Safe to Run? Physiologic Assessments for the Lower Quarter

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Know Before You Go

- **Session Format:** This 2 hour session will include both lecture and lab components. Participation is at your own risk—engage as actively as you feel comfortable.
- **Preparation & Attire:**
- If you plan to participate, please dress appropriately.
- Download the following apps before the session:
  - **Metronome App**: Use any metronome app or this Google Metronome.
  - **Bubble Level App**: Install a bubble level app on your mobile device to use as an inclinometer.
  - **OnForm App**: Download the free version of OnForm on your phone or tablet for motion analysis. Ensure your account is activated before the session. https://onform.com/
  - Know your Height in cm
  - Know your Leg Length ASIS to Medial Malleolus in cm

Objectives

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

Epidemiology

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.

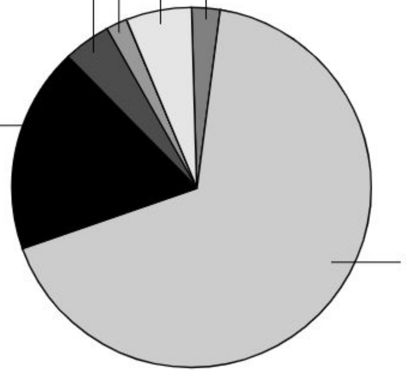

Figure 1 Breakdown of running surfaces.

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.

ORIGINAL ARTICLE

A prospective study of running injuries: the Vancouver Sun Run "In Training" clinics

J E Taunton, M B Ryan, D B Clement, D C McKenzie, D R Lloyd-Smith, B D Zumbo

Br J Sports Med 2003;**37**:239–244

The Running Injury Equation

- Running injuries occur when training load exceeds physiologic capacity
- **Injury risk equation: Training Load ÷ Physiologic Capacity = Injury Risk**
- Statistics on running injury prevalence (50-75% annual injury rate among runners)
- Reference: 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.

What is the problem?

LOAD [What you want to do.]

- Volume
- Intensity
- Frequency
- Mindset

CAPACITY [What you can done.]

- 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)

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Limitations of Basic Assessment Techniques

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

- Plantar fasciitis: Limited ankle dorsiflexion (particularly with the knee extended) associated with 2.1x higher risk (Pohl et al., 2009)
- Patellofemoral pain: Reduced quadriceps and hamstring flexibility correlated with increased risk (Witvrouw et al., 2000)
- Iliotibial band syndrome No clear relationship with flexibility measures (Aderem & Louw, 2015)
- Achilles tendinopathy Both excessive flexibility and stiffness showed associations with injury development (O'Neill et al., 2016)

Limitations of Basic Assessment Techniques

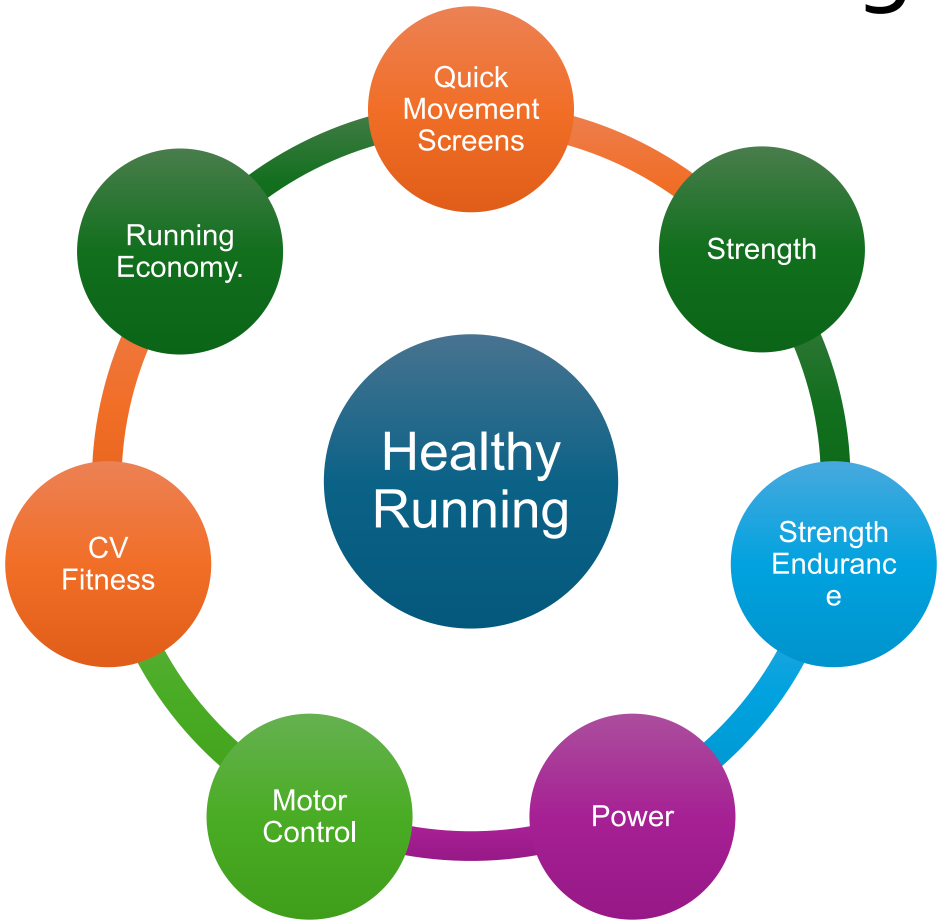
Validity Concerns for MMT related to running related Injures

- **Functional Correlation**: Poor relationship to athletic function
  - MMT grades 4-5 fail to correlate with functional performance in running tasks (Hickey et al., 2018)
  - Static strength measured via MMT showed weak correlation (r = 0.31-0.48) with dynamic strength during running (Schmitt et al., 2012)
- **Sensitivity Issues**: Limited ability to detect deficits in athletes
  - Ceiling effect: Most runners score 4-5/5 despite measurable strength differences on instrumented testing (Kolber et al., 2010)
  - Failure to detect bilateral deficits common in runners (Arnall et al., 2012)
  - Small but clinically relevant strength deficits (10-20%) undetectable via MMT (Bohannon, 2005)

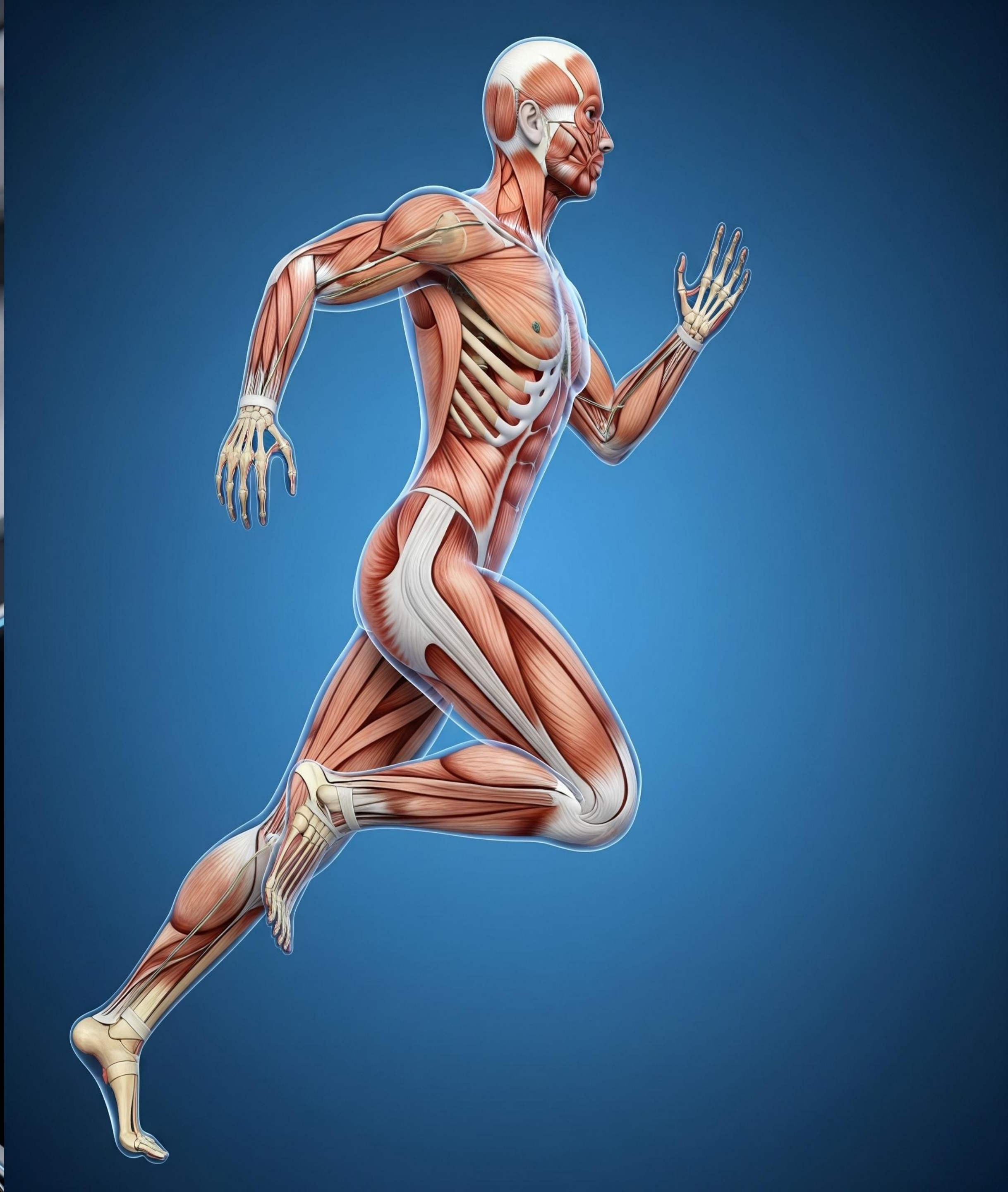
Specific Limitations for Runners

- **Inability to Assess Strength Endurance**:
  - Single maximal contraction fails to assess fatigue resistance crucial for running (Bazett-Jones et al., 2013)
  - Running injuries often manifest under fatigue conditions not captured by MMT (Hayes et al., 2004)

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.


RUNNING ECONOMY
MOTOR CONTROL
FLEXIBILITY
STRENGTH
POWER


Quick Movement Screens

- Overhead Forward Squat
- Arms Forward Squat
- Weight Bearing Lunge Test
- Navicular Drop Test
- Single-Leg Balance

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.

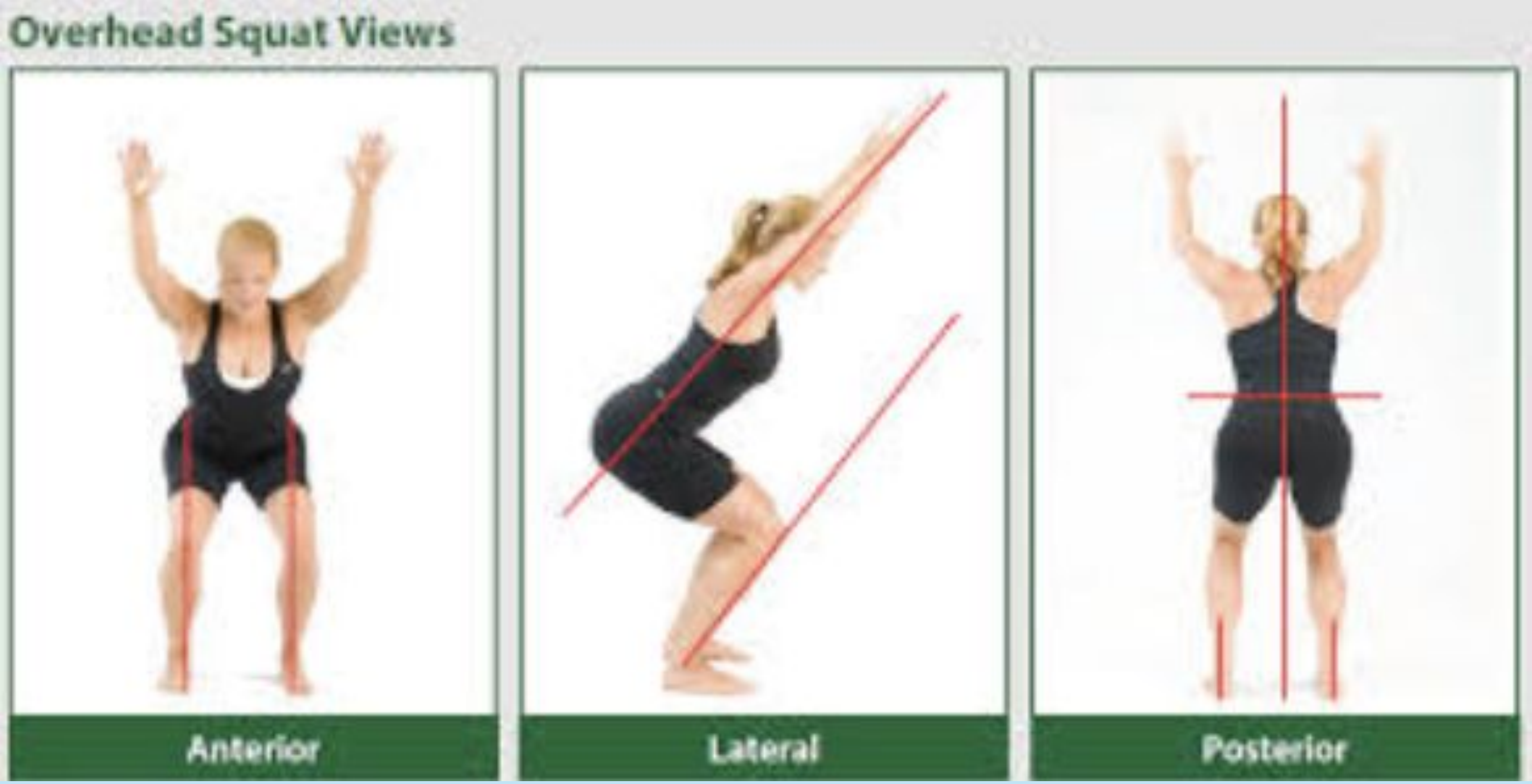
OVERHEAD SQUAT TEST (BISHOP 2006)

[redacted]


RESEARCH Open Access

Overhead squat assessment reflects treadmill running kinematics

Ozan Sever[1], Rıdvan Kır[2], Cihan Baykal[3], Zeki Akyildiz[3] and Hadi Nobari[4,5*]



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)

Figure 1. Overhead squat–negative (score 3).

UTILITY OF THE OVERHEAD SQUAT AND FORWARD ARM SQUAT IN SCREENING FOR LIMITED ANKLE DORSIFLEXION

ALON RABIN AND ZVI KOZOL
Department of Physiotherapy, Ariel University, Ariel, Israel

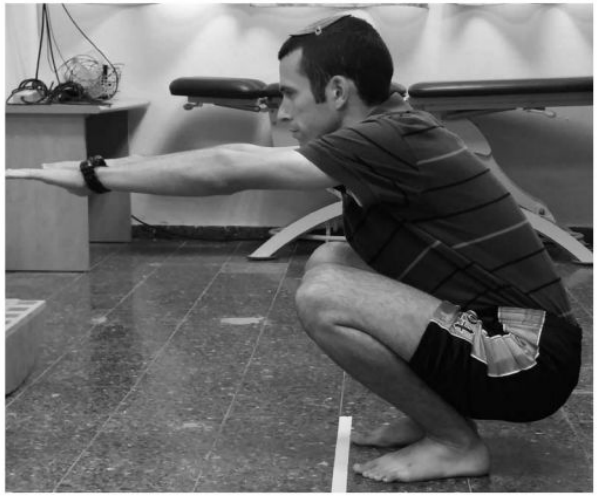


Figure 2. Forward arm squat–negative (score 0).

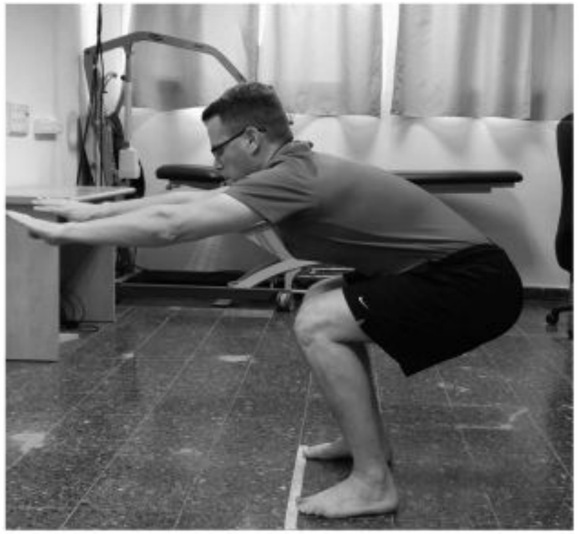


Figure 3. Forward arm squat–positive (score 1).

Arms Forward Squat Test

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

Evidence:

- Better isolation of lower extremity mechanics (Myer et al., 2014)
- Higher completion rates in clinical populations
- Comparable lower extremity kinematics to overhead squat (Pantoja et al., 2016)
- Reduced compensatory patterns from upper body restrictions

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

Arms Forward Squat Test

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

References:

- 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.
- 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.
- Schoenfeld BJ. Squatting kinematics and kinetics and their application to exercise performance. J Strength Cond Res. 2010;24(12):3497-3506.
- 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.

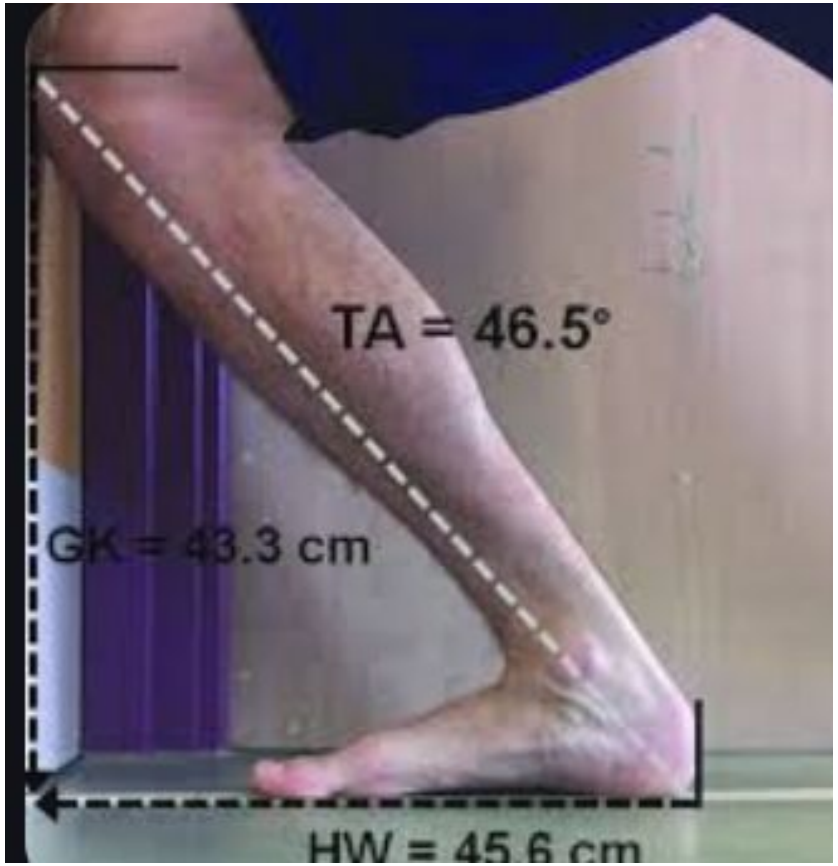
Weight-Bearing Lunge Test

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



WEIGHT BEARING LUNGE TEST (ANKLE DF)

- Warning a fair amount of procedure variability in the literature
- **References**:

- 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.
- 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.
- 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.

Modified = Degrees

Kneeling/standard = distance

Navicular Drop Test

Procedure: measuring dynamic foot pronation

- - Normative values: 5-9mm acceptable
- - Clinical significance: >10mm associated with medial lower extremity injuries

  Current Evidence & Limitations

- * Questionable inter-rater reliability (ICC = 0.51-0.79) (McPoil et al., 2008)
- * Limited correlation with dynamic foot function during running (Kasmer et al., 2016)
- * Poor predictive value as standalone test for running injuries (Barton et al., 2010)
- * Recommend using as part of comprehensive assessment rather than in isolation

References:

- * Neal BS, Griffiths IB, Dowling GJ, et al. Foot posture as a risk factor for lower limb overuse injury: a systematic review and meta-analysis. J Foot Ankle Res. 2014;7(1):55.
- * McPoil TG, Cornwall MW, Medoff L, et al. Arch height change during sit-to-stand: an alternative for the navicular drop test. J Foot Ankle Res. 2008;1(1):3.
- * Barton CJ, Levinger P, Menz HB, et al. Relationships between the Foot Posture Index and foot kinematics during gait in individuals with and without patellofemoral pain syndrome. J Foot Ankle Res. 2011;4:10.

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

https://www.physio-pedia.com/Single_Leg_Stance_Test

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

Reference:

- 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

- 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.
- **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
- 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.
- **Consider LSI**

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 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)

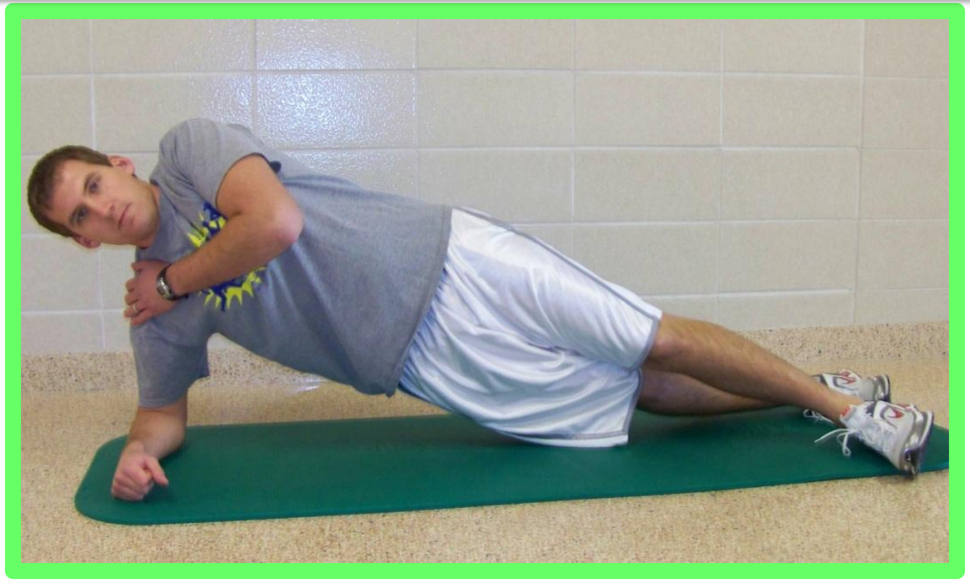
Core Endurance Ratio:

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

References:

- 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 TESTS (MCGILL 2002)



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

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

Reference: 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.

Motor Control Assessment

- Lateral Step-Down Test (Piva Protocol)
- Single-Leg Squat For Dynamic Control
- Running Gait Analysis

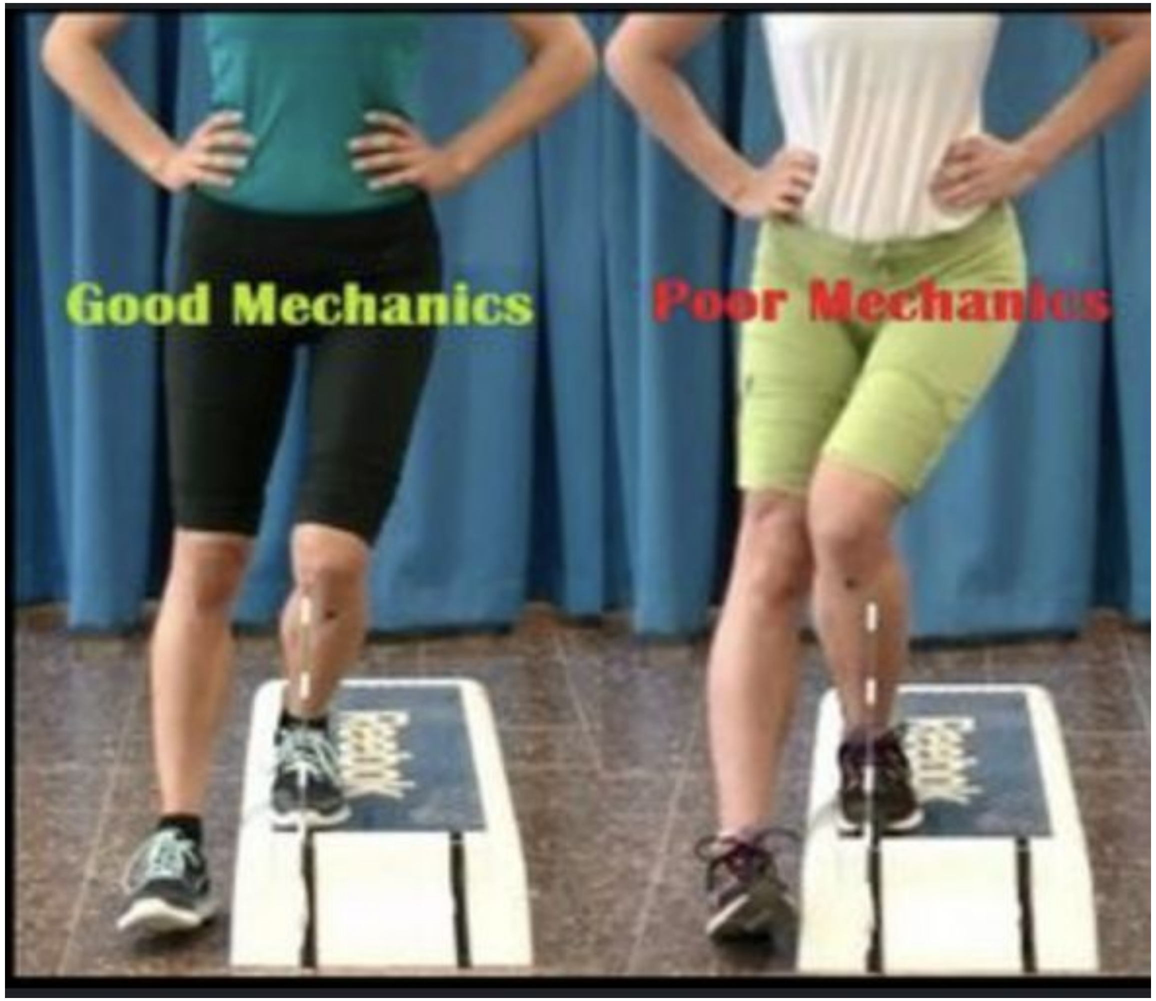
Lateral Step-Down Test (Piva Protocol)

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 (Piva et al., 2006)
- Intra-rater reliability: ICC = 0.80-0.85 (Rabin et al., 2014)
- Test-retest reliability: ICC = 0.78-0.82 (Park et al., 2016)



https://wikism.org/Lateral_Step_Down_Test

Piva Step Down Test Score Sheet

Name:	**Date:**	**Age:**	**Gender: M F**
P1:		**P2**	
P3:		**P4:**	
Step Height:		**Load:**	
Pre-Test Sx's.		**Post-Test Sx's.**	

PROCEEDURES		
Step # 1	STAND ON 20 CM STEP	
Step # 2	HANDS ON HIPS	
Step # 3	TEST FOOT TO EDGE OF STEP	
Step # 4	5 REPS	
Step # 5	INSTRUCT: "Tap your heel lightly on the floor and stand up quickly."	
Step # 6	Test both LE	Lateral < Anterior

Lateral Step Down

LEFT	SCORING	RIGHT
ARM STRATEGY	1 Point Per Fault	ARM STRATEGY
TRUNK STRATEGY	0-1 = GOOD	TRUNK STRATEGY
PELVIC STRATEGY	2-3 = MEDIUM	PELVIC STRATEGY
KNEE MEDIAL 2nd TOE	> 4 = POOR	KNEE MEDIAL 2nd TOE
KNEE MEDIAL MLA		KNEE MEDIAL MLA
UNSTEADINESS	Total each side & compare	UNSTEADINESS
Total =	ICC = 0.94	Total =

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

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
- 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)

Single-Leg Squat for Dynamic 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

References:

- 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.
- 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.

Power Tests

- Single Hop Test
- Triple 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

Reference: 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.

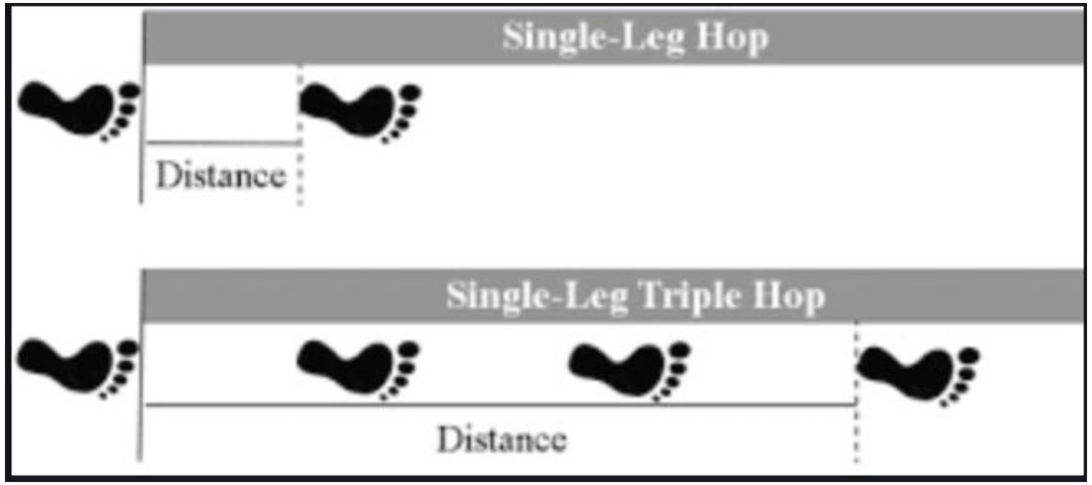
Triple Hop Test

Procedure: maximum distance in three consecutive hops

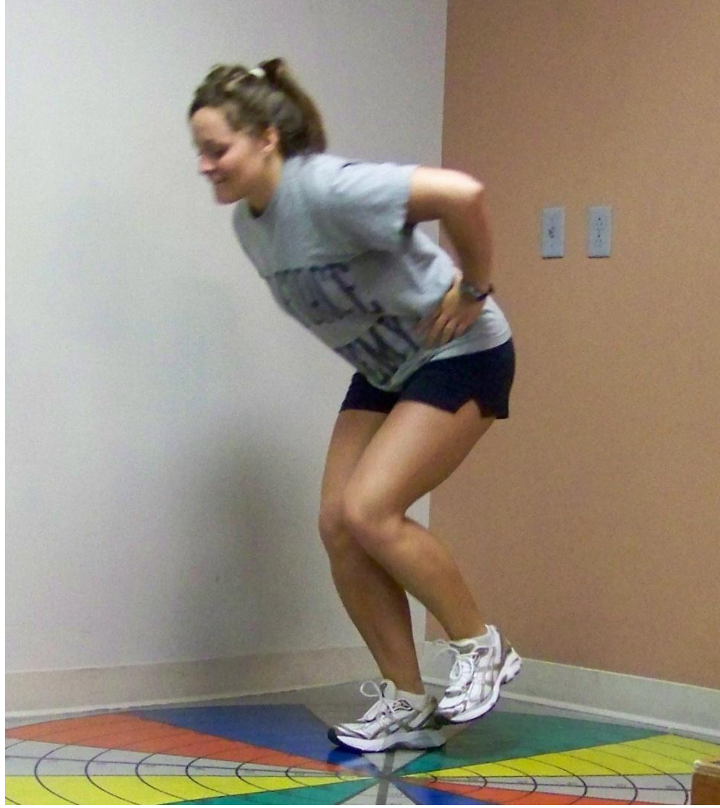
- Normative values: >250% of height for healthy runners
- LSI threshold: >90% between limbs

Clinical significance: more sensitive than single hop for detecting subtle deficits

Reference: Munro AG, Herrington LC. Between-session reliability of four hop tests and the agility T-test. J Strength Cond Res. 2011;25(5):1470-1477.



In-Place Single-Leg Hop Test



Evidence support:

- Good test-retest reliability (ICC = 0.82-0.87) (Meira & Brumitt, 2011)
- Strong correlation with running performance (r = 0.74) (Flanagan et al., 2007)
- High sensitivity (84%) for identifying Achilles tendinopathy (Debenham et al., 2017)
- Predicts running economy better than standard strength tests (Azevedo et al., 2016)

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

References:

- Meira EP, Brumitt J. Influence of the hip on patients with patellofemoral pain syndrome: a systematic review. Sports Health. 2011;3(5):455-465.
- 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.
- 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.

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 (%)

In-Place Single-Leg Hop Test

Scoring:

- 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
- 0 = No deviation (excellent control)
- 1 = Small deviation (good control)
- 2 = Moderate deviation (fair control)
- 3 = Large deviation (poor control)

Supporting References

- 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.
- Applied this scale to repetitive single-leg hop testing in runners
- Demonstrated its ability to identify altered landing mechanics in runners with Achilles tendinopathy
- Found 84% sensitivity using this assessment scale

Running Gait Analysis

- Maykut JN, Taylor-Haas JA, Paterno MV, DiCesare CA, Ford KR. Concurrent validity and reliability of 2D kinematic analysis of frontal plane motion during running. Int J Sports Phys Ther. 2015;10(2):136-146.
- Dingenen B, Barton C, Janssen T, Benoit A, Malliaras P. Test-retest reliability of two-dimensional video analysis during running. Phys Ther Sport. 2018;33:40-47
- 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.
- Schurr SA, Marshall AN, Resch JE, Saliba SA. Two-dimensional video analysis is comparable to 3D motion capture in lower extremity movement assessment. Int J Sports Phys Ther. 2017;12(2):163-172.
- Munro A, Herrington L, Carolan M. Reliability of 2-dimensional video assessment of frontal-plane dynamic knee valgus during common athletic screening tasks. J Sport Rehabil. 2012;21(1):7-11.

Cardiorespiratory Fitness Assessment - Recreational vs. Competitive

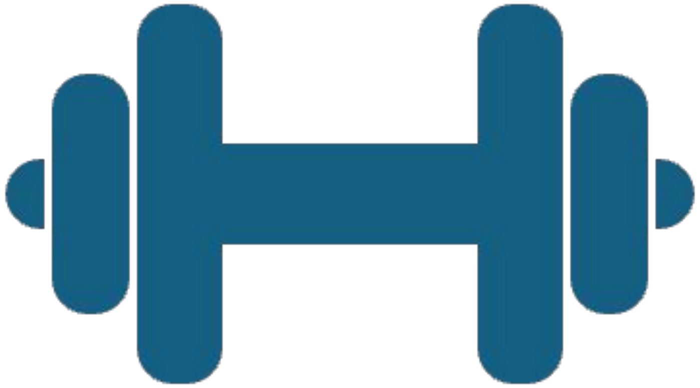
Why Assess Aerobic Fitness?

- 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 vs. Competitive

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 - Recreational vs. Competitive

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

Cardiorespiratory Fitness Assessment

- Use an exertion Scale & HR Monitor
- YMCA 3-Minute Step Test [V02]
- Talk Test for Lactate Threshold
- 5-Minute Steady State-Run Test

PERCEIVED EXERTION

GOPHER Teach-nique

RATING	EXERTION LEVEL	TALK TEST	% OF 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)

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

YMCA 3-Minute Step Test-Predicted VO_2 max Assessment

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

References:

- 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.

Talk Test for Lactate Threshold - Field Tests for Running Economy and Lactate Threshold

Clinical applications:

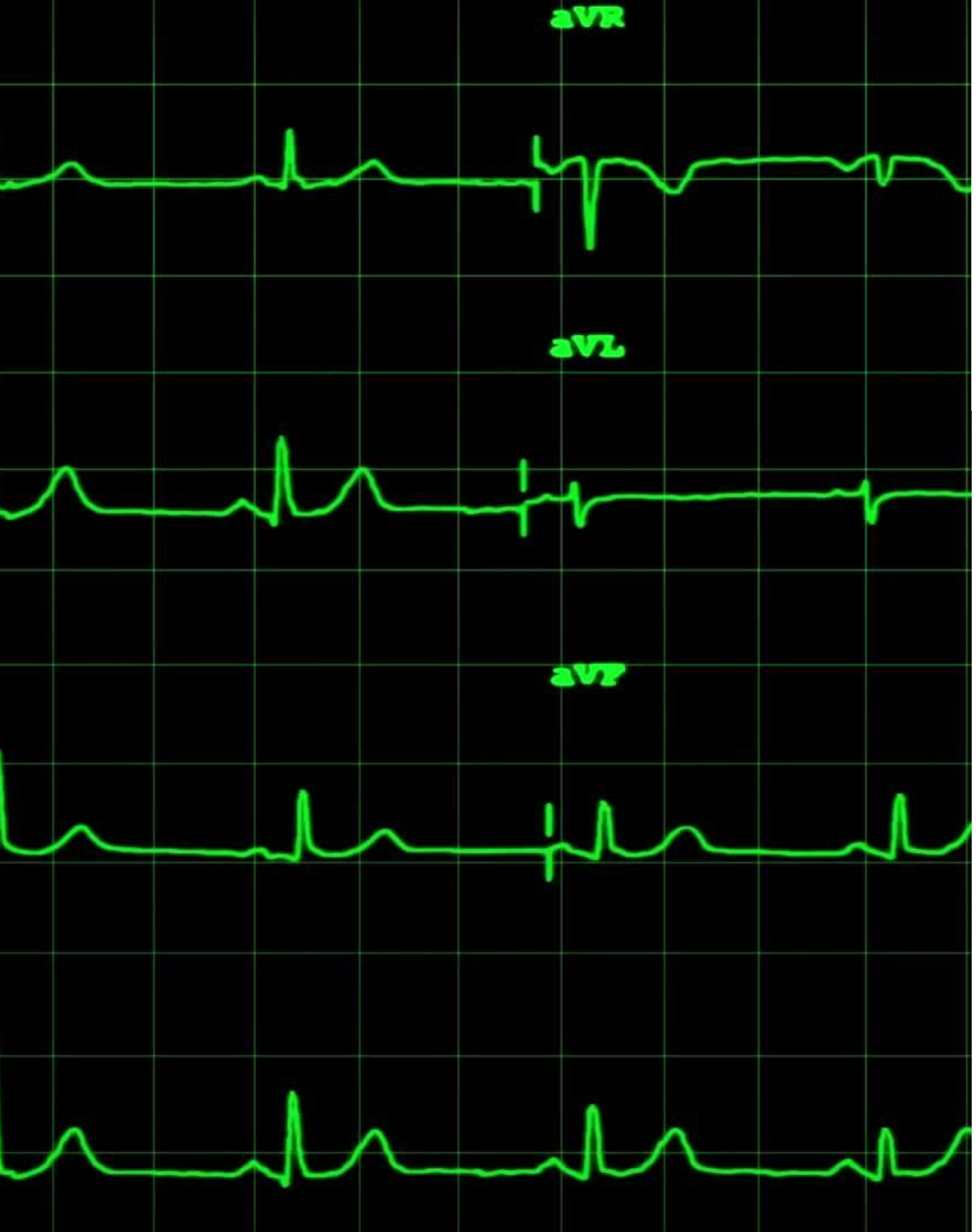
- Simple field test requiring no specialized equipment
- Can be performed during regular training sessions
- Helps establish appropriate training zones

References:

- Quinn TJ, Coons BA. The talk test and its relationship with the ventilatory and lactate thresholds. J Sports Sci. 2011;29(11):1175-1182.
- Recalde PT, Foster C, Skemp-Arlt KM, et al. The talk test as a simple marker of ventilatory threshold. S Afr J Sports Med. 2017;25(1):23-27.
- Persinger R, Foster C, Gibson M, et al. Consistency of the talk test for exercise prescription. Med Sci Sports Exerc. 2004;36(9):1632-1636.

Talk Test for Lactate Threshold - Field Tests for Running Economy and Lactate Threshold

1. PROCEDURE (RECALDE 2017): PROGRESSIVE INTENSITY RUNNING WITH SPEECH ASSESSMENT
2. START AT CONVERSATIONAL PACE
3. INCREASE INTENSITY EVERY 3 MINUTES
4. INITIAL PACE, RPE 2 “EASY”
5. INCREASE IN VELOCITY OF 0.22 M/S OR 0.49 MPH UNTIL A RPE OF 4 “SOMEWHAT HARD”
6. THEREAFTER INCREASE INCLINE 2% UNTIL SUBJECT BECOME FATIGUED
7. AT EACH STAGE, PATIENT RECITES STANDARD PARAGRAPH (E.G., PLEDGE OF ALLEGIANCE)
8. CONTINUE UNTIL SPEECH BECOMES CONSISTENTLY DIFFICULT/BROKEN



Talk Test for Lactate Threshold - Field Tests for Running Economy and Lactate Threshold

Interpretation:

- Last stage with comfortable speech = below threshold
- First stage with difficult/broken speech = at/above threshold

Evidence support:

- Correlation with laboratory-determined lactate threshold: r = 0.85-0.94
- Test-retest reliability: ICC = 0.81-0.88
- Population-specific findings:
- Recreational runners: tends to occur at 75-80% of max HR
- Competitive runners: tends to occur at 80-85% of max HR

5-Minute Steady State-Run Test - Submaximal Running Economy Test

Procedure: 5-minute run at self-selected comfortable pace

- Measures: HR response, HR recovery, RPE
- Equipment: Treadmill or measured outdoor course, HR monitor
- Population-specific interpretation:

5-Minute Steady State-Run Test - Submaximal Running Economy Test

Recreational Runners

- Target HR: 65-75% of age-predicted max at comfortable pace
- Recovery: HR should drop by ≥25 beats in first minute post-test
- RPE: Should report 3-4/10 effort level at paces that would be moderate for recreational

5-Minute Steady State-Run Test - Submaximal Running Economy Test

Competitive Runners:

- Target HR: 60-70% of age-predicted max at same absolute pace as recreational
- Recovery: HR should drop by ≥30 beats in first minute post-test
- RPE: Should report 2-3/10 effort level at paces that would be moderate for recreational

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

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

Assessment Interpretation

Establishing Baseline Values**

- Track changes over time
- Patient Centered and data driven decision making for interventions and progression
- Documentation templates (provide example)
- Color-coding system for deficits (red, yellow, green)
- Assessment Scorecard: visual representation of patient's performance across domains

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]

Return-to-Running Progression - Recreational vs. Competitive

Decision criteria: Advance progression when all assessment domains show ≥90% of baseline

When to hold: Any pain >2/10 during or >3/10 after, or increased morning stiffness

Willy RW, Paquette MR. The physiology and biomechanics of the master runner. Sports Med Arthrosc Rev. 2019;27(1):15-21.

Reference: Rambaud AJ, Ardern CL, Thoreux P, et al. Criteria-based return to running program after lower limb injury: scientific evidence, practical aspects, and perspectives. Ann Phys Rehabil Med. 2018;61(6):443-450.

Return-to-Running Progression - Recreational vs. Competitive

Recreational Runners:

- Initial load: 20-30% of pre-injury volume
- Progression rate: 10-15% increase per week if symptom-free
- Walk-run ratio: Begin with 1:1 to 1:2 run:walk ratio
- Intensity cap: Keep HR below 75% of max for first 2 weeks
- Key metrics: Monitor RPE (should stay <4/10) and HR recovery

Return-to-Running Progression - Recreational vs. Competitive

Competitive Runners:

- Initial load: 30-40% of pre-injury volume with demonstrated adequate VO_2 max
- Progression rate: 15-20% increase per week if symptom-free
- Walk-run ratio: May begin with continuous running if metabolic fitness preserved
- Intensity considerations: Can introduce threshold work by week 3 if no symptoms
- Key metrics: Monitor running economy metrics and lactate threshold preservation

Case Study Examples - Recreational vs. Competitive

Case 1: Case 1: Recreational Runner with Patellofemoral Pain**

- 42-year-old female, running 15 miles/week, training for first half marathon
- Initial findings:
- VO_2 max: 32 ml/kg/min (below adequate range)
- Running economy: HR 88% of max at "comfortable" pace
- Hip strength deficits: 65% LSI for abductors

Intervention Framework the Recreational Runner

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.

Case 1: Case 1: Recreational Runner with Patellofemoral Pain

- Intervention focus
- .
- .
- .
- .
- .

Case Study Examples - Recreational vs. Competitive

Case 2: Competitive Runner with Achilles Tendinopathy**

- 28-year-old male, 50 miles/week, 10K specialist (34:30 PR)
- Initial findings:
- VO_2max: 62 ml/kg/min (adequate range)
- Economy: Preserved at submaximal paces
- Heel raise endurance: 60% LSI, calf power deficit

Intervention Framework the Competitive Runner

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.

Case 2: Competitive Runner with Achilles Tendinopathy**

- Intervention focus:
- .
- .
- .
- .
- .

Clinical Decision-Making

- Case Study Application**
- - Example runner profile with assessment results
- - Identification of key deficits across domains
- - Prioritization of interventions based on assessment findings
- - Re-assessment timeline and minimal clinically important differences (MCIDs)

- 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

Comprehensive assessment reveals impairments not identified by basic examination

Movement analysis is valuable but does not reveal root causes or assess physical exercise capacity

Evidence-based assessment test battery enables objective measurement of key physiologic measures to guide treatment decision

Data-driven decision-making improves outcomes and reduces re-injury risk

This presentation attempts to share application of best evidence in determining if a patient has the capacity to safely tolerate a training load

As always, more research needs to be done and shared

Additional References

•Willy, R. W., & Paquette, M. R. (2019). The physiology and biomechanics of the master runner. Sports Medicine and Arthroscopy Review, 27(1), 15–21. doi:10.1097/JSA.0000000000000237.

•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.