Identifying Factors That Contribute to Adolescent Bony Stress Injury in Secondary School Athletes: A Comparative Analysis With a Healthy Athletic Control Group

Eric D. Nussbaum, MEd, LAT, ATC,*[†] Jaynie Bjornaraa, PT, PhD, MPH, SCS, LAT, ATC, CSCS,[‡] and Charles J. Gatt Jr, MD[†]

Background: Bony stress injuries (BSIs) are common among adolescents involved in high school sports. A better understanding of factors that contribute to adolescent BSI is needed to target preventative measures.

Hypothesis: Individuals who suffer a BSI will demonstrate significant differences in training methods, sleep, diet, and history of injury compared with a healthy, noninjured control group.

Study Design: Descriptive epidemiologic study.

Methods: Data from the National High School Stress Fracture Registry (NHSSFR), an internet-based adolescent BSI survey, were used to identify variables reported with adolescent (13-18 years of age) BSI. These findings were compared with a survey of 100 (50 males, 50 females) healthy athletic controls to identify significant differences between healthy adolescents and those with BSI.

Results: A total of 346 stress fractures were reported in 314 (206 females, 108 males) athletes within the NHSSFR. Comparison with healthy control participants demonstrated multiple significant findings. In particular, body mass index was significantly lower for patients with BSI injury compared with controls ($P < 0.001$). Patients slept significantly less than the control group (7.2 vs 7.95 hours; $F = 34.41$; $P < 0.001$). Females also slept significantly less hours than males (7.2 vs 7.63 hours; $F = 11.02$; $P < 0.001$). Fifty-eight percent of those who reported a BSI did not engage in any weight training. Those with a BSI had significantly higher average stress ratings than control participants (1.67 vs 1.42; $P < 0.001$), and females also rated their stress levels significantly higher than males (1.8 vs 1.38; $P < 0.001$). A significant difference between patients with any BSI and control participants existed for history of "shin splints" (Pearson $\chi^2 = 28.31$; $P < 0.001$), and females also expressed having shin pain lasting for longer than 4 weeks (Pearson $\chi^2 = 8.12$; $P < 0.001$) and more often (Pearson $\chi^2 = 5.84$; $P = 0.02$) than males. There was also a significant difference between patients with BSI and control subjects regarding dairy intake (2.25 vs 2.69; $F = 6.43$; $P = 0.01$).

Conclusion: Findings revealed significant differences between those who reported a BSI relative to healthy athletic adolescents. These differences included body mass index, prior history of shin splints, involvement in weight training, amount of sleep, daily stress, and dairy intake. Preventive measures should be developed to address these areas to reduce the incidence of BSIs in the adolescent population.

Keywords: adolescent; bony stress injury; National Stress Fracture Registry; epidemiology

From [†]Department of Orthopaedic Surgery, Robert Wood Johnson Medical School, Rutgers, Somerset, New Jersey, and [‡]Doctor of Physical Therapy Program, St Catherine University, Minneapolis, Minnesota

*Address correspondence to Eric D. Nussbaum, MEd, LAT, ATC, Clinical Instructor, Department of Orthopaedic Surgery, Robert Wood Johnson Medical School, Rutgers, 2 Worlds Fair Drive, Somerset, NJ 08873 (email: ericn@uognj.com).

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According to the National Federation of State High School Associations, participation in high school sports continues to grow,²¹ as does the incidence of adolescent overuse injuries, including bony stress injury (BSI).⁵ Young athletes appear to be more susceptible to BSI than adults^{6,13,15,24}; 40% to 50% of all reported BSIs occur in those younger than 20 years of age.^{10,16,19}

There is much variability in the definition of a stress fracture by physicians.³ Some practitioners refer to grades of stress reaction compared with others who call significant stress reaction a stress fracture. To simplify this discrepancy and reflect a growing trend, all stress fractures were referred to as BSIs in this study.²¹

Adolescence is a time of growth and involvement in formal, organized club and high school-based sports. High school sports often increase the demands on time by increasing duration, frequency, and intensity of sporting activity. Athletes may be expected to train year-round, specialize at a younger age, and become involved in more intensive training. Consequently, participation in organized sports during adolescence has been noted as a risk factor for adolescent BSI.¹

Understanding the factors that contribute to injury is an important first step in the development of preventative strategies. Therefore, the objective of this study was to identify and compare factors associated with adolescents involved in high school sports who experienced BSIs relative to a healthy athletic control group.

METHODS

Study Population

The survey and methodology were reviewed and approved by a university institutional review board. We analyzed data from the National High School Stress Fracture Registry (NHSSFR), an internet-based data recording system, for 53 different variables that may be associated with adolescent stress fracture or BSI. A total of 60 certified athletic trainers from 11 different states who worked in varied demographical high school settings during a 2-year time period volunteered and registered to collect the deidentified data. Reports were filed by the athletic trainer when an adolescent athlete (13-18 years of age) was diagnosed by a physician as having a BSI. The athletic trainer would log onto the site with the athlete and complete the 53-question survey.

Questions selected for the registry were gathered from reviews of published literature and identified as factors that contributed to BSI. This survey was validated by a review of 10 licensed athletic trainers who reviewed the survey for content. Revisions to the final version were made based on feedback from the review group.

Questions on the registry included demographics, training activity, sports participation, nutrition, shin pain history, pain, diet, sleep, stress, equipment, and facilities. The healthy control group data were collected from athletes in various sports from 2 different schools who did not have any history of athletic-related bony pain and who completed the same 53-question survey.

Definition of Injury

The NHSSFR defined BSIs as those injuries diagnosed by a physician and confirmed by either radiograph, magnetic resonance imaging, bone scan, or computed tomography. A reportable BSI occurred as a result of involvement with a high school sport. Individuals who reported more than 1 BSI were recorded as separate injuries, but results were only analyzed based on each reporting individual. A detailed explanation of the inclusion criteria, which included notation of history, positive imaging, and formal physician diagnosis, was provided to all athletic trainers who registered with and participated in the study.

Statistical Analysis

Descriptive statistics are reported for all relevant continuous variables. Comparative bivariate analyses between groups (BSI vs control) and sexes for continuous variables were performed using a 2-way analysis of variance, where $P < 0.05$ was considered significant. Post hoc Tukey tests were completed where necessary, and P values were adjusted accordingly. Comparative analyses for categorical variables were performed using chi-square analysis. All analyses were executed using SPSS software (v 24.0; IBM Corp).

RESULTS

The NHSSFR reported 346 adolescent BSIs in 314 (206 females, 108 males) athletes during the 2-year recording period. The majority (89.9%) of athletes reporting BSI were Caucasian. Twenty-four females (11.7%) reported more than 1 BSI location compared with 6.5% of males; 13 of the 24 (54.1%) were bilateral. Seven males reported BSI in multiple areas, and 1 (14.3%) was bilateral. BSI locations included the following: 14 (45.2%) in the lower leg (tibia/fibula), 14 (45.2%) in the foot, and 3 (9.7%) in the lumbar spine. The tibia was the most frequently reported site, followed by the foot (25.7%), fibula (8.3%), lumbar spine (6.6%), hip/pelvis (5.1%), and femur (3.2%).

Based on chi-square analysis, males and females alike reported stress injury with a frequency that would be as expected based on the sample size. Significant differences between patients and controls were noted for body mass index (BMI), sleep, weight training, stress levels, history of "shin splints," and dairy intake (Table 1). The mean BMI for patients with BSI was 20.96 for females and 21.52 for males, compared with 23.24 for female and 24.19 for male control participants. Although BMI was in the normal range for their age, BMI was significantly lower for patients with BSI injury compared with controls ($P < 0.001$).

With regard to diet, patients with BSI reported consuming significantly fewer dairy products than the control group (2.25 vs 2.69; $F = 6.43$; $P = 0.01$). Females also consumed significantly fewer servings of dairy than males (2.17 vs 2.64; $P < 0.001$).

Athletes were asked to rate their daily stress as high, moderate, low, or no stress. A stress score was computed based on a scoring of 3 points for high stress, 2 points for moderate stress, 1 point for low stress, and 0 points for no stress. Normal

Table 1. Significant comparative findings

	All Participants			BSI Group			Control Group		
	Male	Female	All	Male	Female	All	Male	Female	All
Age, ^{a,b} y	15.94	15.72	15.80	15.87	15.62	15.7	16.16	16.17	16.17
No. of stress fractures	115	231	346	115	231	346	0	0	0
BMI, ^{a,b,c,d} kg/m ²	23.02	21.35	21.94	21.52	20.96	21.62	24.19	23.24	23.66
Seasons per year ^a	2.21	2.29	2.27	2.26	2.31	2.3	2.05	2.15	2.11
Weight training sessions per week ^{a,b,c,d,e}	1.74	0.97	1.25	1.36	0.87	1.03	2.95	1.47	2.12
Dairy intake, servings per day ^{a,c}	2.64	2.17	2.35	2.48	2.12	2.25	3.11	2.36	2.69
Hours of sleep ^{a,c,d,e}	7.63	7.2	7.37	7.44	7.06	7.2	8.19	7.76	7.95
Stress level ^{a,c,d}	1.38	1.8	1.6	1.45	1.87	1.67	1.16	1.62	1.42

BMI, body mass index; BSI, bony stress injury.

^aSignificant difference between stress fracture and control group.

^bSignificant difference between females × group (stress fracture and control).

^cSignificant difference between sexes (all participants).

^dSignificant difference between sexes for stress fracture group.

^eSignificant difference between males × group (stress fracture and control).

daily stress levels were significantly different between patients with BSI compared with controls. Those with BSI had significantly higher average stress ratings than control participants (1.67 vs 1.42; $P < 0.001$), independent of specific sport involvement. Females also rated their stress levels significantly higher than males (1.8 vs 1.38; $P < 0.001$).

Forty-eight percent of athletes who reported BSI played 3 seasons per year. Most participants were involved in more than 2 seasons, and patients with BSI were involved in significantly more seasons per year than control participants ($P = 0.045$).

Patients with BSI reportedly slept significantly less than the control group (7.2 vs 7.95 hours; $F = 34.41$; $P < 0.001$). Females also slept significantly less hours than males (7.2 vs 7.63 hours; $F = 11.02$; $P < 0.001$).

Fifty-eight percent of those who reported a BSI did not engage in any weight training. There was a main effect for group, with BSI patients training with weights significantly less times per week than controls (1.03 vs 2.12; $P < 0.001$). There was also a main effect for sex, with male patients training with weights significantly more times per week than females (1.74 vs 0.97; $P < 0.001$). A significant interaction was also noted across groups, with males in the control group training with weights significantly more times per week than females with BSI (2.95 vs 0.87; $P < 0.001$).

A significant difference between patients with BSI and controls existed for history of “shin splints” (Pearson $\chi^2 = 28.31$; $P < 0.001$). More patients with BSI expressed a history of shin pain greater than expected, while fewer control participants reported

shin pain greater than expected. Within the patients with BSI, a significant difference existed between males and females, with females reporting a history of shin pain more frequently than males relative to what would be expected (Pearson $\chi^2 = 10.07$; $P < 0.001$). Females also expressed having shin pain lasting for greater than 4 weeks (Pearson $\chi^2 = 8.12$; $P < 0.001$) and more often than males (Pearson $\chi^2 = 5.84$; $P = 0.02$).

Patients with BSI were asked to subjectively rate their pain on a scale of 0 to 10 (0, no pain; 10, worst pain). The mean subjective pain score was 7 (Figure 1). Eighty-one percent of respondents with BSI expressed a score of greater than 6. Given that the control group was uninjured, they did not express any bony pain, for comparison between groups. Chi-square analysis was performed to note any significant differences between males and females within the group with BSI with regard to pain measures. Significant differences were reported for night pain, with females expressing more pain at night (Pearson $\chi^2 = 4.33$; $P = 0.04$), pain with ambulation (Pearson $\chi^2 = 10.25$; $P < 0.001$), and pain negatively affecting performance (Pearson $\chi^2 = 8.75$; $P < 0.001$) compared with males.

DISCUSSION

Few studies have examined BSI in the adolescent population across a variety of boys' and girls' sports and relative to a healthy control group while considering a wide sample of variables.^{5,15} We were not able to capture the actual incidence of stress fracture, as tracking daily/seasonal participation was fluid for this

study and therefore considered logistically challenging. Rather, the purpose of this study was to identify factors that contribute to BSI and these factors were found to be significant when compared with a healthy, athletic control group.

Sixty-eight percent of females and 58% of males who reported to the NHSSFR competed at the varsity level, which was consistent relative to the control group (70% females, 64% males). When considering that the mean age for reported fracture was 15.62 years for females and 15.87 years for males and the age for junior/senior level participation in high school sports is 16 to 18 years, it appears evident that those who are younger and competing at a higher level may be at greater risk for BSI. Competing with older, more physically developed varsity athletes may increase the intensity of competition, physical demands, psychological stress, demands on time, and expectations. All factors may contribute to overload in a younger athlete and make them more prone to BSI.²⁷ Goldberg and Pecora¹⁰ demonstrated that a change in sporting level from high school to collegiate was noted as a risk factor for BSI, as intensity of training and competition increased.

The BSI group noted shin pain that lasted longer than 4 weeks and occurred more often than that in the control group. This may indicate shin pain as a predisposition to injury^{14,18,20,29,30} and emphasizes earlier recognition and more aggressive treatment recommendations for those experiencing adolescent bony pain.²

Current understanding of adolescent BSI suggests that injuries not identified and managed appropriately may take significantly more time to heal, may progress to a more serious bony injury, including fracture,^{9,14,22,23} and do not always culminate in a good outcome after treatment.^{7,8,15,24} There also appears to be a high recurrence rate of BSI, from 6% to 36%.^{10,12,17,19,26} A prior history of BSI is a strong predictor of future BSI.^{11,13,26,28}

Eighty-one percent of athletes reported a BSI pain score of greater than 6, with a median score of 7 (see Figure 1). Night pain, pain with ambulation, and pain that affected performance were all noteworthy findings. The incidence of BSI is frequently underreported or underappreciated by athletes and physicians.⁴ In athletics, there is often a “no pain, no gain” mentality and a perceived toughness expected during competition.

Consequently, many athletes will attempt to push through and continue to compete while experiencing pain.²⁵ Therefore, determination of existing pain and duration is important.

Limitations

This study was performed using an online collection system that involved self-reporting of BSI. Significant limitations exist with the accuracy of self-reported data. The authors relied on the integrity of those reporting the BSI and related information. Survey questions were intended to focus on general concepts and do not reflect relative risk of injury or specific tracking of data from sleep/practice/dietary logs or devices.

CONCLUSION

Some male and female high school athletes across a wide range of high school sports are at risk for suffering a BSI. The adolescent athletic population is a distinctly unique group that should receive extra scrutiny considering the age of these athletes, involvement in competitive strenuous activity, growth, and development. A better understanding of factors that contribute to adolescent BSI needs to be refined and preventative strategies developed to reduce their impact.

Because of developmental differences in strength, size, ability, coordination, and bone strength between adolescents and adults, training variables suggested for adult athletes such as specialization, extended duration of practice, number of successive days of practice, and acceptable rest may not be appropriate for the adolescent population. Based on the findings from NHSSFR and the comparison of reported data with a healthy control group, significant targets for preventative strategies include the reduction of psychosocial stress, weight training, dairy intake, and appropriate sleep and rest.

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REFERENCES

1. Bennell K. Models for pathogenesis of stress fracture in athletes. *Br J Sports Med*. 1996;30:200-204.
2. Bennell K, Malcolm SA, Brukner PD, et al. A 12 month prospective study of the relationship between stress fractures and bone turnover in athletes. *Calcif Tissue Int*. 1998;63:80-85.
3. Bolin D, Kemper A, Bolinson PE. Current concepts in evaluation and management of stress fractures. *Curr Sports Med Rep*. 2005;4:295-300.
4. Brunet ME, Cook SD, Brinker MR, Dickinson JA. A survey of running injuries in 1505 competitive and recreational runners. *J Sports Med Phys Fitness*. 1990;30:307-315.
5. Changstrom BG, Brou L, Khodae M, Braund C, Comstock RD. Epidemiology of stress fracture injuries among US high school athletes 2005-2006 through 2012-2013. *Am J Sports Med*. 2014;43:26-33.
6. Courtenay BG, Bowers DM. Stress fractures; clinical features and investigation. *Med J Aust*. 1990;153:155-156.
7. Faigenbaum AD, Myer GD. Pediatric resistance training: benefits, concerns, and program design considerations. *Curr Sports Med Rep*. 2010;9:161-168.
8. Fishgrund J, Paley D, Suter C. Variables affecting time to bone healing during limb lengthening. *Clin Orthop Relat Res*. 1994;301:31-37.
9. Fredericson M, Jennings F, Beaulieu C, Matheson GO. Stress fractures in athletes. *Top Magn Reson Imaging*. 2006;17:309-325.

10. Goldberg B, Pecora C. Stress fractures: a risk of increased training in freshman. *Phys Sportsmed*. 1994;22:68-78.
11. Hame SL, LaFemina JM, McAllister DR, Schaadt GW, Dorey FJ. Fractures in the collegiate athlete. *Am J Sports Med*. 2004;32:446-451.
12. Huret KG, Shippley DL, Knapik JJ. The physical training and rehabilitation program: duration of rehabilitation and final outcome of injuries in basic combat training. *Mil Med*. 2001;166:820-826.
13. Heyworth B, Green DW. Lower extremity stress fractures in 40 pediatric and adolescent athletes. *Curr Opin Pediatr*. 2008;20:58-61.
14. Heaney R. BMD: the problem. *Osteoporosis Int*. 2005;16:1013-1015.
15. Hulko A, Orava S. Fractures in athletes. *Int J Sports Med*. 1987;8:221-226.
16. Iwamoto J, Takeda T. Stress fractures in athletes: review of 196 cases. *J Orthop Sci*. 2003;8:273-278.
17. Kelsey JL, Barrack LK, Proctor-Gray E, et al. Risk factors for stress fracture among young female cross-country runners. *Med Sci Sports Exerc*. 2007;39:1457-1463.
18. Magnusson HI, Westlin NE, Nyqvist F, Gärdsell P, Seeman E, Karlsson MK. Abnormally decreased regional bone density in athletes with medial tibial stress syndrome. *Am J Sports Med*. 2001;29:712-715.
19. Matheson GO, Clement DB, McKenzie DC, Taunton JE, Lloyd-Smith DR, MacIntyre JG. Stress fractures in athletes. A study of 320 cases. *Am J Sports Med*. 1987;15:46-58.
20. Moran DS. Physical and psychological stressors linked with stress fracture in recent training. *Scand J Med Sci Sports*. 2013;23:443-450.
21. National Federation of State High School Associations. 2016 participation data. <https://www.nfhs.org/ParticipationStatistics/ParticipationStatistics>. Accessed June 1, 2018.
22. Nichols JF, Rauh MJ, Lawson MJ, Ji M, Barkai HS. Prevalence of the female athlete triad syndrome among high school athletes. *Arch Pediatr Adolesc Med*. 2006;160:137-142.
23. Nieves JW, Melsap K, Curtis M, Kelsey JL. Nutritional factors that influence change in bone density and stress fracture risk among young female cross country runners. *PM R*. 2010;2:740-750.
24. Ohta-Fukushima M, Mutoh Y, Takasugi S, Iwata H, Ishii S. Characteristics of stress fractures in young athletes under 20 years. *J Sports Med Phys Fitness*. 2002;42:198-206.
25. Papalada A, Malliaropoulos N, Tsitas K, et al. Ultrasound as a primary evaluation tool of bony stress injury in elite track and field athletes. *Am J Sports Med*. 2012;40:915-919.
26. Purvis D, Gonsalves S, Deuster PA. Physiological and psychological fatigue in extreme conditions. Overtraining and elite athletes. *PM R*. 2010;2:442-450.
27. Romani WA, Gieck JH, Perrin DH, Saliba EN, Kahler DM. Mechanisms and management of stress fractures in the physically active persons. *J Athl Train*. 2002;37:306-314.
28. Tenforde AS, Sayres LC, McCurdy ML, Sainani KL, Fredericson M. Identifying sex-specific risk factors for stress fractures in adolescent runners. *Med Sci Sports Exerc*. 2013;45:1843-1851.
29. Warden J, Burr DB, Brukner PD. Stress fractures: pathophysiology, epidemiology and risk factors. *Curr Osteoporosis Rep*. 2006;4:103-109.
30. Wentz L, Liu PY, Haymes E, Illich JZ. Females have a greater incidence of stress fractures than males in both military and athletic populations; a systemic review. *Mil Med*. 2011;176:420-430.

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