Functional Movement and Injury Risk

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Objectives:

- Define functional movement assessment
- Define injury risk assessment and how to establish a risk profile
- Identify common musculoskeletal and neuromuscular risk factors for injury
- Review common screening tests
- Considerations for test selection and screening
- How do we build lifelong athletes for long-term prevention and resiliency?
- Review prevention strategies for:
  - ACL Tears
  - Stress Fractures
  - Ankle Sprains

What is a Functional Movement Assessment?

- Assessment of a variety of foundational movements that are sport specific in the context of a specific test or in isolation.
- Athletes require:*
  - A variety of movement patterns or options
  - Coordination of movement options
  - Competence in body weight movements
- What is functional for an athlete?
  - Ability to adapt to the given demands of a sport using a variety of movement patterns/strategies, some compensatory in nature.

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What is an Injury Risk Assessment?

- Use of a variety of screening measures to create a risk profile
- Includes:
  - Medical history review
  - Musculoskeletal and neuromuscular factors
  - Lifestyle habits (dieting, sleep hygiene, etc.)
  - Non-athletic stressors (school, parents, other extracurriculars)
  - Athletic stressors (coaches, parents, offseason length, self-pressure)
  - Long-term athletic goals

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  - Athletic stressors (coaches, parents, offseason length, self-pressure)
  - Long-term athletic goals
- Stratify information gathered in the above areas to determine what you can address within your scope of practice, and what necessary referrals need to be made.

Risk Factors for Injury

- Side-to-side strength asymmetries
- Ineffective movement strategies (knee valgus, lumbar hyper-extension)
- Ineffective force absorption/production
- Balance
- Load tolerance (acute vs. chronic)
- Joint range of motion/mobility
- Muscle extensibility
- Decreased training age
- Ineffective landing mechanics
- Larger Q-angle
- Intercondylar notch width
- Foot (arch) position
- Previous injury

Common Screening Tests

- Functional Movement Screen (FMS)*
- Selective Functional Movement Assessment (SFMA)
- Y-balance Test*
- Star Excursion Balance Test (SEBT)*
- Lower Extremity Functional Test (LEFT)
- Hop Testing
- Balance Error Scoring System (BESS)
- Landing Error Scoring System (LESS)*
- Local Muscular Fatigue Testing
- Fatigue Index

Functional Movement Screen (FMS)

- Series of 7 movement based tests used as a screening tool to determine functional limitations to movement.
  - Overhead Squat
  - In-line Lunge
  - Hurdle Step
  - Shoulder Mobility
  - Rotational Stability
  - Straight Leg Raise
  - Trunk Stability Pushup
- Each test is scored 0-3 with a max score of 21

Functional Movement Screen (FMS)

- What is the cutoff score for determining injury risk?
- Duke et al. – Experienced male Rugby Union players
  - A score of 14 or less was associated with a 10.42x increased risk of injury in the first half of the season (95% specificity), and 4.97x increased risk of injury in the second half of the season (90% specificity).
- Kiesel et al. – Professional American Football players
  - A score of 14 or less was associated with 11.67x increase in risk, LR+ 5.92, LR- 0.51. Sensitivity 54%, specificity 91%.

Functional Movement Screen (FMS)

- Advantages of the FMS
  - Quick and easy to administer
  - Inexpensive
  - Normative values have been established for age and some sports*
  - It has been shown to be a reliable test
- Challenges of the FMS
  - Variable sensitivity (12-84%) and specificity (46-94%) to predict injury has been reported
    - What is the operational definition of injury (time-loss vs. non-time-loss)?
  - More specific than sensitive (higher chance of false negatives).

Functional Movement Screen (FMS)

- Should we utilize cutoff scores?
  - Team vs. individual
- Regardless of a cutoff score, the collection of FMS tests can provide valuable information regarding:
  - Quality of movement
  - Functional limitations
  - Competency in multi-joint body weight movements
  - Determine the need for further evaluation

Y-Balance Test/Star Excursion Balance Test (SEBT)

- Test dynamic balance and the ability to reach in the anterior, posterolateral, and posteromedial directions.
- Results may be presented in terms of normalized score, reach asymmetry, or as a normalized composite score (CS).
  - Normalized score: Maximum score in each singular direction expressed as a percent of limb length.
  - Reach asymmetry: expressed as the difference between sides
  - CS: Maximum score in each direction is averaged, and expressed as a percent of limb length.
- Inter-rater reliability has been shown to be good for both normalized and composite scores

Y-Balance Test/Star Excursion Balance Test (SEBT)

- Gonnell et al. – Limb Reach Asymmetry and Mean
  - A difference of 4cm or more between limbs in the posteromedial direction was associated with a 3.86x more likelihood of sustaining a LE injury.
  - Players with a score lower than the mean in any direction were 2x more likely to sustain lower extremity injury.
- Plisky et al. – Limb Reach Asymmetry and CS
  - Difference of 4 cm or greater between anterior reach distance increased risk by 2.5x.
  - Girls with CS <94% were 6.5x more likely to sustain LE injury
- Butler et al. – Limb Reach Asymmetry and CS
  - CS <89.6% yielded a 3.5% higher risk of injury (Sensitivity 100%, Specificity 71.7%)
  - Were unable to establish an ideal cutoff score for limb reach asymmetry.

Y-Balance Test/Star Excursion Balance Test (SEBT)

- Do these tests fully represent the association between dynamic balance and risk of injury?
- While some studies show conflicting evidence, there is evidence that poor performance on these tests could be associated with an increased risk of LE injury.
- How do we train to improve performance?
  - Identify and address the limiting factors (ankle DF, core stability, single limb stability, strength, etc.)

Landing Error Scoring System (LESS)

- Athlete stands on a 30cm surface and jumps to a location on the floor that is 50% of their body height. Upon landing the athlete jumps for maximum height.
- The task is filmed from the sagittal and frontal plane for analysis (Hudl)
- The athlete is scored based on criteria including:
  - Stance width
  - Symmetric/asymmetric initial foot contact
  - Lateral trunk lean
  - Knee valgus
  - Toe out
  - Foot initial contact (toe vs. heel/flat)
  - Trunk flexion displacement
  - Knee flexion displacement
  - Total joint displacement
  - Overall impression
- Max score is 15 (higher the score the worse the performance)

Landing Error Scoring System (LESS)

- Demonstrates excellent reliability (intra- = 0.91, inter- = 0.84)
- LESS scoring has been shown to be influenced by factors such as sex, fatigue, and prior ACLR.
- LESS scoring can be modified through training
  - Training including PREs, core stability, power, and agility was shown to have a greater effect on post-test scores compared to just UE/LE PREs. (Distefano et al.)
- Padua et al. examined the ability of the LESS to identify those at risk for ACL injury in elite-youth soccer players.
  - Found that injured athletes had a higher mean score (6.24 +/- 1.75) compared to uninjured athletes (4.43 +/- 1.71)
  - ROC analysis suggested a cutoff score of 5 (86% sensitivity, 64% specificity)
  - A score of 5 or more was associated with a 10.7x greater risk of ACL injury

Landing Error Scoring System (LESS)

- Advantages
  - Quick and easy to administer
  - Use of slow-motion analysis
  - Places high demand on athlete similar to demands of sport
  - Provides a lot of information in a short period of time
- Disadvantages
  - Scoring can be time consuming
  - Technological difficulties
- Are the sensitivity (86%) and specificity (64%) good enough for a cutoff score of 5?

Considerations for Test Selection

- Number of athletes to be tested
- Time constraints
- Sport (tennis vs. lacrosse)
- What are common injuries for that sport?
- Test setting (clinic vs. outdoors/indoors during practice)
- Test sequencing (non-fatiguing vs. fatiguing tests)

Building Athletes for Life

- What can we do as clinicians to cultivate long-term resiliency?
- Educate athletes
  - Ensure they know the **WHY** behind the test
  - Ensure they understand the interplay between common risk factors and injury risk
- Promote long-term healthy habits within your scope
- Make it fun

Specific Injury Prevention Strategies

- ACL injury
- Stress fractures
- Ankle sprains

APPROPRIATE USE CRITERIA FOR ACL INJURY PREVENTION PROGRAMS

Adopted by the American Academy of Orthopaedic Surgeons Board of Directors

October 2, 2015

III. PATIENT INDICATIONS AND TREATMENTS

INDICATIONS

Table 4 Patient Indications and Classifications

Indication	Classification(s)
Sex	a) Male b) Female
Pubertal Status/Maturity	a) Pre-Pubertal b) Pubertal c) Post-Pubertal/Mature
Level of Activity	a) Competitive athlete b) Recreational athlete

- High Risk (*Athletes with characteristics such as poor knee, hip, and trunk control during landing/cutting screening tests, poor joint alignment, and those who have previously experienced an ACL injury are at higher risk for injury*)

TREATMENTS

Treatments Addressed Within This AUC

1. Supervised ACL Injury Prevention Program

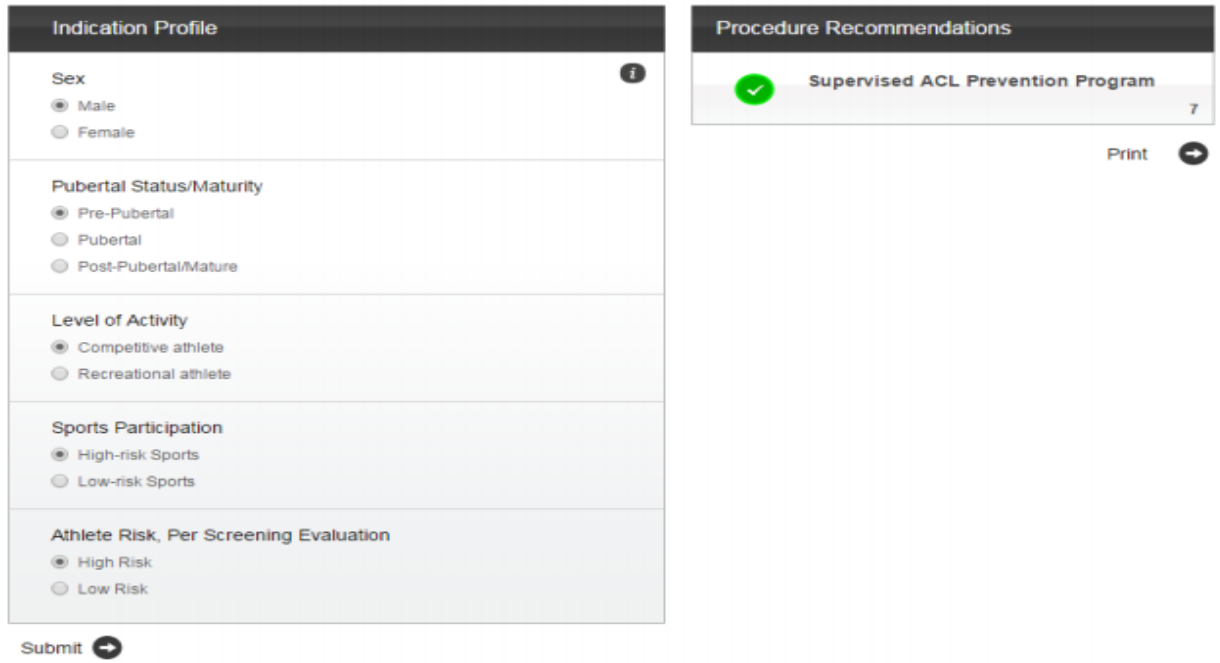
Includes:

- Appropriate instruction and supervision
- Dynamic warm-up
- Strength training (core, hip and thigh)
- Technique training (jumping, cutting)
- Plyometrics
- Balance and proprioceptive training
- Feedback cueing
- High-frequency utilization

IV. RESULTS OF APPROPRIATENESS RATINGS

For a user-friendly version of these appropriate use criteria and the supporting literature review findings, please access our AUC web-based application at www.aaos.org/aucapp. To view the interactive literature review used for this AUC, please click the following link: Interactive Literature Review.

Web-Based AUC Application Screenshot



Click Here to Access the AUC App!

- May be appropriate:
  - Male, Pre-Pubertal, Competitive athlete, **Low-risk Sports, Low Risk**
  - Male, Pre-Pubertal, Recreational athlete, **Low-risk Sports, Low Risk**
  - Male, Pubertal, Competitive athlete, **Low-risk Sports, Low Risk**
  - Male, Pubertal, Recreational athlete, **Low-risk Sports, Low Risk**
  - Male, Post-Pubertal/Mature, Recreational athlete, **Low-risk Sports, Low Risk**
  - Female, Pubertal, Recreational athlete, **Low-risk Sports, Low Risk**
  - Female, Post-Pubertal/Mature, Competitive athlete, **Low-risk Sports, Low Risk**
  - Female, Post-Pubertal/Mature, Recreational athlete, **Low-risk Sports, Low Risk**
- Probably appropriate:
  - Male, Pubertal, Competitive athlete, **High-risk Sports, High Risk**
  - Male, Post-Pubertal/Mature, Competitive athlete, **High-risk Sports, High Risk**
  - Female, Pre-Pubertal, Competitive athlete, **High-risk Sports, High Risk**
  - Female, Pre-Pubertal, Competitive athlete, Low-risk Sports, **High Risk**
  - Female, Pre-Pubertal, Recreational athlete, **High-risk Sports, High Risk**
  - Female, Pubertal, Competitive athlete, **High-risk Sports, High Risk**
  - Female, Pubertal, Competitive athlete, **High-risk Sports**, Low Risk
  - Female, Pubertal, Recreational athlete, **High-risk Sports, High Risk**
  - Female, Post-Pubertal/Mature, Competitive athlete, **High-risk Sports, High Risk**

But what does this mean???

Am J Sports Med. 2005 Jul;33(7):1003-10. Epub 2005 May 11.

Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up.

Mandelbaum BR[1], Silvers HJ, Watanabe DS, Knarr JF, Thomas SD, Griffin LY, Kirkendall DT, Garrett W Jr.

RESULTS: During the 2000 season, there was an 88% decrease in anterior cruciate ligament injury in the enrolled subjects compared to the control group. In year 2, during the 2001 season, there was a 74% reduction in anterior cruciate ligament tears in the intervention group compared to the age- and skill-matched controls.

Knee Surg Sports Traumatol Arthrosc. 1996;4(1):19-21.

Prevention of anterior cruciate ligament injuries in soccer. A prospective controlled study of proprioceptive training.

Caraffa A[1], Cerulli G, Projetti M, Aisa G, Rizzo A.

⊕ Author information

Abstract

Proprioceptive training has been shown to reduce the incidence of ankle sprains in different sports. It can also improve rehabilitation after anterior cruciate ligament (ACL) injuries whether treated operatively or nonoperatively. Since ACL injuries lead to long absence from sports and are one of the main causes of permanent sports disability, it is essential to try to prevent them. In a prospective controlled study of 600 soccer players in 40 semiprofessional or amateur teams, we studied the possible preventive effect of a gradually increasing proprioceptive training on four different types of wobble-boards during three soccer seasons. Three hundred players were instructed to train 20 min per day with 5 different phases of increasing difficulty. The first phase consisted of balance training without any balance board; phase 2 of training on a rectangular balance board; phase 3 of training on a round board; phase 4 of training on a combined round and rectangular board; phase 5 of training on a so-called BABS board. A control group of 300 players from other, comparable teams trained "normally" and received no special balance training. Both groups were observed for three whole soccer seasons, and possible ACL lesions were diagnosed by clinical examination, KT-1000 measurements, magnetic resonance imaging or computed tomography, and arthroscopy. We found an incidence of 1.15 ACL injuries per team per year in the proprioceptively trained group ($P < 0.001$). Proprioceptive training can thus significantly reduce the incidence of ACL injuries in soccer players.

BMJ. 2005 Feb 26;330(7489):449. Epub 2005 Feb 7.

Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial.

Olsen OE[1], Myklebust G, Engebretsen L, Holme I, Bahr R.

Box 2: Programme of warm-up exercises used to prevent injuries

Warm-up exercises
(30 seconds and one repetition each)
Jogging end to end
Backward running with sidesteps
Forward running with knee lifts and heel kicks
Sideways running with crossovers ("carioca")
Sideways running with arms lifted ("parade")
Forward running with trunk rotations
Forward running with intermittent stops
Speed run

Technique
(One exercise during each training session; 4 minutes and 5×30 seconds each)
Planting and cutting movements
Jump shot landings

Balance
(On a balance mat or wobble board, one exercise during each training session; 4 minutes and 2×90 seconds each)
Passing the ball (two leg stance)
Squats (one or two leg stance)
Passing the ball (one leg stance)
Bouncing the ball with eyes closed
Pushing each other off balance

Strength and power
(2 minutes and 3×10 repetitions each)
One quadriceps exercise:
- Squats to 80° of knee flexion
- Bounding strides (*Sprunglauf*)
- Forward jumps
- Jump shot—two legged landing
- "Nordic hamstring lowers" (2 minutes and 3×10 repetitions each)

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Table 4 Numbers and severity of injuries

	Intervention group (n=958)	Control group (n=879)	Rate ratio (95% CI)*	P value (z test)
All injuries:	103	195	0.49 (0.39 to 0.63)	<0.0001
Match	56	112	0.48 (0.35 to 0.66)	<0.0001
Training	47	83	0.53 (0.37 to 0.75)	<0.001
Slight	4	8	0.47 (0.14 to 1.55)	0.21
Minor	47	62	0.71 (0.48 to 1.03)	0.07
Moderate	20	56	0.33 (0.20 to 0.55)	<0.0001
Major	32	69	0.43 (0.28 to 0.66)	<0.0001
Overuse injuries:	18	39	0.43 (0.25 to 0.75)	0.003
Slight	0	3	—	—
Minor	4	9	0.41 (0.13 to 1.35)	0.14
Moderate	7	12	0.54 (0.21 to 1.38)	0.2
Major	7	15	0.44 (0.18 to 1.07)	0.07
Acute injuries:	85	156	0.51 (0.39 to 0.66)	<0.0001
Slight	4	5	0.76 (0.20 to 2.78)	0.66
Minor	43	53	0.75 (0.51 to 1.13)	0.17
Moderate	13	44	0.28 (0.15 to 0.51)	<0.0001
Major	25	54	0.43 (0.27 to 0.69)	0.001
Contact	51	82	0.58 (0.41 to 0.82)	0.002
Knee ligament injuries	3†‡	14‡§	0.20 (0.06 to 0.70)	0.01
Meniscus injuries	2	7	0.27 (0.06 to 1.28)	0.1
Players with two or more injuries	8	19	0.39 (0.17 to 0.90)	0.03
Re-injury¶	0	3	—	—

*Rate ratio obtained from Poisson model.
†Anterior cruciate ligament: n=3.
‡Anterior cruciate ligament (n=10), posterior cruciate ligament (n=3), medial collateral ligament (n=1).
§10 of the 16 ligament injuries to the cruciate ligament also included concomitant injuries to the medial collateral ligament, lateral collateral ligament, bone bruise, or meniscus injuries, or a combination of these.
¶Same type and location of injury.

Stress Fractures

- Most common sites
  - Tibia
  - Navicular
  - Metatarsal
  - Fibula
  - Femur (!!)
  - Pelvis
  - Spine

Risk Factors

- Consuming >10 alcoholic drinks per week
- Excessive physical activity with limited rest
- Female athlete triad
  - Eating disorders, amenorrhea, osteoporosis
  - Osteoporosis family history
  - Older age at menarche
- Female sex
- Low levels of vitamin D
- Recreational running (>25 miles per week)
- Running on hard surfaces
- Smoking
- Sudden increase in training
- Track (running sports)

Patel 2011, Chen 2013

Prevention

- Identify and address modifiable risk factors

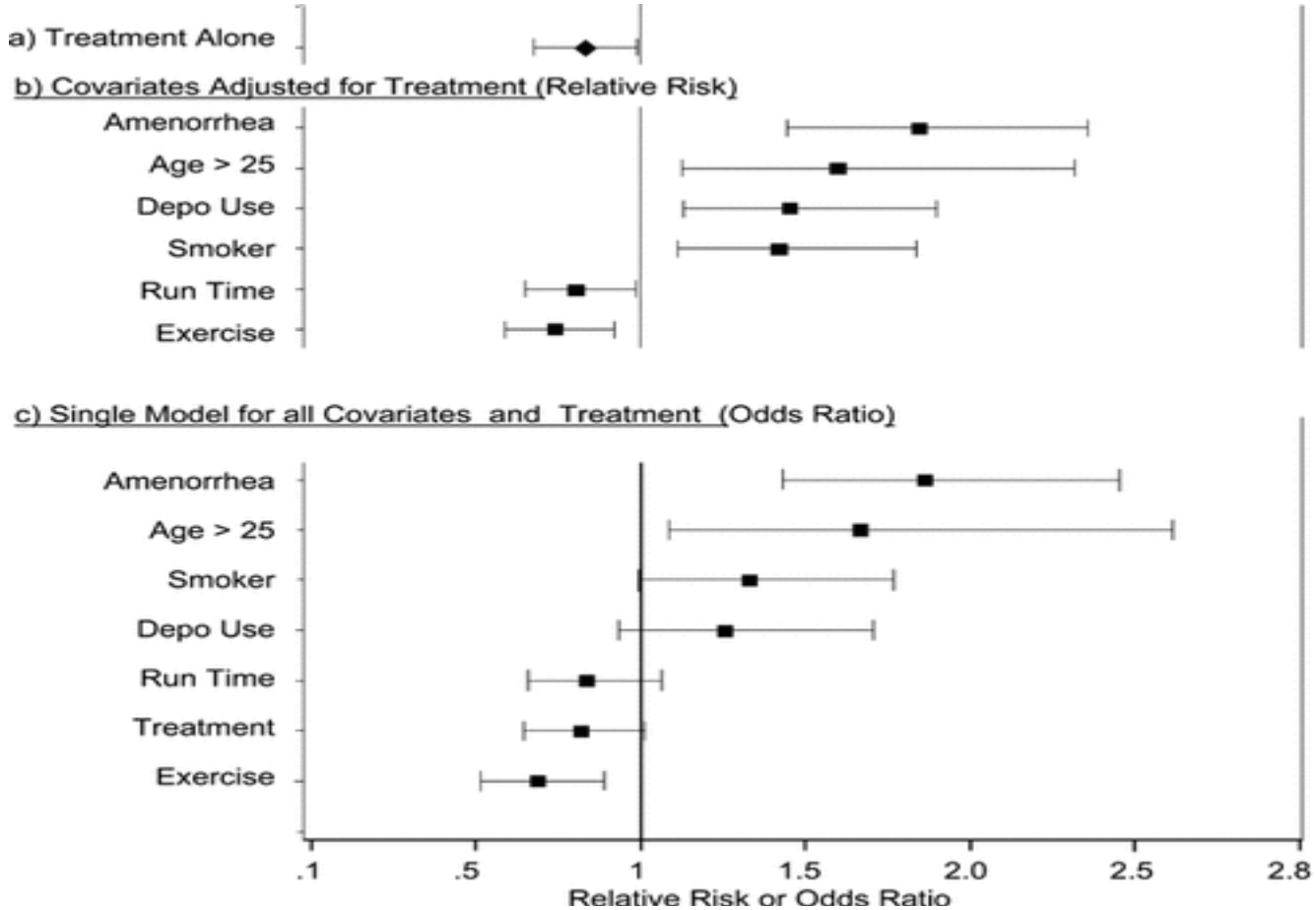
- Consuming >10 alcoholic drinks per week → Decreasing alcoholic intake
- Excessive physical activity with limited rest → Increase rest
- Female athlete triad → Identify female athlete triad
  - Eating disorders, amenorrhea, osteoporosis
    - Questionnaire
- Female sex
- Low levels of vitamin D → Vitamin D supplementation
- Recreational running (>25 miles per week)
- Running on hard surfaces
- Smoking → Smoking cessation education
- Sudden increase in training → Increase cross training
- Track (running sports) → Educate on pre-season fitness
  - Step Test

Female Triad

- Energy availability←→Menstrual function ←→ Bone Mass
- Low energy availability
  - Undernutrition
- Mismatch of nutrition intake and exercise expenditure →amenorrhea, estrogen deficiency, hormonal dysfunction

Prevention

- Modify activity level or training patterns
  - Preparticipation fitness associated with risk in military recruits
  - Rule of thumb – don't increase running program by >10% per week
- Ensure adequate rest
- Muscle strength
  - Dysfunctional muscle (weak, fatigued, altered activiation) → Load attenuation decreased
  - Fatigue can also lead to altered mechanics
- Surface?
  - CHANGE in surface
  - Less compliant surfaces
  - More compliant surfaces (sand) → increase energy expenditure
  - Downhill slopes
- Encourage pubescent and adolescents to participate in sports (Tenforde 2011)
  - Specifically high impact sports (basketball, soccer gymnastics, volleyball, jumping sports, etc)
- Consider daily supplementation of calcium (2000mg) and vitamin D (800 IU) (Lappe 2008)
- Address abnormal biomechanics
  - Knee flexion stiffness during initial loading (knee IR)
  - Greater hip adduction
  - Rearfoot eversion angles
  - Rearfoot strike
- Shock absorbing inserts
  - Shown effective in military recruits (Rome 2005, Gillespie 2000, Baxter 2011)



Journal of Bone and Mineral Research, Volume: 23, Issue: 5, Pages: 741-749, First published: 04 December 2009, DOI: (10.1359/jbmr.080102)

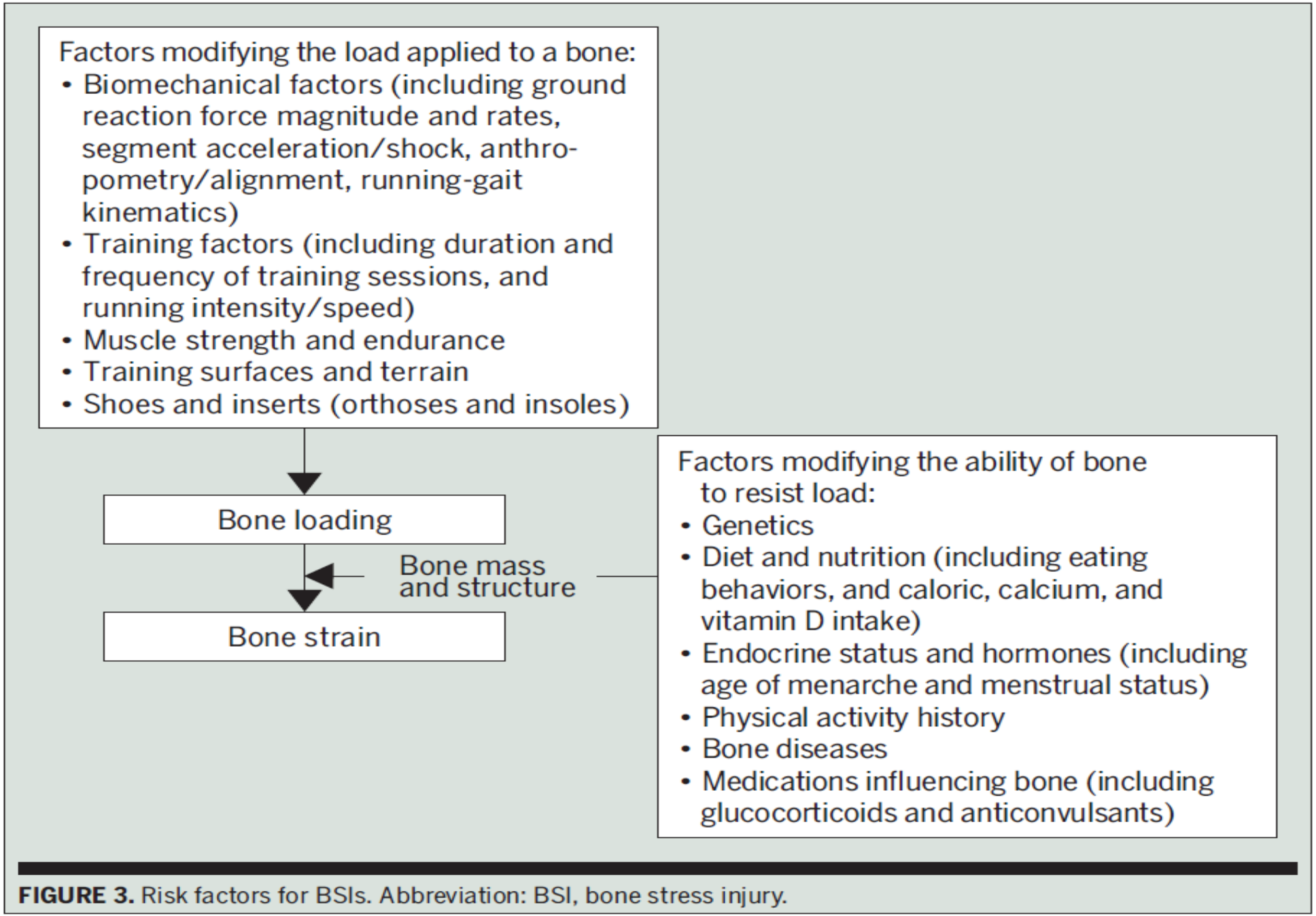


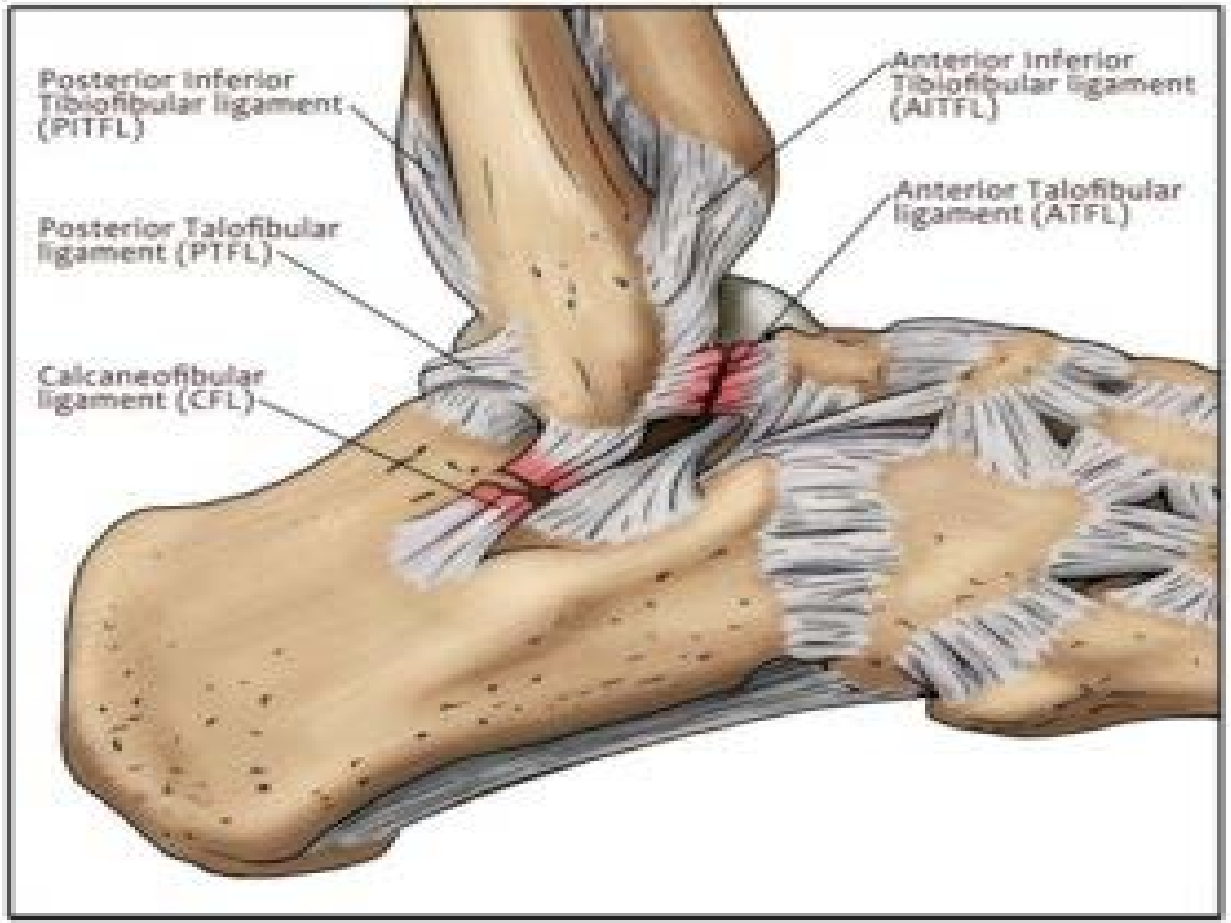
FIGURE 3. Risk factors for BSIs. Abbreviation: BSI, bone stress injury.

Warden 2014)

What hasn’t been shown to work

- Stretching (Rome 2005)
- Bisphosphonates (Milgrom 2004)
  - Abnormal bone deposition?
  - Potential teratogenicity?
  - Lack of FDA approval for this indication

Ankle Sprains



Ankle Sprain Risk Factors

Intrinsic

- Limited dorsiflexion
- Reduced proprioception
- Preseason deficiencies in postural control/balance
- BMI
  - High or low?
- Female
- Height

Extrinsic

- Sport
  - Aeroball, basketball, indoor volleyball, field sports, climbing
- Surface
  - Indoor turf vs grass
- Position
- Footwear

Prevention Strategies

- Functional support
  - **Brace** or tape
- Exercise therapy
  - Coordination and balance training
  - Neuromuscular training, focus on proprioception
- Sporting footwear?
  - Inconclusive

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