Stress Fractures 2010

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Overview

• What is a stress fracture?
• Diagnosis and Treatment
• Specific Fractures
  – Metatarsal
  – Anterior tibia
Definition

Microfracture in bone that results from repetitive physical loading below the single cycle failure threshold.
Microdamage Accumulation
Wolff’s Law

If there exist gradual and repetitive increase in stress applied to bone, the bone will modify its molecular structure and adapt with hypertrophy.
Pathophysiology of Stress Fractures

• Remodeling
  – Adaptation to mechanical environment
    • Removal of damaged bone by osteoclasts
    • Formation of new bones by osteoblasts

• Imbalance of remodeling
  – Damage accumulation
    • Stress reaction
    • Stress fracture
    • Complete fracture
Etiology

- Theory 1: excessive forces transmitted to bones when muscles fatigue
- Theory 2: muscular forces concentrated across a localized area of bone
Changes In Bone In Relation To Strain

- Priest, 1977- tennis players, men with 44% and women 29% increased dominant extremity bone thickness
- Uhthoff and Jaworski, 1978- casted forelimb of young adult beagle dogs, increased osteoclastic activity and significantly decreased bone density compared with control

Different Types of Bone Strain

• Questionnaire 156 elite female and 118 elite male distance runners
• Playing youth ball sports decreased incidence of future stress fractures
• In men, dose response curve with each year of playing ball sports conferred 13% decreases incidence of stress fracture

Optimum Geometric Predictor For Stress Fracture

Franklyn, AJSM 2008;36:1179-1189
Time
Stress
Adaptation
Maladaptation
Individual Stress Limit

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Female Athlete Triad

- Disordered eating
- Amenorrhea
- Osteoporosis

Prior Menstrual History as Predictor of Bone Status

Drinkwater, *JAMA* 1990
Risk Factors for Stress Fractures

- Training changes
- Running and jumping activities
- Inappropriate footwear
- Muscle inflexibility
- Excessive muscle strength
- Lower extremity alignment anomalies
- Female gender
- Extremes of body size and composition
- “Type A” behavior
- Previous history of injury
- Low bone density
- Poor running technique

Frey, Clin Sport Med 1997;16(2):249-257
Risk Factors for Recurrent Stress Fractures

- High longitudinal arch of foot
- Leg-length inequality
- Excessive forefoot varus
- High weekly running mileage

Korpelainen, *AJSM* 2001;29:304-310
Stress Fracture = (Bone Health [density and architecture] + Rest) – (Biomechanics [force dissipation] + Rate of change of activity)
Epidemiology

Stress Fractures In College Athletes

- Average annual incidence 1.9%
- 67% freshmen
- Average time to onset of symptoms 4.5 weeks
- Average time from symptoms to presentation 3.5 weeks

Classification Of Stress Fractures: Low Risk

- Upper extremity
  - Clavicle
  - Scapula
  - Humerus
  - Olecranon
  - Ulna
  - Scaphoid
  - Metacarpals
- Ribs
  - First Rib
  - Middle ribs (4-9)
- Pars interarticularis
- Pelvis
  - Sacrum
  - Pubic Rami
- Femoral Shaft
- Tibial Shaft
- Fibula
- Calcaneus
- Metatarsal Shaft

High-Risk Stress Fractures

- Femoral neck
- Patella
- Anterior cortex tibia
- Medial malleolus
- Talus
- Tarsal navicular
- Fifth metatarsal
- Second metatarsal
- Great toe sesamoids

Boden, Am J Sport Med 2001;29(1):100-111
<table>
<thead>
<tr>
<th>Site of stress fracture</th>
<th>Sport or activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coracoid process of scapula</td>
<td>Trapshooting</td>
</tr>
<tr>
<td>Scapula</td>
<td>Running with hand-held weights</td>
</tr>
<tr>
<td>Humerus</td>
<td>Throwing, racquet sports</td>
</tr>
<tr>
<td>Olecranon</td>
<td>Throwing, pitching</td>
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<tr>
<td>Ulna</td>
<td>Racquet sports (especially tennis), gymnastics, volleyball, swimming, softball,</td>
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<td></td>
<td>wheelchair sports</td>
</tr>
<tr>
<td>Ribs—first</td>
<td>Throwing, pitching</td>
</tr>
<tr>
<td>Ribs—second to tenth</td>
<td>Rowing, kayaking</td>
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<tr>
<td>Pars interarticularis</td>
<td>Gymnastics, ballet, cricket fast bowling, volleyball, springboard diving</td>
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<tr>
<td>Pubic ramus</td>
<td>Distance running, ballet</td>
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<tr>
<td>Femur—neck</td>
<td>Distance running, jumping, ballet</td>
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<tr>
<td>Femur—shaft</td>
<td>Distance running</td>
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<tr>
<td>Patella</td>
<td>Running, hurdling</td>
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<tr>
<td>Tibia—plateau</td>
<td>Running</td>
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<tr>
<td>Tibia—shaft</td>
<td>Running, ballet</td>
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<tr>
<td>Fibula</td>
<td>Running, aerobics, race-walking, ballet</td>
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<tr>
<td>Medial malleolus</td>
<td>Basketball, running</td>
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<td>Calcaneus</td>
<td>Long distance military marching</td>
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<tr>
<td>Talus</td>
<td>Pole vaulting</td>
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<tr>
<td>Navicular</td>
<td>Sprinting, middle distance running, hurdling, long/triple jumping, football</td>
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<tr>
<td>Metatarsal—general</td>
<td>Running, ballet, marching</td>
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<tr>
<td>Metatarsal—base second</td>
<td>Ballet</td>
</tr>
<tr>
<td>Metatarsal—fifth</td>
<td>Tennis, ballet</td>
</tr>
<tr>
<td>Sesamoid bones of the foot</td>
<td>Running, ballet, basketball, skating</td>
</tr>
</tbody>
</table>

History

• Insidious onset
• May report a one time event (20%)
• Night pain
• Usually with increase in activity over weeks
• Obtain good training history
• Job and life activity
• Nutritional and menstrual history
Physical Exam

- Tenderness, localized
- Swelling
- Tuning fork, Ultra sound
- +Hop test (lower extremity)
- Exam that does not make sense (pelvic)
- Perform a full biomechanical exam
Diagnostic Testing

- Plain x-ray
- MRI
- Bone scan: larger area (SPECT scan)
- CT Scan
MRI in Stress Fracture

- Grade 1: periosteal edema on T2
  - Soft-surface running in 2-3 weeks
- Grade 2: Grade 1 + marrow edema on T2 images
  - Running in 4-6 weeks
- Grade 3: Grade 2 + marrow edema on T1 images
  - Running in 6-9 weeks
- Grade 4: Grade 3 + visible fracture line
  - Cast x 6 weeks and Low impact x 6 weeks

MRI in Athletes

- 21 asymptomatic runners
- Followed for 12 months
- 43% showed evidence of stress injury on MRI

Radiation

- Radiation from x-rays, CT, and gamma rays from Tc99 in bone scans (not MRI)
- Most radiosensitive tissue located in the trunk
- Effective dose of most imaging modalities 0.03-20 mSv
- Annual natural background dose per year in Australia 1.5 mSv
- Survivors of 2 atomic bombs 5mSv-2Sv
- Use caution with young elite athletes
- ?Keep a radiation log

Cross, Clin J Sport Med 2003;13:164-70
Goals for Stress Fracture Treatment

• Return to pre-injury level of function
  – Shortest time
  – Protect the body part and the athlete
  – Gradual loading program
    • Enhances mechanoreceptors
    • Osteoblasts respond to loading

• Risk factor identification and modification to prevent re-injury

• Maintain fitness while healing
Overall Treatment

- NO PAIN
- Medications?
- Pneumatic tibia brace
- AFO or crutches
- Cast?
- PT/orthotics?
- Surgery?

Swenson
Bone Stimulators

- Pulsed electric field across fracture site
- Increase osteoblastic activity
- History of use for non-healing fractures: femur, clavicle, scaphoid
- Pain free
- Worn for 30 min to 23 hours/day depending on the model
- $2,500 - $5,000

Bone Stimulators with Tibial Stress Fractures

- 44 athletes with tibial stress fractures
- Confirmed healing when could hop 10 cm for 30 seconds
- No difference in healing time compared with control group

Beck, AJSM 2008;36:545-553
Oral Contraceptives

- Multiple studies with mixed results on increases in bone density with use of OCPs
- Cobb failed to show increased bone density or decrease in stress fractures in prospective randomized study of female runners
- Energy shift is key to increase endogenous estrogen production and bone density

Biphosphonates

- Slow osteoclastic activity
- Slow bone loss associated with aging
- ?Treatment/prevention of stress fractures
Vitamin D

• Upregulates expression for genes
  – Intestinal calcium absorption
  – Renal tubular reabsorption
  – Osteoclastic activity
Calcium and Vit D

• Lappe, Female Navy recruits 8 weeks of 800IU Vit D and 2000mg Calcium- 21% decreased stress fracture risk
• Rvohola, Finish military recruits with 25(OH)D <30 ng/ml 1.3 increased stress fracture risk
Bone Density and Fracture Type

- Bone density + if < 1SD
- 8/9 Cancellous bone
- 3/11 Cortical bone
- DEXA?

DEXA Scan
Activity Restriction?

Active Rest

- Maintain aerobic fitness
- Pool running
- Swimming
- Stationary bike
- Elliptical
- Walk / jog
Re-introducing Running

- Start at 1/3 to 1/2 of preinjury mileage
- Increase by 10-15% per week until return to baseline
- Initially, athlete may need to supplement with other cardio activity when done with run
- Consider walk/jog or alternate days
- If develops pain, don’t need to start from the beginning
Prevention

- Increase activity by <10% per week
- Ensure appropriate vitamin D level
- Ensure adequate calcium intake
- Female athletes should maintain normal concentration of circulating estrogen
Let us ask you something.
And tell us the truth.

Does it matter to you that if you skip a day of running, only one person in the world will ever know? Or is that one person too many?

One less excuse to skip a day: the GEL-140™. Its substantial GEL® Cushioning System can handle even the most mile-hungry feet.

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Stress Fracture 1

• 23 year old female vet student was training for her 1st half Ironman triathlon and developed insidious left foot pain x 3 weeks

• Her baseline was running 20 miles per week (in addition to swimming and biking) but increased for her race

• Prior to seeing me, she took a week off but still had pain when restarted running. Walking was 2/10 pain.
Fracture 1: Continued

• Her exam demonstrated tenderness over the 3\textsuperscript{rd} and 4\textsuperscript{th} metatarsals with edema dorsally

• She was unable to hop on the affected foot

• Her gait was antalgic
Fracture 1: Treatment

• Patient was placed in an AFO and on crutches.
• She was able to wean both over 2 weeks.
• She cross trained with swimming and biking.
• She began running lightly every other day in 5 weeks.
• She did well in half Ironman 8 weeks after initial visit.
Metatarsal Stress Fractures

- Military personnel, distance runners, and ballet dancers
- >20 miles per week
- Fatigue of the plantar flexors of the foot results in increased strain
- Responds well to rest and possibly AFO
- Most heal after 4 weeks
- Follow care clinically

Stress Fracture 2

- 20 year old freshman college gymnast with increased uptake at left mid tibia during work up for back pain
- She had mild discomfort in that region for 6 months
- Physical exam was normal
- Follow-up radiographs were normal
Fracture 2

- She was treated with activity modification and pneumatic leg brace
- Despite no gymnastics and remaining pain free the entire summer, she developed pain with return to gymnastics
- Physical exam revealed and area of thickening and tenderness on the left mid anterior tibia
Fracture 2 Treatment

- She was placed in a short leg cast
- Despite monthly follow-up, there was no clinical or radiographic evidence of healing
- Patient had surgery slightly less than 1 year after initial positive bone scan
Anterior Tibial Stress Fractures

- Exclusively in athletes who perform repetitive jumping and leaping activities
- Tension side of the bone
- Prone to non-union
- Usually present with limitation of activity or palpable callus
- Diagnosed by plain radiograph

Treatment Anterior Tibial Stress Fractures

- 60% will develop complete fracture if no treatment
- Casting and non-weight bearing
- Consider bone scan and CT for help with decision
- Surgery
Biomechanics Anterior Tibial Stress Fracture

- Drop landings performed by female gymnasts exhibited higher vertical ground reaction forces
- Decreased knee flexion on landing
- Decreased ankle dorsiflexion

Summary

• Bone Health is a balance of stress and recovery
• Creating the proper bone environment requires good nutrition including calories, vitamin D, and calcium
• Don’t be afraid of low risk stress fractures - they do well
• Recognize and refer high risk stress fractures