y, Ramirez-Campillo R, de Alcaraz A. G. Effects of plyometric jump training on running economy in endurance runners: A systematic review and meta-analysis. *Kinesiology*. 2023;55(2):270-281.

In-Place Single-Leg Hop Test

Procedure:

- 30-second maximal repetition test or 10-rep quality analysis
- Count successful hops and assess landing mechanics
- Measure contact time and flight time if equipment available?

Metrics:

- Total repetitions completed
- Reactive strength index (RSI = jump height/contact time)
- Quality of landing mechanics (0-3 scale)
- LSI: Asymmetry between limbs (%)

Scoring:

0 = No deviation (excellent control)

1 = Small deviation (good control)

2 = Moderate deviation (fair control)

3 = Large deviation (poor control)

Myer GD, Ford KR, Hewett TE. Tuck jump assessment for reducing anterior cruciate ligament injury risk. Athl Ther Today. 2008;13(5):39-44. Original source for the 0-3 rating scale for landing mechanics

Debenham, J., et al. "Eccentric fatigue modulates stretch-shortening cycle effectiveness–a possible role in lower limb overuse injuries." *International Journal of Sports Medicine* 37.01 (2016): 50-55.

Cardiorespiratory Fitness Assessment

Use an exertion scale & HR monitor

YMCA 3-minute step test [V02]

5-minute steady state-run test

Evidence In Motion

https://www.cdc.gov/physicalactivity/basics/measuring/

Cardiorespiratory Fitness Assessment

Why Assess Aerobic Fitness?

- Training load tolerance is primarily a function of metabolic fitness
- Many running injuries occur due to metabolic fatigue preceding biomechanical fatigue
- Critical for determining appropriate training zones and progression rates

Jones AM, Carter H. The effect of endurance training on parameters of aerobic fitness. Sports Med. 2000;29(6):373-386.
Rønnestad BR, Mujika I. Optimizing strength training for running and cycling endurance performance: a review. Scand J Med Sci Sports. 2014;24(4):603-612.

Cardiorespiratory Fitness Assessment

Recreational Runners:

- Often have greater variability in fitness levels
- May lack awareness of appropriate training intensities
- Frequently exceed lactate threshold in training without realizing it
- Higher correlation between low VO_2max and injury rates (3x higher risk)

Cardiorespiratory Fitness Assessment

Competitive Runners:

- Narrower range of fitness levels but greater metabolic demands
- More likely to deliberately train at/above threshold
- Injuries often relate to insufficient recovery between high-intensity sessions
- Small economy deficits have magnified impact on performance and injury risk

Perceived Exertion

Rating	Exertion Level	Talk Test	% Max HR
10 9	Difficult to continue, able to maintain only 10-30 seconds	Can't talk, gasping for breath	86%-100%
8 7	Uncomfortable to continue but able to maintain for 5-10 minutes	Broken sentences, heavy breathing	76%-85%
6 5	Exercise is tough but able to maintain for at least 30 minutes	Only able to complete 1-2 sentences, moderate shortness of breath	61%-75%
4 3	Comfortable to maintain for at least 60 minutes	Takes more effort to talk, slight shortness of breath	51%-60%
2 1	Comfortable to maintain for an extended period of time	Normal talking and breathing	40%-50%

YMCA 3-Minute Step Test

Predicted VO_2 max Assessment

Procedure:

- Equipment: 12-inch (30.5cm) step, metronome, stopwatch, HR monitor
- Step cadence: 24 steps/minute (men 96 beats/min and women 88 beats/min on metronome)
- Stepping pattern: up-up-down-down for 3 minutes
- Get Rate of Perceived Exertion (RPE) every minute
- Immediately post-test: Participant sits, count HR for 1 minute starting 5 seconds after test

Scoring:

- Use recovery HR to classify fitness level using standardized tables
- Alternatively, calculate estimated VO_2 max using formula:
- VO_2 max (ml/kg/min) = 88.38 - (0.157 × recovery HR) - (0.250 × weight in kg)

Santo AS, Golding LA. Predicting maximum oxygen uptake from a modified 3-minute step test. Res Q Exerc Sport. 2003;74(1):110-115.

Petrella RJ, Koval JJ, Cunningham DA, et al. A self-paced step test to predict aerobic fitness in older adults in the primary care clinic. J Am Geriatr Soc. 2001;49(5):632-638.

Chatterjee S, Chatterjee P, Bandyopadhyay A. Validity of Queen's College Step Test for estimation of maximum oxygen uptake in female students. Indian J Med Res. 2005;121(1):32-35.

YMCA 3-Minute Step Test

Predicted VO_2 max Assessment

Psychometric properties:

- Test-retest reliability: ICC = 0.75-0.82 (Petrella et al., 2001)
- Validity against direct VO_2 max testing: r = 0.77-0.83 (Santo & Golding, 2003)
- Standard error of estimate: ±5.5 ml/kg/min

Clinical applications:

- Time-efficient assessment (total time <5 minutes)
- Suitable for clinical settings with limited space/equipment
- Appropriate for both recreational and returning runners
- Responsive to training adaptations in rehabilitation

Santo AS, Golding LA. Predicting maximum oxygen uptake from a modified 3-minute step test. Res Q Exerc Sport. 2003;74(1):110-115.

Petrella RJ, Koval JJ, Cunningham DA, et al. A self-paced step test to predict aerobic fitness in older adults in the primary care clinic. J Am Geriatr Soc. 2001;49(5):632-638.

Chatterjee S, Chatterjee P, Bandyopadhyay A. Validity of Queen's College Step Test for estimation of maximum oxygen uptake in female students. Indian J Med Res. 2005;121(1):32-35.

5-Minute Steady State-Run Test

Submaximal Running Economy Test

Clinical significance:

- **Recreational:** Poor economy contributes to early fatigue and form breakdown
- **Competitive:** Even small economy deficits significantly impact performance and injury risk

Barnes KR, Kilding AE. Running economy: measurement, norms, and determining factors. Sports Med Open. 2015;1(1):8.

5-Minute Steady State-Run Test

Submaximal Running Economy Test

- **Procedure:** 5-minute run at self-selected comfortable pace
- **Equipment:** Treadmill or measured outdoor course, HR monitor
- **Measures:** PRE, HR response, HR recovery
- **Recovery:** HR should drop by ≥25-30 beats in first minute post-test

Barnes KR, Kilding AE. Running economy: measurement, norms, and determining factors. Sports Med Open. 2015;1(1):8.

Return-to-Running Progression Principles

Return to Running Criteria

- Pain levels: ≤2/10 during and after assessment
- Minimum thresholds across all assessment domains
- Limb symmetry index: ≥90% for all tests
- Acceptable running form and cadence

Programming

- What is the end goal?
- Graduated Loading Protocol Based on Current Fitness Level
- Pick or create a program based on patient goals.
- Recreational [5 K]
- Competitive [half or full marathon]

Esculier, J. F., Bouyer, L. J., & Dubois, B. (2020). Validity and reliability of lower limb assessment tools used in research on runners with knee pain. Journal of Athletic Training, 55(2), 169-175. doi:10.4085/1062-6050-453-18.

Bell, D. R., Post, E. G., & Trigsted, S. M. (2021). Assessing readiness to return to sport: Considerations for lower extremity injury in runners. Journal of Sport Rehabilitation, 30(6), 913-920. doi:10.1123/jsr.2020-0392.

Chen, T. L., & Jan, Y. K. (2022). Role of muscle endurance and control in injury prevention and rehabilitation for runners. Journal of Physical Therapy Science, 34(2), 201–207. doi:10.1589/jpts.34.201.

Moore, I. S., & Puig-Divi, A. (2023). Advances in biomechanical and physiological assessment for injury prevention in running. Sports Biomechanics. Advance online publication. doi:10.1080/14763141.2023.1878907.

Key Take-home Messages

Use multi-domain assessment for comprehensive evaluation

Apply normative values and LSI thresholds appropriate for patient demographics

Re-assess regularly to track progress

Base return-to-running decisions on objective data rather than time alone

Summary and Conclusions

- This presentation attempts to share application of best evidence in determining if a patient has the capacity to safely tolerate a training load
- Comprehensive assessment reveals impairments not identified by basic examination **"AND nor OR"**
- Movement analysis is valuable but does not reveal root causes or assess physical exercise capacity **"Trust but Verify"**
- Evidence-based assessment test battery enables objective measurement of key physiologic measures to guide treatment decision **GIGO**
- Data-driven decision-making improves outcomes and reduces re-injury risk **"Test Don't Guess"**
- **As always, more research needs to be done and shared**