Female Athlete Triad Risk Factors Are More Strongly Associated with Trabecular-Rich Bone Stress Injuries in Collegiate Athletes

Nicole B. Katz, B.S.[1], Adam S. Tenforde, M.D.[2], Kristin L. Sainani, Ph.D.[3], Jennifer L. Carlson, M.D.[4], Neville H. Golden, M.D.[4], and Michael Fredericson, M.D.[5]

1. Lewis Katz School of Medicine at Temple University, Philadelphia, PA; 2. Spaulding Rehabilitation Hospital, Spaulding National Running Center, Department of Physical Medicine and Rehabilitation, Harvard Medical School, Charlestown, MA; 3. Stanford University, Department of Epidemiology and Population Health, Stanford, CA; 4. Stanford University, Department of Pediatrics, Division of Adolescent Medicine, Stanford, CA; 5. Boswell Human Performance Laboratory, Department of Orthopaedic Surgery, Stanford, CA; Stanford University, Department of Orthopaedic Surgery, Division of Physical Medicine and Rehabilitation, Stanford, CA

SPAULDING REHABILITATION NETWORK
MASSACHUSETTS GENERAL HOSPITAL
BRIGHAM AND WOMEN'S HOSPITAL
HARVARD MEDICAL SCHOOL TEACHING HOSPITAL

Abstract

Objectives: We hypothesized that Female Athlete Triad (Triad) risk factors would be more strongly associated with Bone Stress Injuries (BSIs) sustained at trabecular- versus cortical-rich bone. **Design:** In this retrospective cohort study of collegiate athletes, Triad-related risk factors were measured from a pre-participation examination and bone mineral density (BMD) were measured using DEXA. The first BSI (if any) sustained subsequent to these examinations was recorded for each athlete. Multinomial logistic regression was used to compare the impact of Triad-related risk factors on trabecular- versus cortical-rich BSI. **Results:** Of 321 athletes, 9.0% sustained a BSI. Previous BSI and cumulative Triad risk score were significantly associated with both types of BSIs. Lower BMD and lower weight increased the risk of a trabecular- significantly more than cortical-rich BSI. Taller height was associated with a significantly higher risk of a cortical- versus trabecular-rich BSI. **Conclusions:** Previous BSI and cumulative Triad risk scores were risk factors for both types of BSI. Lower BMD and lower weight were stronger risk factors for trabecular-rich than cortical-rich BSI; taller height was a stronger risk factor for cortical-rich BSI.

Introduction

Bone stress injuries (BSIs) are common in athletes; however, risk factors differ by anatomical location. Bone matrix is categorized as cortical (compact) or trabecular (honeycomb). BSIs occur in both cortical-rich bone (metatarsal, tibia, femoral shaft, tarsal navicular, talus, cuboid, ulna) and trabecular-rich bone (sacrum, femoral neck, ilium, calcaneus), though associated risk factors have been suggested to differ. We hypothesized that Female Athlete Triad (Triad) risk factors would be more strongly associated with BSIs sustained at trabecular- versus cortical-rich bone.

Methods

- This was a retrospective cohort study of woman-identifying collegiate athletes from multiple sports.
- Triad-related risk factors were measured from a pre-participation examination and bone mineral density (BMD) were measured using dual energy x-ray absorptiometry (DEXA) for the lumbar spine and whole body.
- The first BSI (if any) sustained subsequent to the aforementioned examinations was recorded for each athlete.
- Multinomial logistic regression (with outcomes: no BSI, cortical BSI, or trabecular BSI) was used to compare the impact of Triad-related risk factors on trabecular-rich versus cortical-rich BSI.
- Models were adjusted for cross country participation, given this sport's higher BSI incidence.

Table 1. Athlete Demographics

Category	Value
Anthropometric characteristics	*Mean (SD)*
Caucasian/non-Hispanic	231 (72.0%)
Non-Caucasian	90 (28.0%)
Age (y)	19.8 (1.2)
Height (m)	1.7 (0.1)
Weight (kg)	66.1 (11.0)
BMI (kg/m^2)	22.9 (2.7)
Percent body fat	23.97 (5.49)
Spine BMD (g/cm^2)	1.30 (0.17)
Spine Z-score	0.76 (1.26)
Total BMD (g/cm^2)	1.22 (0.13)
Total Z-score	1.02 (1.01)
Elevated Triad risk factor*	*Number (% of total cohort)*
Low energy availability	7 (2.2%)
Low BMI	7 (2.2%)
Delayed menarche	74 (23%)
Oligomenorrhea/amenorrhea**	61 (26%)
Low BMD	25 (7.8%)
Stress reaction/stress fracture	50 (15.6%)
Triad risk category **	67 (28.5%)
Sport participation	*Number (% of total cohort)*
Distance runners	58 (18.1%)
Non-distance runners	263 (81.9%)

*Elevated Triad risk category includes total portion of population studied meeting moderate or high risk.
**Value unable to be determined in 86 athletes due to current use of hormonal contraception.

Results

Table 2. Odds ratios (95% CI) from adjusted multinomial logistic regression model relating Triad risk factors to risk of prospective trabecular-rich or cortical-rich BSI

	Trabecular-rich BSI vs. None		Cortical-rich BSI vs. None		Trabecular-rich BSI vs. Cortical-rich BSI
Characteristic	**OR (95% CI)**	**p-value**	**OR (95% CI)**	**p-value**	**p-value**
Spine BMD (per std dev)	0.26 (0.11 - 0.60)	0.002	0.81 (0.49 - 1.32)	0.39	0.01
Total BMD (per std dev)	0.55 (0.36 - 0.83)	0.005	1.3 (0.75 - 2.23)	0.35	0.01
Cumulative Risk Score (per point)	1.51 (1.13 - 2.02)	0.006	1.37 (1.07 - 1.76)	0.01	0.52
Cum risk score minus BMD points	1.63 (1.16 - 2.29)	0.005	1.45 (1.09 - 1.93)	0.01	0.52
Oligo risk (per point)	3.08 (1.33 - 7.11)	0.009	1.84 (0.95 - 3.55)	0.07	0.28
BSI risk (per point)	3.19 (1.41 - 7.22)	0.005	3.16 (1.68 - 5.95)	0.0004	0.98
BMD risk (per point)	3.16 (1.09 - 9.15)	0.03	1.65 (0.58 - 4.71)	0.35	0.30
Menarche risk (per point)	2.13 (0.96 - 4.73)	0.06	1.71 (0.92 - 3.18)	0.09	0.64
BMI risk (per point)	3.2 (0.76 - 13.53)	0.11	1.71 (0.36 - 8.08)	0.50	0.44
EA risk (per point)	2.64 (0.63 - 11.07)	0.19	1.91 (0.49 - 7.44)	0.35	0.68
Weight (lbs.)	0.22 (0.07 - 0.73)	0.01	1.16 (0.71 - 1.90)	0.56	0.01
Height (inches)	0.59 (0.23 - 1.50)	0.27	2.14 (1.24 - 3.69)	0.006	0.02
BMI (kg/m^2)	0.25 (0.09 - 0.74)	0.01	0.66 (0.37 - 1.18)	0.16	0.10
Percent body fat (%)	0.64 (0.30 - 1.38)	0.25	0.86 (0.51 - 1.47)	0.59	0.50

- Of the 321 athletes, 9.0% (n=29) sustained a BSI (19 cortical-rich, 10 trabecular-rich).
- Previous BSI and cumulative Triad risk score were significantly associated with both types of BSI (**all p<0.05**).
- Lower BMD and weight increased risk of trabecular-rich BSI significantly more than cortical-rich BSI (**all p<0.05**).
- The odds ratios for trabecular-rich versus cortical-rich BSI for every 1 standard deviation lower value were 3.03 (**p=0.01**) for spine BMD, 2.38 (**p=0.01**) for whole body BMD, and 5.26 (**p=0.01**) for weight.
- Taller height was associated with a significantly higher risk of cortical versus trabecular BSI (OR for cortical versus trabecular BSI per 1 SD taller height=3.57, **p=0.02**).
- Menstrual dysfunction had a qualitatively stronger association with trabecular-rich BSI risk (p=0.06).

Conclusions

Previous BSI and cumulative Triad risk scores were risk factors for both types of BSI. Lower BMD and lower weight were stronger risk factors for trabecular-rich than cortical-rich BSI; taller height was a stronger risk factor for cortical-rich BSI. These findings highlight the critical role of biological data in understanding an athlete's risk for a BSI. Given the strong relationship shown between Triad-related risk factors and components of the Triad with BSIs in trabecular-rich bone, these modifiable risk factors should also be addressed in management of current BSIs and prevention of future ones.