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Outline

Part 1: Determinants BSI healing

- Trabecular-rich vs. cortical-rich sites
- Bone architecture
- Low-risk vs. high-risk sites

Part 2: Specific BSIs

- Sacral
- Femoral shaft
- Femoral neck

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Part 1
Determinants of BSI healing

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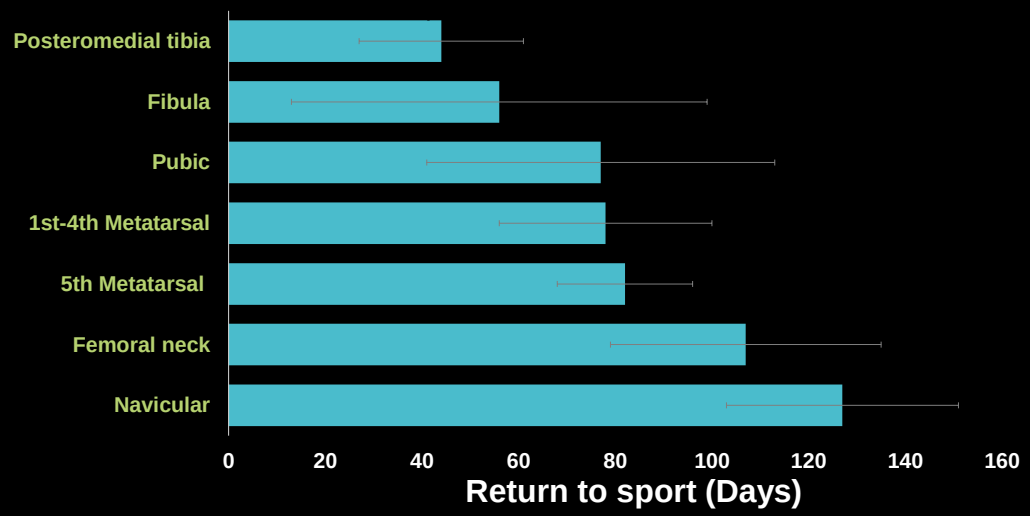
Return to sport timelines vary widely



Hoenig, T, et al. "Return to sport following low-risk and high-risk bone stress injuries: a systematic review and meta-analysis." *BJSM* (2023).

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Cortical versus trabecular-rich bone stress injury sites

Cortical-rich

Less metabolically active

Associated more with areas of high bone loads

Situated more distally, typically

Trabecular-rich

More metabolically active

More sensitive to changes in sex hormones

Trabecular metabolism highly sensitive to underfueling

Tenforde AS et al. Female Athlete Triad Risk Factors Are More Strongly Associated With Trabecular-Rich Versus Cortical-Rich Bone Stress Injuries in Collegiate Athletes. *Orthop J Sports Med*. 2022

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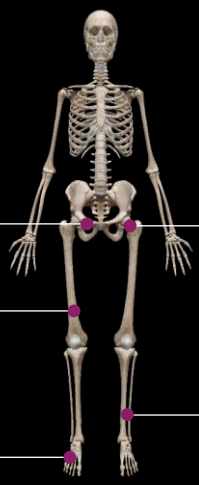
Female vs. Male BSI Risk

Greater risks in female Soldiers



Pubic rami BSIs
100x greater risk

Femoral neck BSIs
7x greater risk

Femoral shaft BSIs
2.7x greater risk

Metatarsal BSIs
2.7x greater risk

Tibial BSIs
2.3x greater risk

Waterman BR., et al. "Epidemiology of lower extremity stress fractures in the United States military." *Military Medicin*e 181.10 (2016): 1308-1313;
[2]Gun K., et al. "Prevalence and risk factors for musculoskeletal back injury among US Army personnel." *Military Medicine* 187.7-8 (2022): e814-e820;

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Tibial and femoral BSIs spike during competitive periods

Sacral bone stress injury risk is constant

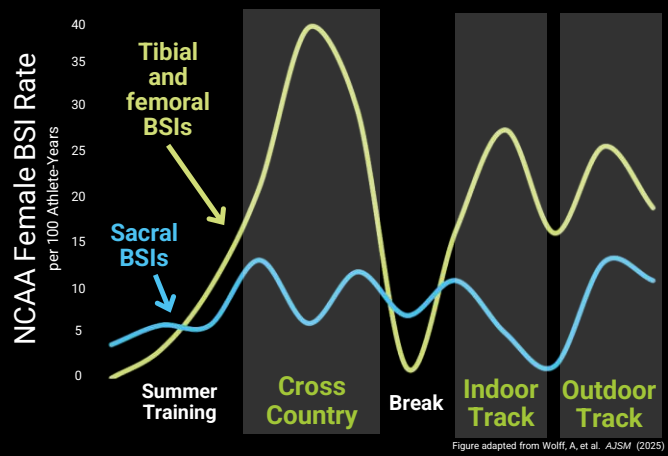

Figure adapted from Wolff, A, et al. *AJSM* (2025)

Problematic low energy availability

Consequences do not fluctuate much throughout the year

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Wolff, A, et al. "A Descriptive Analysis of the Seasonal Patterns of Bone Stress Injury Incidence in Division I Collegiate Distance Runners." *AJSM* (2025)

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Always suspect problematic low energy availability with trabecular-rich bone stress injuries

Every *1-point increase* in Triad Cumulative Score

An *additional 26% increased risk* of a trabecular BSI

The more proximal the BSI, the more likely LEA is involved

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Roche, M, et al. "Higher Triad Risk Scores Are Associated With Increased Risk for Trabecular-Rich Bone Stress Injuries in Female Runners." *Clinical Journal of Sport Medicine* (2022): 10-1097.

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Diaphyseal BSIs heal earlier vs. irregular bone fracture

3rd Metatarsal diaphyseal BSI

Navicular BSI

Sacral BSI

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Not all fractures heal at the same rate

Fracture with poor vascularity

E.g., Navicular bone stress injury
4.1-5.6 months to heal

Fractures under tension

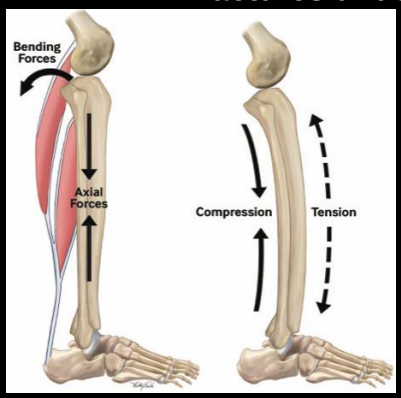

Figure from Arhos & Willy, 2024

Chung et al.,2019

E.g., Anterior cortex tibial bone stress injury
2.8-9 months to heal

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Healthy Running Project

Nutritional intervention in Div. I Female Distance Runners

Registered dietician

Presentation at start of season

Athlete consultations, based on risk profile

1-2 *individualized* goals for bone health

Post-run fueling

Carbohydrates per meal

PC: Courtney Vondracek

Lower incidence of *trabecular-rich* bone stress injuries

Fredericson M, et al. "Healthy Runner Project: a 7-year, multisite nutrition education intervention to reduce bone stress injury incidence in collegiate distance runners." *BMJ Open Sport & Exercise Medicine* 9.2 (2023)

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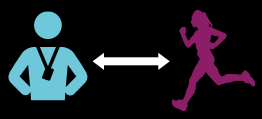
The influence of team culture on runner health and fueling behaviors

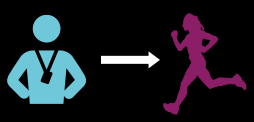


Supportive relationship

Normalizes dialogue on fueling and health;
Athlete health first, performance second

Avoidant relationship

Aversion to discuss health and fueling



Confrontational relationship

Strict rules on body composition,
fueling, and training practices

Hamer, J et al. (2023). A review exploring coach knowledge, attitudes/beliefs and behaviours towards low energy availability in athletes. *Int. J. of Sp Sci & Coaching*, 18(3), 945-969.

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Part 2
Rehabilitation of specific BSIs

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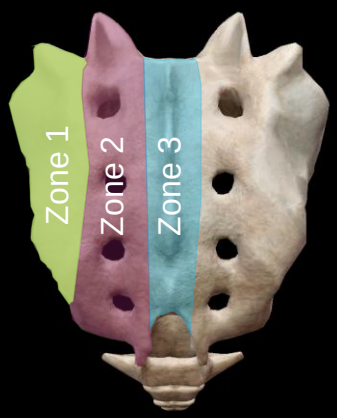
Sacral Bone Stress Injuries

- Trabecular rich: *Always* suspect REDs
- Majority in Zone 1, adjacent to SI Joint
- 78-86% are accompanied with Pubic rami BSI
- Low back, SI, or buttock pain present up to 95% cases

Denis Classification



Zone 1 Sacral Ala BSI

Aretxabala I, et al. Sacral insufficiency fractures. High association with pubic rami fractures. *Clin Rheumatol.* 2000; Tenforde, Adam S., and Michael Fredericson, eds. Bone Stress Injuries: Diagnosis, Treatment, and Prevention. Springer Publishing Company, 2021.

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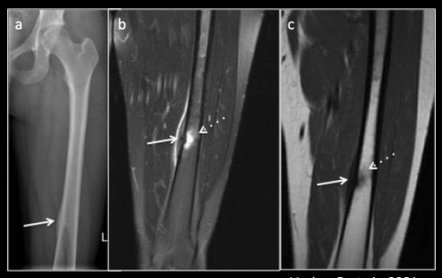
Femoral shaft BSIs

Examination



Hedge G et al., 2021

Fulcrum test
Sensitivity: 0.93
Specificity: 0.75
+LR: 3.72
-LR: 0.09

7.2-25.0% of BSIs

Mostly compression (medial) side. Mid-shaft and proximal shaft most common

Mimics quad strain

Positive hop test and fulcrum test => MRI. Radiographs: poor sensitivity

Rizzone, K. H., Ackerman, K. E., Roos, K. G., Dompier, T. P., & Kerr, Z. Y. (2017). The epidemiology of stress fractures in collegiate student-athletes, 2004–2005 through 2013–2014 academic years. *Journal of Athletic Training*, 52(10), 966-975.

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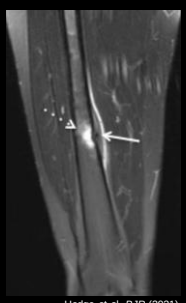
Femoral BSIs typically on medial side

Narrow step width



Hedge et al. *BJR* (2021)

Ground reaction force

Ground reaction force

Cueing a higher running cadence reduces step width

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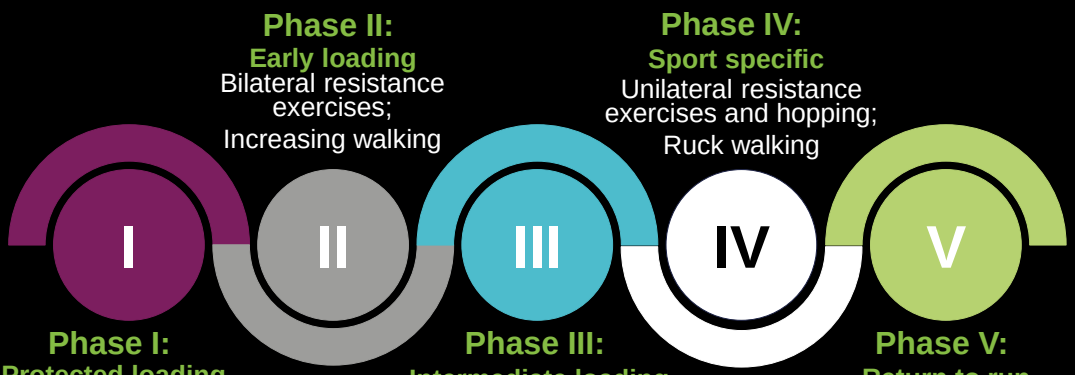
Overview of sacral, femoral shaft and neck BSI rehabilitation



Phase I:
Protected loading
Sacrum and femoral shaft: Partial weight bearing via crutches;
Femoral neck: Non-weight bearing => partial weight bearing as per grading

Phase III:
Intermediate loading
Unilateral resistance exercises;
Bilateral hopping

Phase V:
Return to run
Pass lateral hop test without symptoms; Neg fulcrum for femoral shaft

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Sacral Bone Stress Injuries

Treatment

Phase I: PWB until pain-free; Refer to registered dietician

Phase II: Restoration of trunk and lower extremity strength

A

B

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Aretxabala I, et al. Sacral insufficiency fractures. High association with pubic rami fractures. *Clin Rheumatol.* 2000; Tenforde, Adam S., and Michael Fredericson, eds. Bone Stress Injuries: Diagnosis, Treatment, and Prevention. Springer Publishing Company, 2021.

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Sacral Bone Stress Injuries

Treatment

Phase III and IV: Sport-specific and return to run




Phase IV: Return to run, post-sacral BSI: 14-16 weeks

Aretxabala I, et al. Sacral insufficiency fractures. High association with pubic rami fractures. *Clin Rheumatol.* 2000; Tenforde, Adam S., and Michael Fredericson, eds. Bone Stress Injuries: Diagnosis, Treatment, and Prevention. Springer Publishing Company, 2021; Fredericson M, Salamancha L, Beaulieu C. Sacral stress fractures: tracking down nonspecific pain in distance runners. *Phys Sportsmed*. 2003;

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Femoral neck BSI

Risk factors and return to sport

Risk Factors

Femoral neck BSIs: <5% of all BSIs

Female sex

REDs: Trabecular-rich site

Low bone mineral density: 10-27.8% lower than peers

Biomechanics: No clear evidence

Return to sport (RTS) and avascular necrosis (AVN) rates

- Non-displaced: RTS: up to 100%; AVN: 0%
- Displaced: RTS: 0-32%; AVN: 42%

Robertson and Wood, 2017

Complete, compression-sided femoral neck BSI

Always suspect REDs in femoral neck BSIs

Adkins 3rd, S., et al. "Femoral neck stress fractures in sport: a current concepts review." *Sports Medicine International Open* 1.02 (2017); Bernstein, M., et al. "Femoral neck stress fractures: an updated review." *JAAOS.* 30.7 (2022).

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Femoral neck BSI

Examination

Pain present at the hip, groin, anterior thigh, medial knee

Pain at rest

Exam findings:

- Positive hop test
- Painful endrange flexion, hip flexor and groin spasm
- Positive FADDIR test

FADDIR test

The runner presenting with hip and groin pain has a femoral neck BSI until proven otherwise

Adkins 3rd, S., et al. "Femoral neck stress fractures in sport: a current concepts review." *Sports Medicine International Open* 1.02 (2017); Bernstein, M., et al. "Femoral neck stress fractures: an updated review." *JAAOS.* 30.7 (2022).

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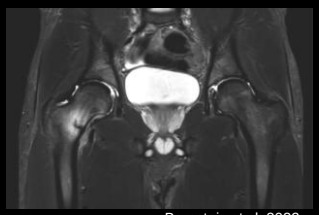
Femoral neck BSI

Classification systems



Bernstein et al. 2022

Compression sided >50% width. Cannulated screw

Bernstein et al. 2022

Robertson and Wood. 2017

Tension-sided, complete. Dynamic hip screw

Various classification systems: Arendt, Fullerton & Snowdy, Provencher, etc.

Basically, classifications are based on:

a) Compression-sided vs. Tension-sided
b) Non-displaced vs. displaced
c) Size of fracture propagation, with 50% neck width being important
d) Presence/absence of bone marrow edema

Bernstein, M., et al. "Femoral neck stress fractures: an updated review." *JAAOS.* 30.7 (2022).

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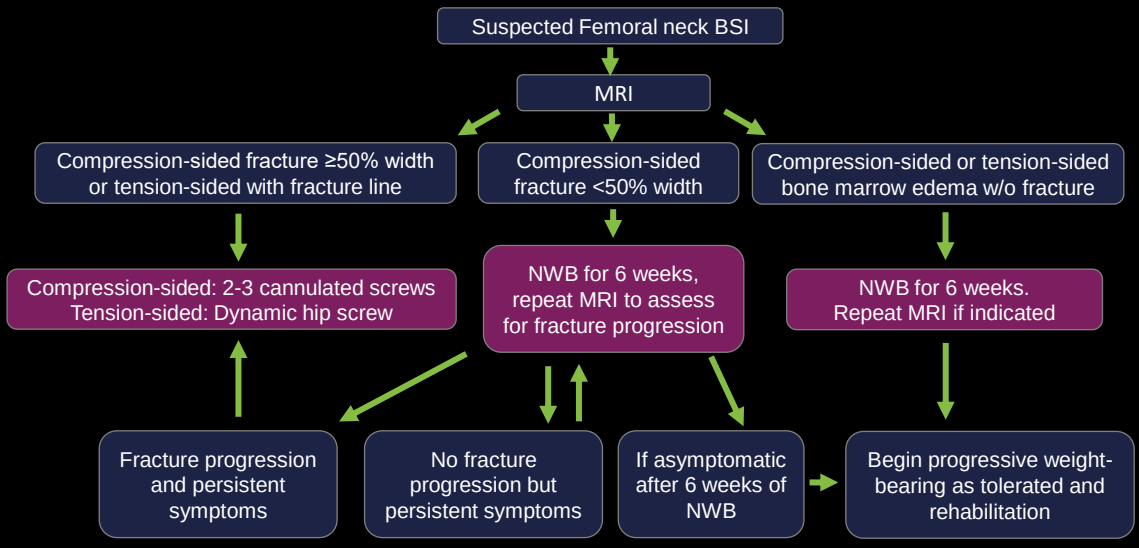
Femoral neck BSI

Management algorithm



Bernstein, M., et al. "Femoral neck stress fractures: an updated review." JAAOS. 30.7 (2022).

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Femoral neck BSI

Surgical and non-surgical treatment

Weight bearing guidance

Surgical: NWB for 2 weeks=> Weeks 3-12: TTWB=> PWB

Non-surgical: NWB => TTWB for 6 weeks; Gradual increase in weightbearing over 2-4 weeks. Must follow the algorithm.

Full WB when pain-free.

Compression sided femoral neck BSI, dual cannulated screws

Bernstein et al. 2022

Rehabilitation

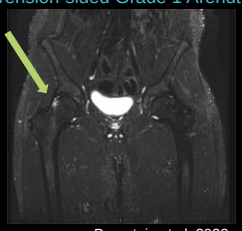
Begin strengthening when fracture healing is evident

Initially, bilateral strengthening (squats, hip thrusters)

Unilateral strengthening: RDLs, step ups, leg press, abductors

Then, bilateral plyos => unilateral plyos. Use bands initially

Tension-sided Grade 1 Arendt



Bernstein et al. 2022

Robertson GA & Wood AM. *Sports Medicine International Open* 2017; Adkins 3rd, S., et al. "Femoral neck stress fractures in sport: a current concepts review." Sports Medicine International Open 1.02 (2017); Bernstein, M., et al. "Femoral neck stress fractures: an updated review." JAAOS. 30.7 (2022).

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Summary

1. Always suspect problematic low energy availability with a femoral neck or sacral BSI
2. Femoral shaft BSIs occur on the compression side
3. Femoral neck BSIs have the highest rate of non-return
4. Start with bilateral loading, progressing to unilateral loading

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