Bone Stress Injuries in Active and Athletic Young Adults: Evaluation & Management Strategies

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Objectives

- To define bone stress injuries and develop a better understanding of common risk factors in active and athletic youth

- To have a better understanding of screening, evaluation and treatment strategies for active and athletic youth with bone stress injuries and discuss ways to optimize bone health

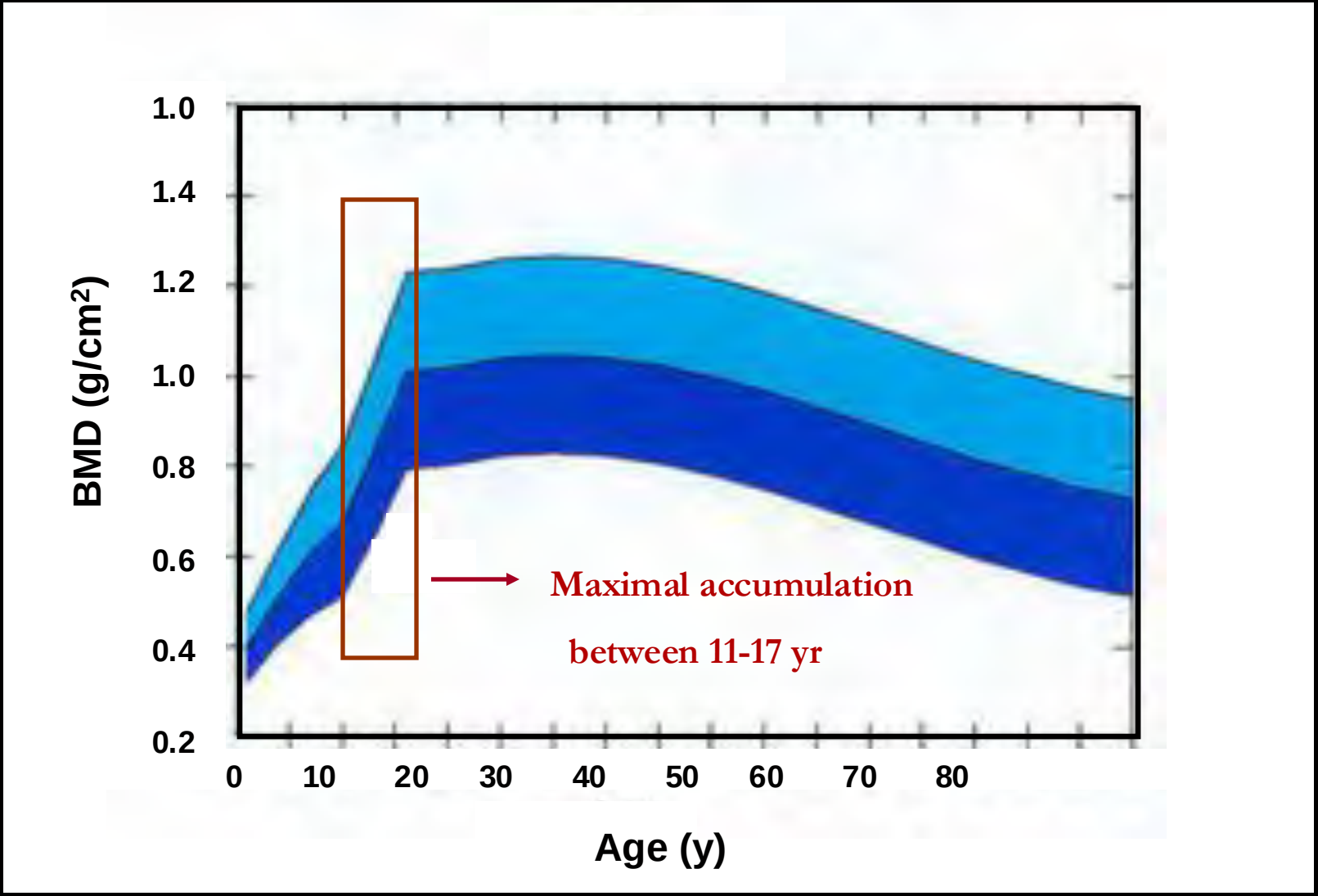
Bone Stress Injury Continuum

- Spectrum of bone stress injury ranges from the normal dynamic processes of bone modeling and remodeling, progressing on to bone fatigue, and with further stress, to frank cortical fracture
- Bone stress injury is new terminology
- Bone strain and stress reaction are other terms used to reflect this progression of bone injury toward a frank fracture

Importance of Peak Bone Mass

- 90% of peak bone mass is attained by age 18
- Optimizing peak bone mass is an important strategy for preventing osteoporosis and fractures

Lifetime BMD Accumulation



Determinants of Bone Mineral Density

Smoking

Drugs

Nutrition

Genetics (60-80%)

Hormones

Exercise
Physical Activity

Alcohol

(Developed by the ACSM SHI for Women, Sport & Physcial Activity. Med Sci Sports Exerc;39(10): 1867-1882, 2007)

Factors Influencing Fracture Risk

- **Non-modifiable**
  - **genetics**
  - **age**
  - **gender**
  - **ethnicity**
  - **body frame/size**

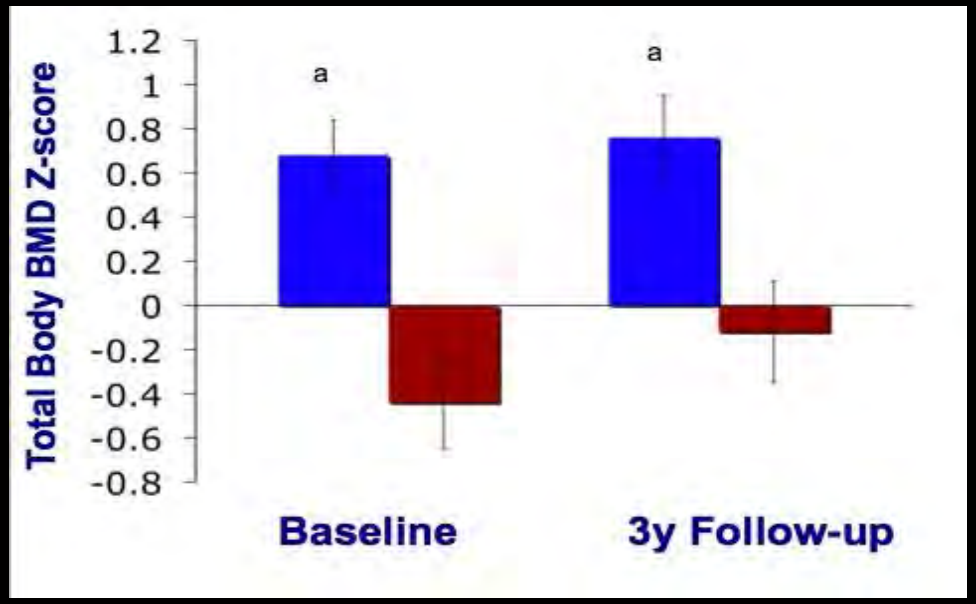
Factors Influencing Fracture Risk

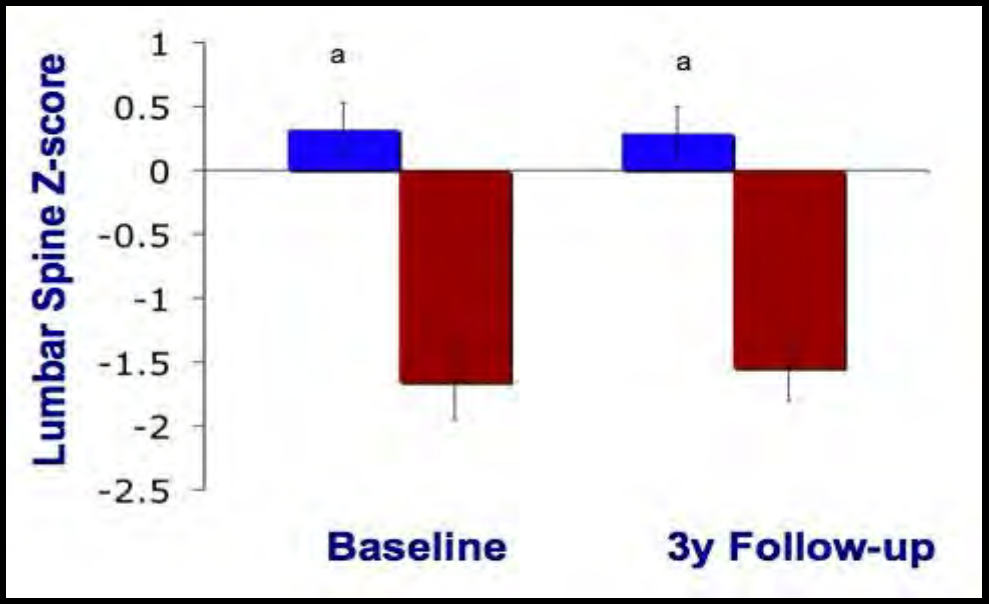
- Modifiable
  - nutritional status
  - hormonal status
  - physical activity
    - weight bearing
    - strengthening
  - lifestyle – smoking, ETOH

Adolescent Athletes: Vulnerable Period for Bone Health and Bone Injury

- Maximal period of bone accrual
- Increased susceptibility to disordered eating/eating disorders
- Increased susceptibility to bone injury
- Potential irreversibility of bmd if optimal bone mass not achieved and life long repercussions

Bone Mass at Baseline and 3-yr Follow-up in Adolescent Female Runners





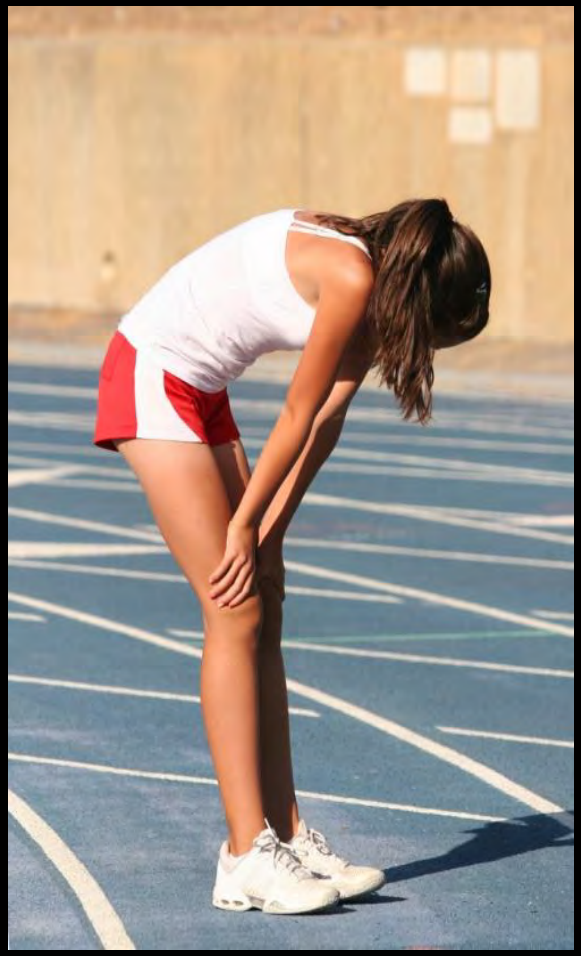
90% of runners with low bone mass (Z-score < -1.0) at baseline had significant lower BMD Z-scores at 3-year follow-up

(Barrack et al. MSSE 2011)

Adolescents are at Increased Risk for Stress Fractures

- Adolescents involved in higher impact sports at increased risk for fracture, especially with high mileage

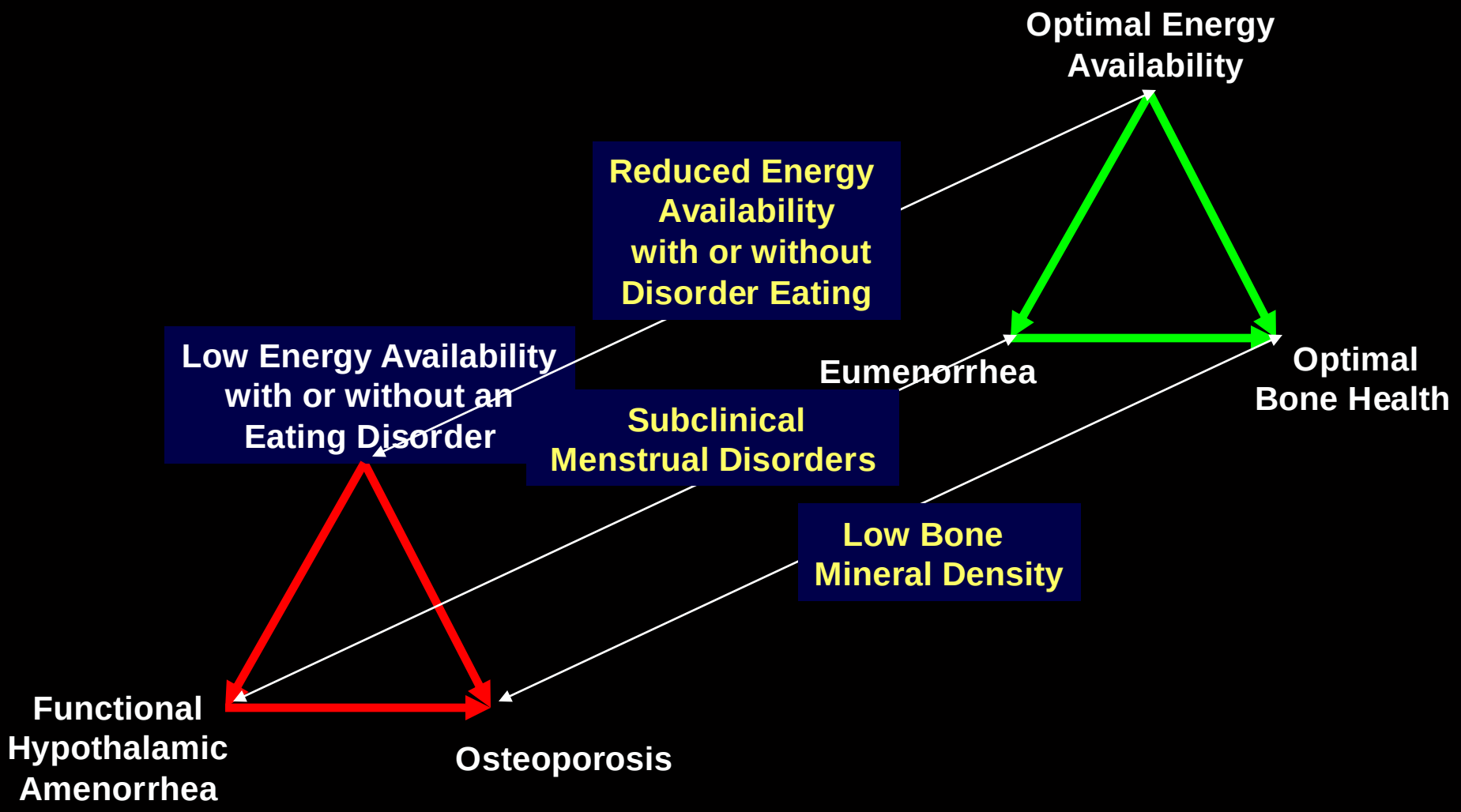
(Loud K. Pediatrics 2005)



Adolescent Cross Country Runner with a Displaced Femoral Neck Stress Fracture


S/p ORIF

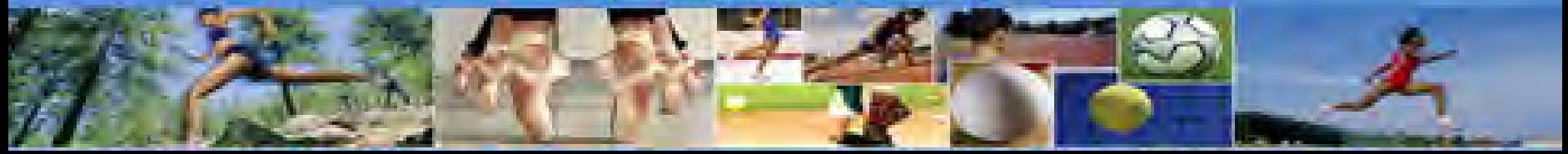
Spectrums of the Female Athlete Triad



Female Athlete Triad Cumulative Risk Assessment

Risk Factors	Magnitude of Risk Low Risk = 0 points each	Moderate Risk = 1 point each	High Risk = 2 points each
Low EA with or without DE/ED	☐ No dietary restriction	☐ Some dietary restriction‡; current/past history of DE;	☐ Meets DSM V criteria for ED*
Low BMI	☐ BMI ≥ 18.5 or ≥ 90% EW** or weight stable	☐ BMI 17.5 < 18.5 or < 90% EW or 5 to < 10% weight loss/month	☐ BMI ≤17.5 or < 85% EW or ≥ 10% weight loss/month
Delayed Menarche	☐ Menarche < 15 years	☐ Menarche 15 to < 16 years	☐ Menarche ≥16 years
Oligomenorrhea and/or Amenorrhea	☐ > 9 menses in 12 months*	☐ 6-9 menses in 12 months*	☐ < 6 menses in 12 months*
Low BMD	☐ Z-score ≥ -1.0	☐ Z-score -1.0*** < - 2.0	☐ Z-score ≤ -2.0
Stress Reaction/Fracture	☐ None	☐ 1	☐ ≥ 2; ≥ 1 high risk or of trabecular bone sites†
Cumulative Risk (total each column, then add for total score)	_____ points +	_____ points +	_____ points = _____Total Score

*http://www.femaleathletetriad.org/

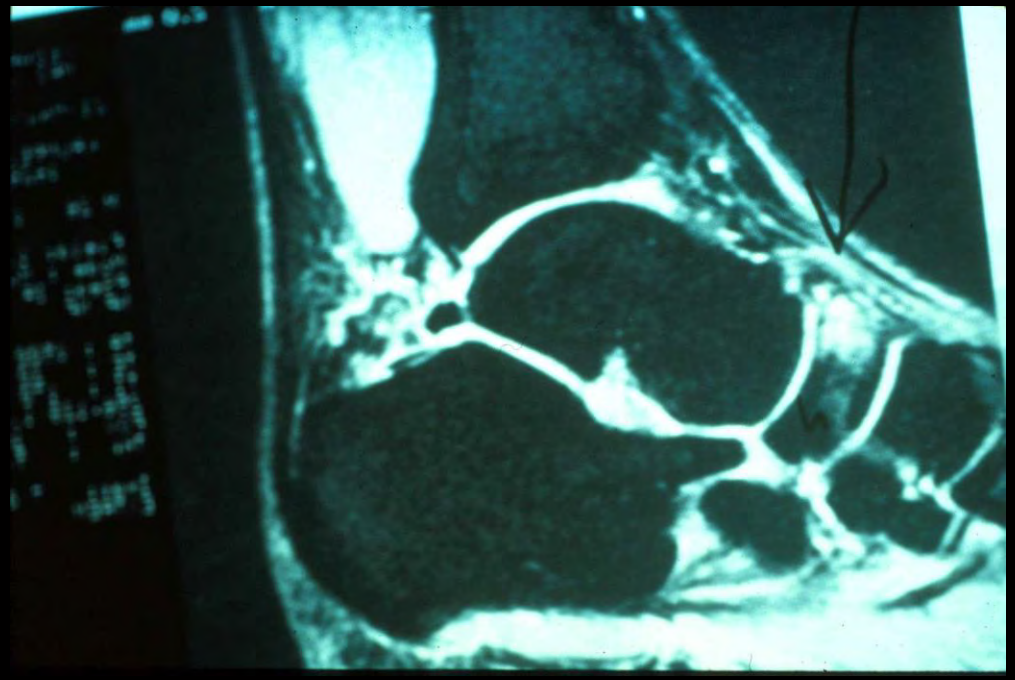


Medical Evaluation and Work Up Stress Fractures

- Imaging Studies
  - Initial radiographs
  - If radiographs negative, MRI for majority of stress fractures/reactions (CT sometimes helpful for tarsal navicular and other sites)
- Nutritional history
  - If evidence of disordered eating/eating disorder involve psychologist and nutritionist and follow patient
  - Increase energy availability; increase calcium and vitamin D
- Menstrual history
  - If amenorrheic or oligomenorrheic, hormonal work up indicated; increase energy availability

Imaging Studies for Suspected Bone Stress Injury

- Radiographs not sensitive (negative initially >75% of time); very specific
- Bone scans are very sensitive; not very specific
- MRI more specific for bone stress injury



MRI Grading of Stress Injury

- **MRI offers an increased appreciation of the continuum of stress injury and biologic reaction to external stress**
- **Better specificity for bone stress injury**
- **Earlier diagnosis of stress injury to bone and prevention of cortical fracture**

(Fredericson et al. Am J Sports Med 1995)

MRI Grading

- **Fredericson and colleagues found that certain clinical signs and exam findings correlated with severity of tibial stress injury as noted on MRI (pain with ambulation and localized tibial tenderness and pain with percussion)**

- **MRI more precisely defined the extent of tibial stress injury and anatomic location vs bone scans**

- **MRI grading system proposed**

(Fredericson et al. Am J Sports Med 1995)

MRI Grade	Bone Stress Injuries MRI Grading Scales		
	Arendt	Fredericson	Nattiv
1	Positive signal change on STIR	Mild to moderate periosteal edema on T2; normal marrow on T2 and T1	Mild marrow or periosteal edema on T2; T1 normal
2	Positive STIR plus positive T2	Moderate to severe periosteal edema on T2; marrow edema on T2 but not T1	Moderate marrow or periosteal edema plus positive T2
3	Positive STIR plus positive T2 and T1	Moderate to severe periosteal edema on T2; marrow edema on T2 and T1	Severe marrow or periosteal edema on T2 and T1
4	Positive fracture line on T2 or T1	Moderate to severe periosteal edema on T2; marrow edema on T2 and T1; fracture line present	Severe marrow or periosteal edema on T2 and T1 plus fracture line on T2 or T1

MRI Grading and Clinical Outcome

- **MRI grading of bone stress injury in track and field athletes correlates with clinical outcome, providing a useful tool in the management of these injuries**

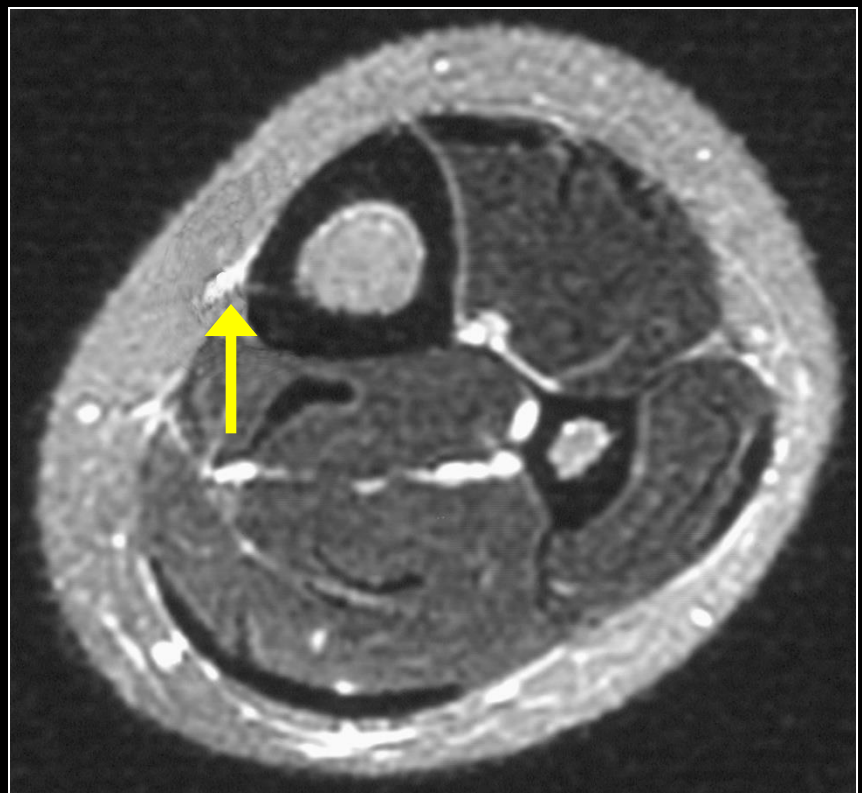
  (Nattiv et al, Am J Sports Med, 2013)

- **Retrospective study in collegiate athletes with similar findings**

  (Arendt et al. Am J Sports Med, 2003)

Grade 1 – Tibia Stress Reaction

- Grade 1 injury:
  - Mild marrow or periosteal edema on T2
  - No marrow edema on T1

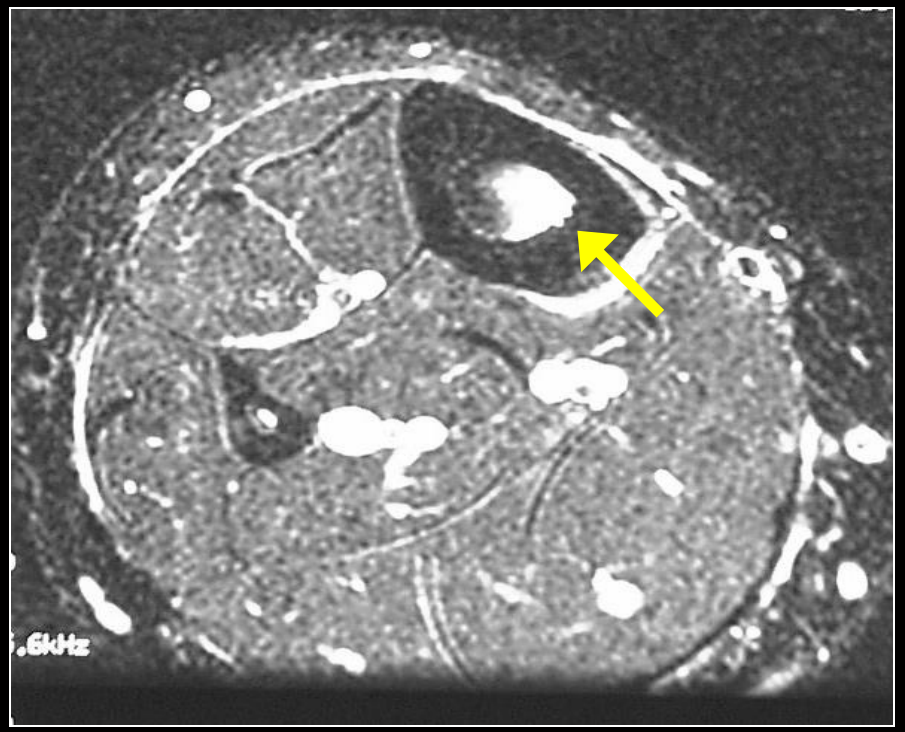


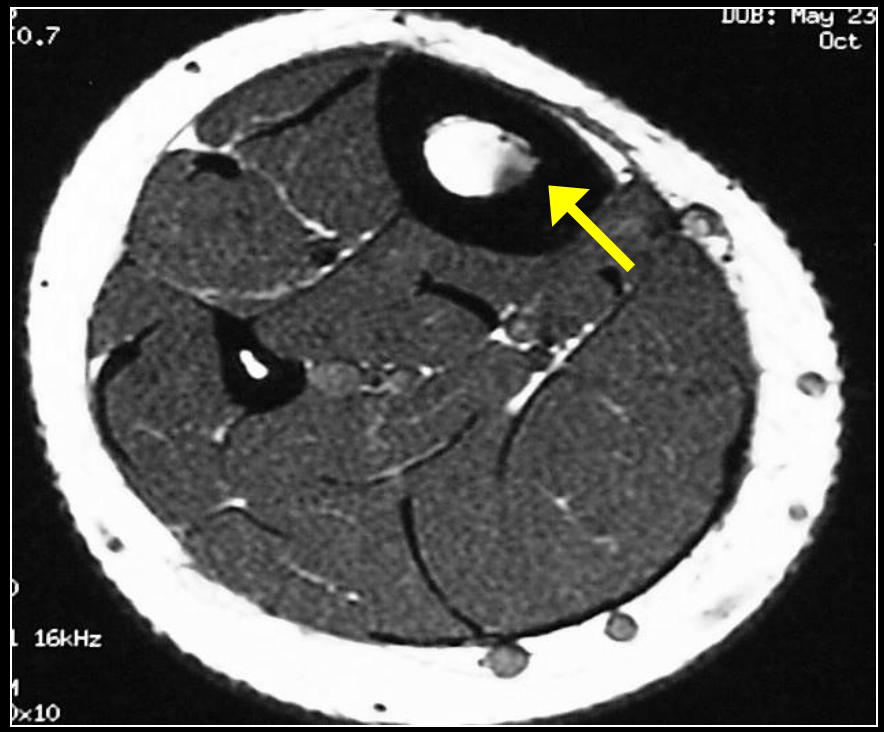
Grade 2 – Stress Reaction of Tibia

- Grade 2 injury:
  - Moderate marrow or periosteal edema on T2
  - No marrow edema on T1

Grade 3 – Stress Reaction of Tibia

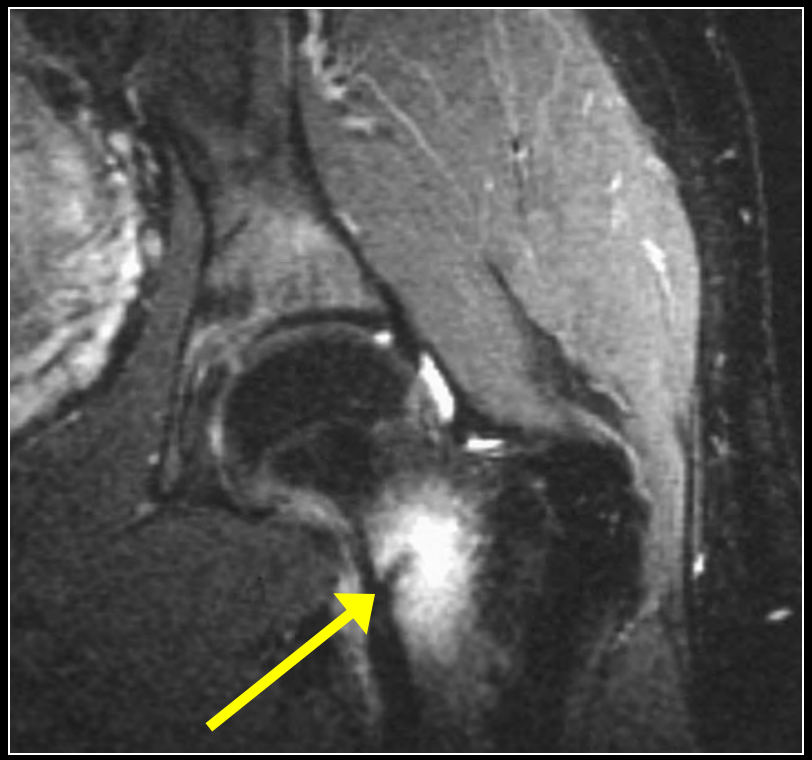
- Grade 3 injury:
  - Severe marrow or periosteal edema on T2 and T1

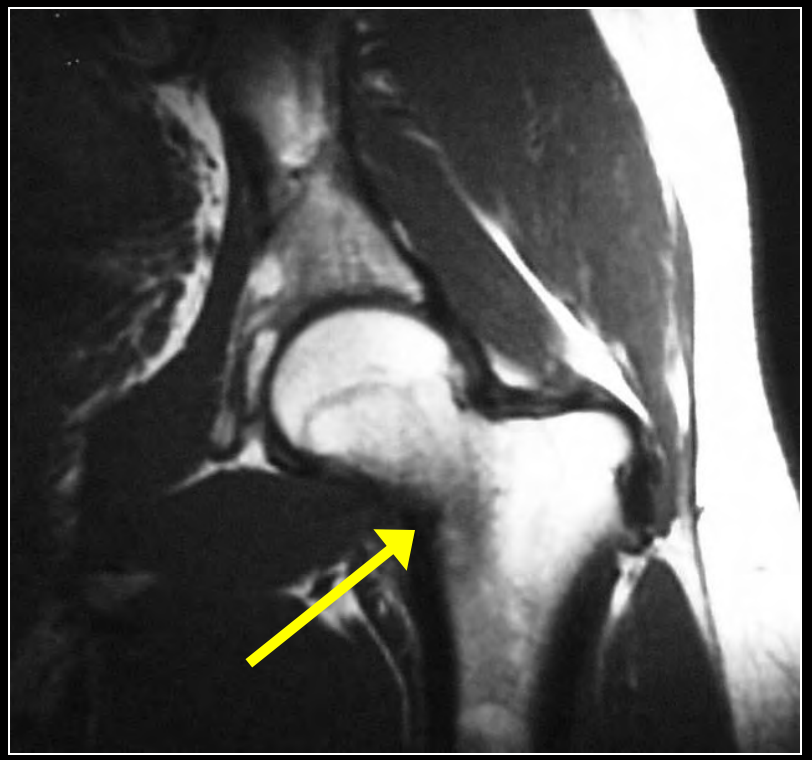




Grade 4 – Stress Fracture of Femur

- Grade 4 injury (stress fracture): Severe marrow or periosteal edema on T2 and T1; and fracture line





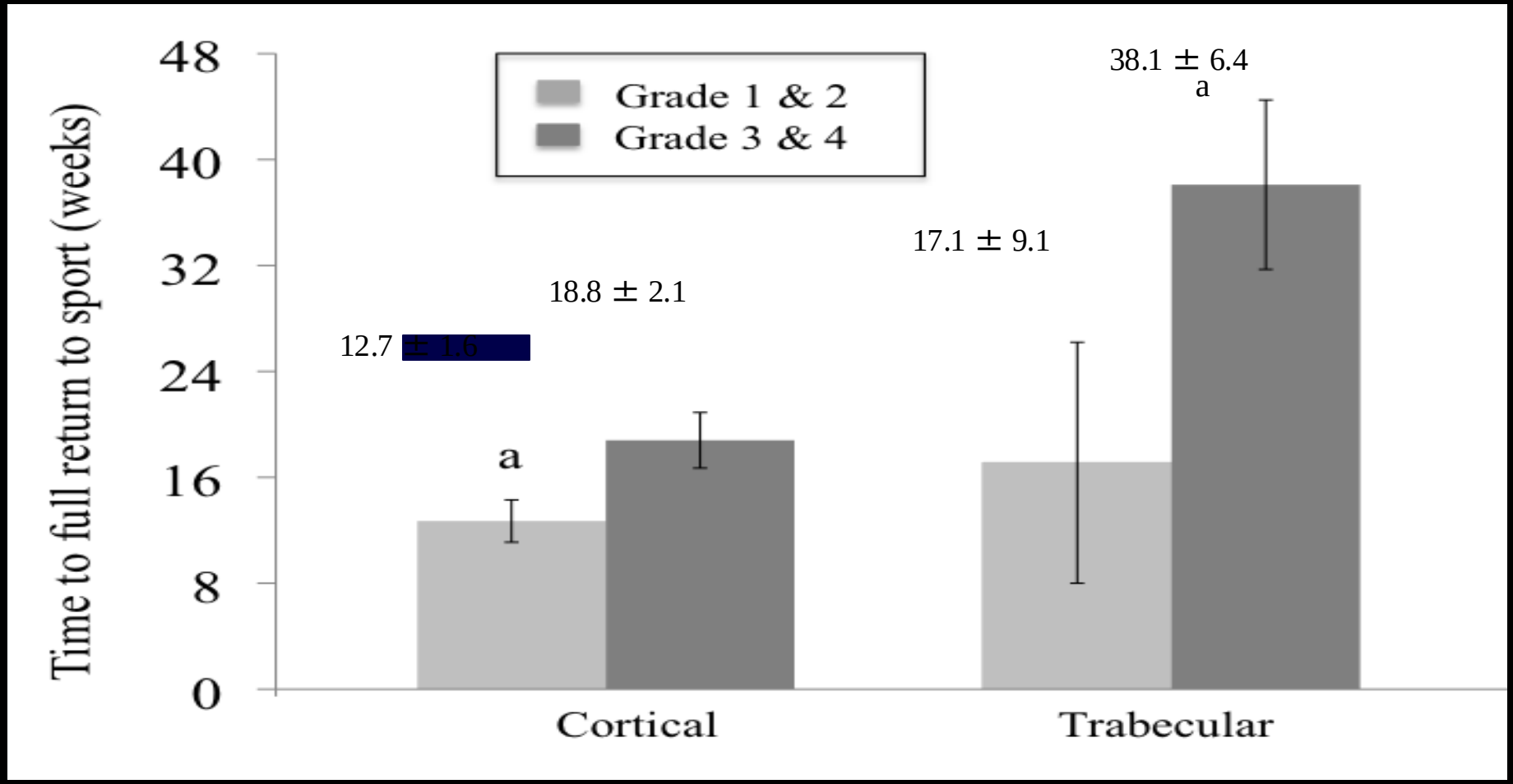
MRI Grading and RTP

- **Female athletes with oligomenorrhea and amenorrhea had bone stress injuries of higher MRI grades compared with eumenorrheic athletes**

- **Higher MRI grade, lower BMD and skeletal sites of predominantly trabecular bone structure were associated with delay in RTP**

(Nattiv et al. AJSM 2013)

Delay in Return to Play with Bone Stress Injuries in Trabecular Bone Sites



Metabolic Work Up

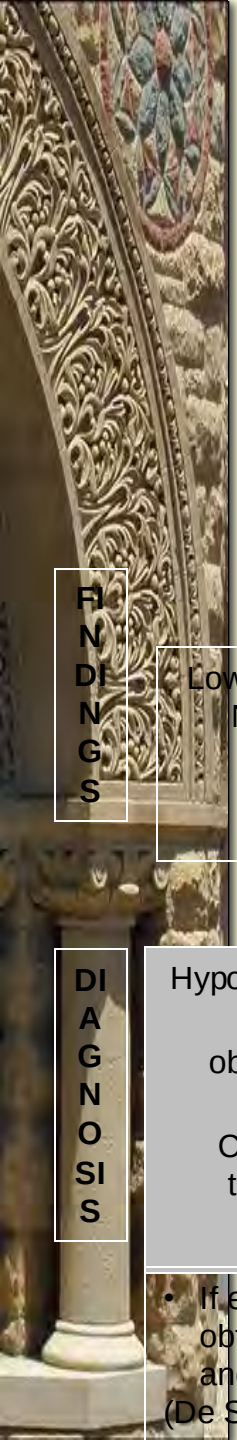
- What athletes need a metabolic work up?
- What tests should you order?

Metabolic Work Up – Labs in the "At Risk" Young Athlete with Low BMD

- CBC with platelets
- Chemistry panel
- Vitamin D 25-OH
- TSH, free or total T3 and T4
- PTH, calcium
- Consider celiac disease - anti-tissue transglutaminase antibody (IgA TTG)

Hormonal Work Up

- Hormonal work up in female athletes with primary or secondary amenorrhea
- Consider free and total testosterone in male endurance athletes



History and Examination

- Uterine pathology or outflow tract disorder
- Disorders of sexual differentiation

Initial investigation

- LH, FSH, hCG
- Prolactin
- Estradiol, testosterone (total and free), DHEA/S ± 8AM 17(OH) progesterone
- TSH, free T4
- Progesterone challenge test
- ± Pelvic ultrasound

Rule out Pregnancy

FINDINGS

Low to normal gonadotropins Negative progesterone challenge test Possibly ↑ prolactin	Normal gonadotropins Possibly ↑ LH/FSH ↑ total/free testosterone Positive progesterone challenge test	↑ gonadotropins Negative progesterone challenge test	Abnormal TSH, prolactin, DHEA/S or 8 AM 17(OH) progesterone

DIAGNOSIS

Hypothalamic-pituitary etiology Rule out outflow tract obstruction if not done so previously Consider FHA (prolactin typically not elevated)*	Chronic anovulation/ PCOS	Primary ovarian insufficiency	Specific investigation of endocrine disorder

- If energy deficiency-related amenorrhea, including exercise, weight loss, or disordered eating related, consult with sports dietitian and obtain a bone mineral density test (site of testing should be based on the age of the patient: spine and whole body for growing children and adolescents, spine and hip for adult women); Refer or consult with endocrinologist if not experienced in treatment.

(De Souza et al. 2014 Female Athlete Triad Consensus Statement on Treatment and RTP of the Female Athlete Triad, BJSM 2014)

WHO SHOULD GET A DXA?

DXA Recommendations using Triad Risk Stratification

- ≥ 1 "High risk" Triad Risk Factors
  - History of DSM-V dx ED
  - BMI ≤ 17.5 kg/m2, < 85% estimated wt or recent weight loss of ≥ 10% in 1 month
  - Menarche ≥ 16 yrs of age
  - Current or past history < 6 menses over 12 months
  - ≥ 2 prior stress reactions/fractures, ≥ 1 high risk stress rxn/fx or a low energy traumatic fracture
  - Z-score of < -2.0 (after at least 1 yr interval from baseline DXA)

  (De Souza et al. Female Athlete Triad Consensus on Treatment and RTP. Br J Sports Med 2014)

DXA Recommendations using Triad Risk Stratification

- OR ≥ 2 "Moderate Risk" Triad Risk Factors:
  - Current or past history of DE for ≥ 6 months
  - BMI between 17.5-18.5, < 90% estimated weight or recent weight loss of 5-10% in 1 month
  - Menarche between ages 15-16 yrs
  - Current or history of 6-8 menses over 12 months
  - One prior stress reaction/fracture
  - Prior Z-score between -1.0 and -2.0 after at least 1 year interval from baseline DXA

(De Souza et al. Female Athlete Consensus Statement on Treatment and RTP. Br J Sports Med 2014)

DXA Recommendations with Triad Risk Stratification

- History of ≥1 non-peripheral or ≥ 2 peripheral long bone traumatic fractures (non-stress) + ≥1 moderate or high risk Triad risk factors
- Athletes on medications for ≥ 6 months that may impact bone (depot provera, oral prednisone, others)

(De Souza et al. Female Athlete Triad Consensus Statement on Treatment and RTP. BJSM 2014)

DXA - Male Athletes

- Consider in those with recurrent bone stress injuries
- Consider in those with higher risk stress fractures and bone stress injury in trabecular bone sites (fem neck, sacrum, pelvis)
- Fractures with low trauma

Additional Metabolic Work Up to Consider

- In those with low BMD and/or recurrent fracture history of unclear etiology
- 24 hr urine for calcium (or spot urine) – assessing for hypercalciuria

Metabolic Work Up – one step further

- Genetic testing
  - osteogenesis imperfecta – work with metabolic bone center and/or geneticist if history suggestive of OI – multiple low trauma fractures, family history
  - other

Treatment to Optimize Bone Health

Treatment: Low Energy Availability

- Athletes with disordered eating/eating disorder
  - Multidisciplinary team treatment with physician, dietitian and mental health professional
- Athletes with low energy availability, but no evidence of disordered eating
  - Dietitian

GOAL: Optimize energy intake and stored energy to result in normal menstruation

Treatment: Menstrual Dysfunction

- Non-pharmacologic interventions are the mainstay of treatment
  - Ensuring adequate energy intake
  - Optimizing stored energy
  - Goal being restoration of normal ovulatory function
- For those who fail non-pharmacologic management, pharmacologic therapy to be considered, with the first choice for the amenorrheic athlete being transdermal estrogen (if not sexually active)

Treatment: Low BMD

- Non-pharmacologic interventions – mainstay of treatment in the young athlete with low BMD
  - Optimize nutritional intake (Calcium, vitamin D)
  - Increase energy availability
  - Weight gain if underweight
- Pharmacologic management – transdermal estrogen or oral contraceptives if fail conservative management and are amenorrheic
- Rarely is there need for osteoporosis medications

Treatment – Bone Stress Injuries

Risk Stratification

- Differentiate High vs Low Risk

High Risk Stress Fractures

- Femoral neck
- Patella
- Anterior tibial cortex
- Medial malleolus
- Talus
- Tarsal navicular
- 5th metatarsal base
- Proximal 2nd metatarsal
- Sesamoids of great toe

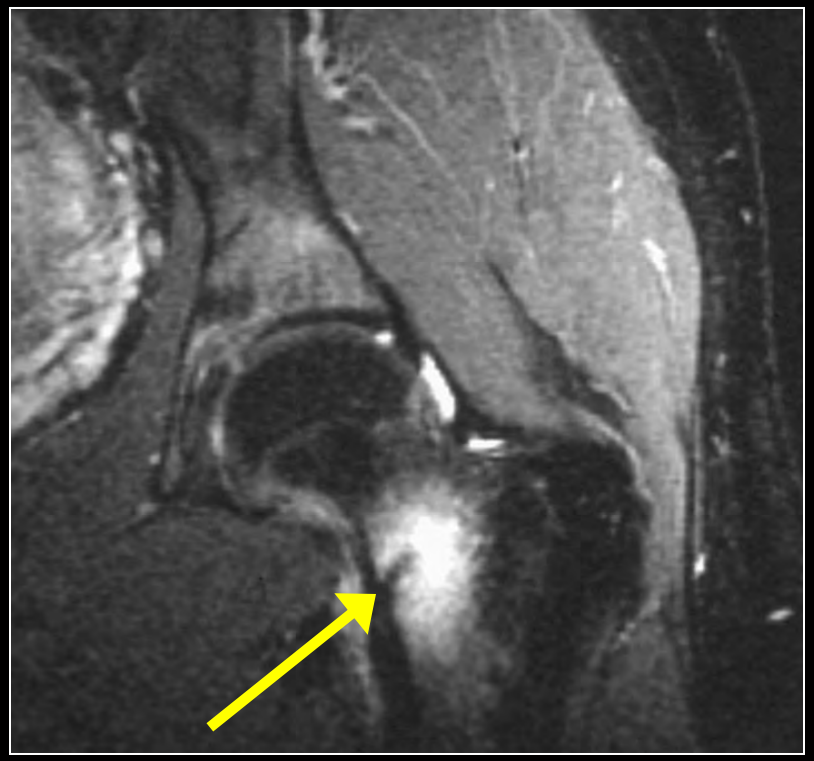
(Boden & Osbahr, AJSM 2000)

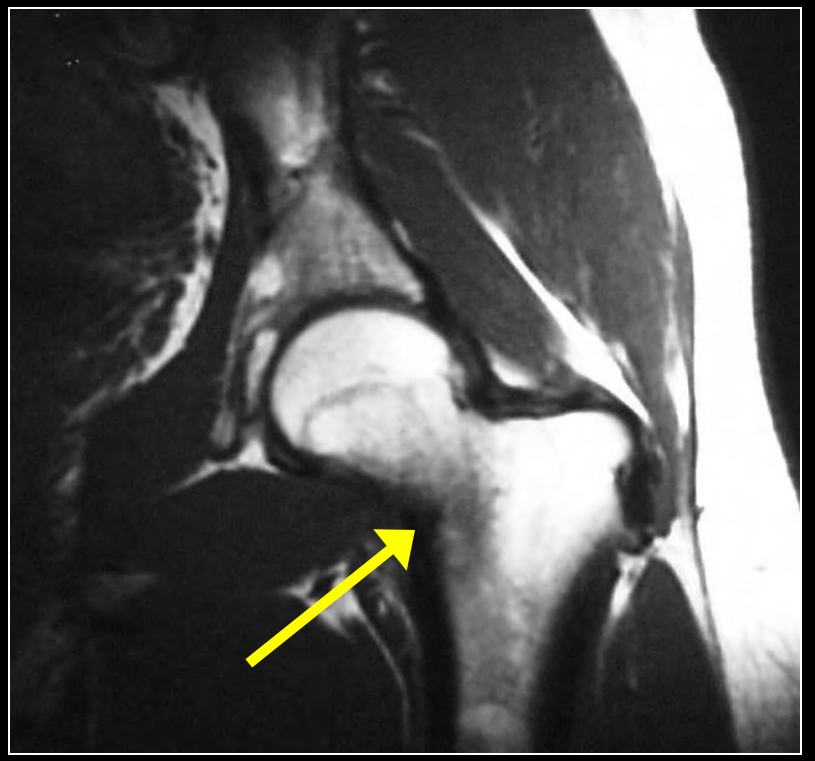
Treatment: High Risk Stress Fractures

- High risk
  - Predilection for progression to complete fracture
- Immediate non weight-bearing
- Consider surgical intervention

(Boden & Osbahr, AJSM 2000)

Femoral Neck Stress Fracture





Low Risk Stress Fractures

- Posteromedial tibia
- Fibula
- Distal metatarsals 2-5

(Boden et al. AJSM, 2001)

Treatment: Low Risk Stress Fractures

- Activity modification to pain free level
- Immobilize only if painful ambulation
- Graded progression, using pain as guide

(Boden et al. AJSM 2001)

Medium Risk Stress Fractures

- Pelvis
- Femoral shaft
- Proximal tibia
- Cuboid
- Cuneiform
- Calcaneous

(Fredericson 2016)

Treatment: Medium Risk Stress Fractures

- May need short term immobilization or short term NWB until pain free
- Cross train – initial non impact exercise
- Address underlying risk factors

Factors Related to Delay in Return to Play in Runners with Bone Stress Injuries

- Higher MRI grade, lower BMD and skeletal sites of predominant trabecular bone (fem neck, pelvic, sacrum) independently associated with delayed recovery and delay in return to play in runners

(Nattiv et al. Am J Sports Med 2013)

What Can We Do To Minimize Risk for Fracture?

- Optimize peak bone mass
- Reduce risk of bone loss

Vitamin D and Calcium

- Optimize vitamin D status (32-50 ng/ml)
- Vitamin D replacement if necessary
- Vitamin D, calcium supplementation (IOM)

	Vitamin D (IU/d)		Calcium (mg/d)	
	RDA	Max	RDA	Max
9-18y	600	4000	1300	3000
19-50y	600	4000	1000	2500

Vitamin D Concentrations and Stress Fractures

- Association between low vitamin D 25-OH and lower extremity stress fractures in the military (N=2,634, 8 studies)
  (Dao et al. Serum 25-OH vitamin D levels and stress fractures in military personnel: A systematic review and meta-analysis. AJSM 2015)

- Lack of studies assessing relationship of vitamin D concentrations and bone stress injury in athletes

Calcium and Vitamin D Supplementation Reduced Stress Fx Incidence in Navy Recruits

- Female navy recruits (N=5,201) randomized to 2000 mg calcium/day and 800 IU/day of vit D3 vs placebo for 8 weeks
- 20% reduction of stress fractures
- Vitamin D not measured

(Lappe et al. J Bone Miner Res 2008)

Adequate Energy Availability

- If energy availability can be reliably estimated, the target should be to achieve **45 kcal/kgFFM/day**

(Nattiv A, Loucks A, Manore M et al. Female Athlete Triad Position Stand. MSSE, 2007)

Avoidance of Prolonged Amenorrhea and Oligomenorrhea

- Work up and treat amenorrhea and prolonged oligomenorrhea
- Increasing energy availability initial management

(De Souza et al. 2014 Female Athlete Triad Consensus Statement on Treatment and RTP of the Female Athlete Triad. BJSM 2014)

Increase in Weight Improves BMD in Amenorrheic Athlete

- In hypothalamic amenorrhea, increases in BMD are more closely associated with increases in weight than with OCP/ERT

  (Nattiv et al. ACSM Triad PS. MSSE, 2007)

- Weight goal ≥90% predicted weight

  (De Souza et al. 2014 Female Athlete Triad Coalition Consensus Statement on Treatment and RTP, BJSM 2014; CJSM 2014)

Avoid Excessive Training

- **Avoidance of excessive training mileage and/or abrupt changes in training**
- **Start exercise gradually**
- **Adhere to sound training principles** (Jones et al. Epidemiology Reviews 2002)

Type of Exercise in Youth Can Decrease Fracture Risk in Later Life

- Studies in runners and military population have shown that higher impact and multi-directional loading activities in youth may reduce stress fracture risk

(Fredericson et al. CJSM 2005; Milgrom et al. AJSM 2000)

Playing Ball Sports in Youth Reduced Risk of Stress Fractures as Adults

- Fredericson and colleagues studied 156 elite female and 118 elite male distant runners ages 18-44 yrs of age in a retrospective cohort study
- In both men and women, previous participation in ball sports in youth was assoc with a reduction of stress fractures by almost half
- Females with menstrual dysfunction *did not* confer benefits from ball sports

(Fredericson et al. CJSM 2005)

Reduction of Training and Increased Sleep Decreased Fracture Risk in the Military

- Reduction of cumulative marching in training of infantry recruits (N=276) and 6 hrs minimum sleep requirement reduced stress fx incidence by 62% in military compared to historical cohort
- Bone stress injuries were lower grade

(Finestone and Milgrom. MSSE 2008)

Current Research – Optimize Bone Healing

- Double-blind randomized multi-site study to evaluate extracorporeal shockwave therapy for management of stress fractures and bone stress injuries of pelvis and lower extremity

- Stay tuned…

Summary

- Strive to achieve peak bone mass early in life
- Adequate energy availability, calcium and vitamin D are important determinants for bone health and for prevention of bone stress injury
- Further research is needed on the role of calcium and vitamin D in fracture prevention and bone healing in young athletes
- IOM guidelines for calcium and vitamin D are recommended
- Screen and treat the female and male athlete triad

Summary

- Adhere to sound training principles
- Initial X-ray for diagnosis of bone stress injury, and MRI is gold standard for advanced imaging
- MRI grading progression is correlated with return to play
- Gradual progression of activity is recommended for return to play
- High impact loading and multidirectional sports early in life can help BMD later in life and reduce fracture risk
- More research is needed in finding nonpharmacologic treatment strategies that optimize bone health and impact fracture risk in the young athlete

Thank you!