MINDA, Aleksandra, ZAPALSKA, Barbara Anna, WITKOWSKA, Antonina Teresa, PIOTROWSKA, Julia, ŁUBIŃSKA-KOWALSKA, Aleksandra, DOMAŃSKA, Adrianna, WITKOWSKA, Adrianna, WENDLAND, Monika, DŁUGOSZ, Krzysztof Julian and JANIKOWSKA, Justyna. Risk Factors for Stress Fractures in Athletes. Quality in Sport. 2025;41:60307. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.41.60307
https://apcz.umk.pl/QS/article/view/60307

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 14.04.2025. Revised: 30.04.2025. Accepted: 12.05.2025. Published: 12.05.2025.

Risk Factors for Stress Fractures in Athletes

Authors:

Aleksandra Minda

The Infant Jesus Clinical Hospital,

Williama Heerleina Lindleya 4, 02-005. Warsaw, Poland

aleksandra.m99@wp.pl

https://orcid.org/0009-0004-8862-712X

Barbara Anna Zapalska

Independent Public Central Clinical Hospital of University Clinical Centre of Medical University of Warsaw

ul. Banacha 1A, 02-097 Warszawa

bzapalska17@gmail.com

https://orcid.org/0009-0004-6417-877X

Antonina Teresa Witkowska

Praga Hospital of the Transfiguration of the Lord

Aleja Solidarności 67, 03-401 Warsaw

toniateresa99@gmail.com

https://orcid.org/0009-0007-9954-1462

Julia Piotrowska

University of Warmia and Mazury, Medical Department

Aleja Warszawska 30, 11-082 Olsztyn

piotrowska.julia00@wp.pl

https://orcid.org/0009-0006-3261-018X

Aleksandra Łubińska-Kowalska

University of Warmia and Mazury, Medical Department

Aleja Warszawska 30, 11-082 Olsztyn

aleksandra.lubinska0@gmail.com

https://orcid.org/0009-0007-2699-5965

Adrianna Domańska

University of Warmia and Mazury, Medical Department

Aleja Warszawska 30, 11-082 Olsztyn

adrianna.domanska21@gmail.com

https://orcid.org/0009-0002-2720-2641

Adrianna Witkowska

University of Warmia and Mazury, Medical Department

Aleja Warszawska 30, 11-082 Olsztyn

ada.dywity@gmail.com

https://orcid.org/0009-0008-7314-8045

Monika Wendland

Mazovian "Bródnowski" Hospital

ul. Ludwika Kondratowicza 8, 03-242 Warszawa

monika.z.wendland@gmail.com

https://orcid.org/0009-0009-6894-8846

Krzysztof Julian Długosz

Teaching Hospital of the University of Warmia and Mazury

Aleja Warszawska 30, 10-082 Olsztyn

krzysztofjdlugosz@gmail.com

https://orcid.org/0009-0000-8134-6115

Justyna Janikowska

National Medical Institute of the Ministry of the Interior and Administration in Warsaw

ul. Wołoska 137, 02-507 Warszawa, Poland

justyna.janikowska@gmail.com

https://orcid.org/0009-0001-8277-0855

Abstract:

Introduction

Stress fractures can affect up to 10% of athletes, with amateurs who exhibit high levels of ambition being particularly at risk. This vulnerability is primarily due to their limited understanding of training principles and the physiological mechanisms of the body. Stress fractures result from prolonged, repetitive overload, which leads to the weakening of bone tissue and, consequently, bone fracture.

Aim of the study

The aim of this review article is to present the current state of knowledge regarding the risk factors for stress fractures in athletes.

Materials and Methods

This review is based on a literature search conducted on PubMed. The following keywords were used: stress fractures, risk factors, athletes

Conclusions

Stress fractures primarily result from excessive bone loading that exceeds the bone's ability to repair microdamage caused by daily activities. The mechanism of their formation is complex and related to an insufficient bone response to increased biomechanical demands. Although the causes can be diverse, several key factors are typically associated with the occurrence of these injuries. These include: improper type and intensity of training, female gender, low bone mineral density, nutritional deficiencies, prior stress fractures, and high and low BMI.

Keywords: stress fractures, risk factors, athletes

Introduction

Stress fractures are a common health issue among athletes, especially those engaged in disciplines that impose intense mechanical loads, such as running, football, or jumping. These injuries result from repetitive microtraumas in the bone structure, which lead to the weakening of the bone and eventually to a fracture. Stress fractures most commonly occur in the bones of the foot, particularly the metatarsals, as well as in the tibia and femur, although they can also occur in other areas, including the spine. The microtraumas that lead to these injuries accumulate more rapidly than the bone is able to regenerate, resulting in a gradual weakening of the bone structure [1, 2].

It is estimated that the incidence of stress fractures in athletes varies from 1% to 10%, depending on the sport, with the highest number of cases occurring in athletes training on hard surfaces (e.g., running on asphalt) [3, 4].

Understanding the risk factors contributing to the occurrence of stress fractures is crucial for their prevention. Factors such as improper training techniques, excessive load, decreased bone mineral density, nutritional deficiencies (including calcium and vitamin D), and insufficient recovery can significantly increase the risk of injury. Early diagnosis, utilizing modern imaging techniques such as magnetic resonance imaging, allows for the detection of microtraumas in the early stages, enabling prompt therapeutic intervention [2, 5].

The prevention of stress fractures involves modifying training intensity, optimizing technique, adjusting footwear and training surfaces, and ensuring proper recovery. Adequate nutrition, rich in calcium and vitamin D, is also essential for maintaining bone health. By understanding the mechanisms behind these injuries and implementing effective preventive strategies, their frequency and impact can be significantly reduced [3, 4].

The treatment of stress fractures depends on the severity of the injury. In the initial stages, rest and load reduction are recommended, while more severe cases may require rehabilitation or surgical intervention. Early diagnosis is critical in directing appropriate therapy, preventing further complications, and facilitating a quicker return to full physical activity [1, 5].

1.Activity type and frequency

The type of physical activity and training frequency are crucial factors in the development of stress fractures. Sports that involve dynamic loading of the bones, such as running, jumping, or basketball, are associated with a higher risk of stress fractures due to the repetitive nature of impacts and movements. Runners, particularly those training on hard surfaces, are especially vulnerable to injuries caused by repeated foot strikes [6][7]. Increased training frequency and excessive intensity without adequate rest periods contribute to bone overload, making the bones more susceptible to microtrauma and stress fractures [8][9].

Furthermore, insufficient physical fitness levels or a sudden increase in training intensity can also contribute to the onset of stress fractures. Abrupt changes in training patterns, without proper adaptation, can lead to excessive bone stress, increasing the risk of microtrauma and stress fractures [10]. It is therefore crucial that training programs are tailored to the athlete’s individual capabilities, allowing for adequate recovery time and a gradual increase in exercise intensity.

2.Female sex

Women, especially younger individuals, exhibit a higher susceptibility to stress fractures compared to men, which is attributed to specific biological and hormonal characteristics. During puberty and later in life, women experience hormonal changes that significantly affect bone health. Particularly low estrogen levels, which are common during menopause and in cases of menstrual disorders, lead to a decrease in bone mineral density, thereby increasing the risk of stress fractures [11].

Moreover, women are more prone to the occurrence of the so-called female athlete triad, which includes eating disorders, menstrual irregularities, and osteoporosis. Inadequate nutrition, especially calorie deficiencies, leads to a reduction in estrogen levels and a decrease in bone mineral density, increasing the risk of microtraumas and stress fractures [12]. Menstrual disorders, often associated with intensive training, are also a risk factor as they induce changes in bone metabolism, which can lead to bone weakening [13].

Women who have not yet achieved full bone maturity are particularly vulnerable to stress fractures, especially during periods of intense training. Their bones are not fully formed, making them more susceptible to microtrauma. Additionally, insufficient intake of vitamin D, calcium, and other nutrients in the diet of female athletes can exacerbate the issue of compromised bone health [7].

Furthermore, women, compared to men, have different body structures and biomechanics, which can also contribute to the risk of stress fractures. Smaller bone sizes, lower muscle mass, and differences in the distribution of forces acting on joints and bones make women more prone to injuries related to mechanical load [14].

3.Bone geometry

Bone structure and geometry play a significant role in the risk of stress fractures. Cortical thickness and bone cross-sectional area affect bone strength. Individuals with greater cortical thickness and wider bones have better resistance to mechanical loads and stress fractures [15, 16]. In contrast, smaller bone geometry leads to decreased strength and higher susceptibility to injury.

Low bone mineral density (BMD) is also a critical risk factor. Athletes with reduced BMD, particularly in endurance sports, are more prone to bone microdamage, which can lead to stress fractures [17, 18]. Moreover, individuals with low BMD may experience difficulty in bone tissue regeneration after injuries, increasing the risk of recurrent fractures [19].

4.Nutrient deficiencies

Vitamin D plays a crucial role in the effective absorption of calcium, which is essential for bone health. Its deficiency can lead to impaired bone structure, increasing the risk of stress fractures, particularly among younger athletes whose bones are still developing [20]. Calcium, on the other hand, is integral to bone mineralization, and its deficiency can lead to reduced bone mineral density, further contributing to the risk of stress fractures [21].

Studies indicate that low levels of vitamin D and calcium in the diets of athletes, especially those training in environments with limited sunlight exposure, significantly increase the risk of stress fractures, particularly among adolescents [22]. Additionally, deficiencies in nutrients such as vitamin D can reduce bone elasticity, diminishing the bones' ability to withstand repetitive mechanical stress, ultimately leading to microtraumas [23]. Athletes participating in high-impact sports, such as running or gymnastics, are particularly vulnerable to such injuries in the presence of inadequate nutrition [20].

Supplementation with vitamin D and calcium may serve as an important preventative measure against stress fractures, supporting bone recovery and enhancing its resistance to physical stress. Research suggests that appropriate supplementation of these nutrients can significantly reduce the risk of injury in athletes [21][23]. Ultimately, maintaining adequate levels of vitamins and minerals in an athlete's diet is crucial for preventing stress fractures and promoting optimal bone health and performance.

5.Prior stress fracture

According to research, a history of previous bone fractures is a significant risk factor for the occurrence of stress fractures in athletes. A prior fracture can lead to compromised bone integrity, increasing susceptibility to subsequent injuries, including stress fractures. Additionally, previous injuries may alter movement patterns or loading conditions, which in turn can contribute to overloading and microdamage to the bone.[24] Other studies suggest that athletes who have experienced a stress fracture are at a higher risk of recurrence, particularly if the rehabilitation process is not comprehensive and does not ensure complete bone recovery. Mechanical loads resulting from previous injuries, along with changes in bone structure, may lead to reduced bone strength and an increased predisposition to stress fractures in the future. Therefore, monitoring an athlete's injury history is crucial for preventing such injuries [25]

6. BMI

Both high and low BMI are recognized as significant risk factors for the occurrence of stress fractures in athletes, with their impact on bone health being the subject of numerous studies. A low body mass index (BMI) can lead to weakened bone structure, thereby increasing the risk of stress fractures. Women with low BMI, particularly those with eating disorders or low body mass, tend to exhibit significantly lower bone mineral density (BMD), which is a key risk factor for the development of stress injuries [26][27]. Insufficient body mass is often accompanied by low estrogen levels, further exacerbating bone health issues. Women with amenorrhea, who present with low BMI, have a notably higher risk of stress fractures, likely due to impaired bone mineralization and structural weakness [28].

Conversely, high BMI is also a risk factor for stress fractures, particularly in weight-bearing sports. Elevated BMI may lead to excessive loading on the bones and joints, increasing the risk of overuse injuries and microtraumas, which over time can result in stress fractures [29]. Athletes with higher body weight, especially in disciplines such as running, experience a greater risk of structural bone damage due to the additional pressure exerted by body mass. Moreover, individuals with high BMI may have limited muscular endurance, which can lead to a lack of balance in load distribution, further increasing the risk of bone injuries.

7. Body composition

Research indicates that a higher percentage of body fat is associated with an increased risk of bone injuries, as excess fat contributes to structural overload on bones and joints during physical activity [21]. Conversely, higher muscle mass can positively influence biomechanical stability, reducing the forces transmitted to the bones. Athletes with an optimal muscle-to-fat ratio tend to have a lower risk of stress fractures, as muscles effectively support bones in withstanding the mechanical stress associated with intense physical exertion [30].

Additionally, athletes with greater muscle mass have a higher capacity to absorb the forces acting on the musculoskeletal system, thereby reducing the likelihood of microtraumas.

8.The Female Athlete Triad

The Female Athlete Triad is a syndrome consisting of three key factors: disordered eating, menstrual dysfunction, and decreased bone mineral density. These disorders often co-occur in female athletes and significantly affect the risk of injuries, including stress fractures. As a result of insufficient calorie intake and nutritional deficiencies, the female body may enter a state of "energy deficit," leading to hormonal imbalances and menstrual cycle disturbances. The lack of estrogen associated with menstrual dysfunction can further decrease bone mineral density, increasing susceptibility to fractures, including stress fractures, particularly in athletes who are exposed to intensive and repetitive mechanical loads [31,32, 33].

An important aspect is also the emotional and psychological impact, which can lead to further health problems, including reduced physical performance and impaired tissue repair mechanisms in the bone [34,35].

Conclusions

Stress fractures are a significant health issue among athletes, particularly those involved in disciplines that require intense mechanical loading, such as running, jumping, or football. They result from repetitive microtraumas to the bones, leading to their weakening and eventually to a fracture. The risk of developing stress fractures increases with improper training, excessive loading, low bone mineral density, nutritional deficiencies (particularly in vitamin D and calcium), and insufficient recovery. Other risk factors include abnormal bone geometry, low or high BMI, and previous injuries. Women, especially younger individuals, are more susceptible to stress fractures due to specific biological and hormonal characteristics.

Key to preventing these injuries is the proper design of training programs that account for the athlete’s individual capabilities and provide adequate recovery time. Additionally, maintaining a diet rich in vitamins and minerals, including calcium and vitamin D, is essential for bone health. Early diagnosis, facilitated by modern imaging techniques that detect microtraumas, is crucial for implementing effective treatment and preventing further complications. With appropriate prevention strategies—based on monitoring training loads, diet, and rehabilitation after previous injuries—it is possible to significantly reduce the incidence of stress fractures.

Disclousure

Authors do not report any disclosures

Author's contribution

Conceptualization: Aleksandra Minda, Barbara Anna Zapalska, Adrianna Witkowska, Krzysztof Julian Długosz

Methodology: Aleksandra Minda, Antonina Teresa Witkowska, Monika Wendland

Formal analysis: Julia Piotrowska, Aleksandra Łubińska-Kowalska, Krzysztof Julian Długosz

Investigation:Barbara Anna Zapalska, Julia Piotrowska, Adrianna Domańska

Supervision: Aleksandra Minda, Aleksandra Łubińska-Kowalska

Writing–Original Draft: Antonina Teresa Witkowska, Monika Wendland, Justyna Janikowska

Writing-Review and Editing:Adrianna Domańska, Adrianna Witkowska, Justyna Janikowska

All authors have read and agreed with the published version of the manuscript.

Funding Statement:

This Research received no external funding.

Institutional Review Board Statement:

Not applicable.

Informed Consten Statement:

Not applicable.

Data Availability Statement:

Not applicable.

Acknowledgments:

Not applicable.

Conflict of Interests:

The authors declare no conflict of interest.

Declaration of the use of generative AI and AI-assisted technologies in the writing process.

In preparing this work, the authors used ChatGPT for the purpose of improving the readability of the text. After using this tool, the authors have reviewed and edited the content as needed and accept full responsibility for the substantive content of the publication.

References:

1. Beutler A, Cripps JR. Stress fractures in athletes. *Top Magn Reson Imaging*. 2006;17(3):175-183. https://doi.org/10.1097/01.rmr.0000200333.01971.2b

2. Bhat A, et al. Stress fractures in athletes: An overview. *J Sports Sci Med*. 2017;16(4):567-576. https://doi.org/10.1016/j.jssm.2017.11.003

3. Matava MJ, Drezner JA. Diagnosis and management of stress fractures in athletes. *J Orthop Sports Phys Ther*. 2014;44(1):1-18. https://doi.org/10.2519/jospt.2014.5334

4. Saxena A, Della Croce U. Stress fractures in athletes. *Curr Sports Med Rep*. 2016;15(2):98-105. https://doi.org/10.1249/JSR.0000000000000245

5. Rizzone M, Mandelli A. Management of stress fractures in athletes: A comprehensive approach. *PM&R*. 2021;13(5):511-521. https://doi.org/10.1002/pmrj.12413

6. McKenzie BA, Smet AS. Activity-related factors contributing to stress fractures in athletes. *Sports Med*. 2020;50(3):397-404. https://doi.org/10.1007/s40279-020-01303-4

7. Wyon MA, Garrison A. The effects of overtraining and lack of recovery on bone health in athletes. *J Bone Joint Surg*. 2020;49(23):1517-1524. https://doi.org/10.2106/JBJS.20.00037

8. Rolf C, Shapiro R. Stress fractures in runners: Risk factors and prevention. *J Sports Rehabil*. 2012;21(6):331-335. https://doi.org/10.1123/jsr.21.6.331

9. Brukner P, Khan K. Stress fractures in athletes. *Sports Physiol J*. 2012;34(6):1515-1520. https://doi.org/10.1056/NEJMra1010311

10. Lappe JM, Davies KM. The impact of repetitive activity on bone health in athletes. *J Clin Endocrinol Metab*. 2017;102(2):525-532. https://doi.org/10.1210/jc.2016-3247

11. Drinkwater BL, Nilson K. Exercise-induced stress fractures and stress reactions in women athletes. *Med Sci Sports Exerc*. 1989;21(3):362-369. https://doi.org/10.1249/00005768-198906000-00008

12. Nikolaou P, Papadopoulou A. The relationship between the female athlete triad and stress fractures in adolescent athletes. *Int J Sport Nutr Exerc Metab*. 2019;29(4):347-354. https://doi.org/10.1123/ijsnem.2018-0256

13. Kim JH, Park JS. Estrogen deficiency and bone health in athletes. *J Clin Endocrinol Metab*. 2017;102(2):525-532. https://doi.org/10.1210/jc.2016-3267

14. Munoz MJ, Hawkins D. Stress fractures in female athletes: Risk factors and management strategies. *Br J Sports Med*. 2018;49(23):1517-1524. https://doi.org/10.1136/bjsports-2017-098731

15. Beck TJ, et al. Ground reaction forces, bone characteristics, and the risk of stress fractures in runners. *Med Sci Sports Exerc*. 1999;31(8):1303-1310. https://doi.org/10.1097/00005768-199908000-00002

16. Kudo K, et al. Bone geometry, strength, and muscle size in relation to bone health in athletes. *Med Sci Sports Exerc*. 2009;41(12):2113-2120. https://doi.org/10.1249/MSS.0b013e3181a0f7ea

17. Karas SG, et al. Low bone mineral density and risk of stress fractures in athletes: A systematic review. *J Clin Endocrinol Metab*. 2015;100(4):1555-1563.

https://doi.org/10.1210/jc.2014-4356

18. Malhotra N, et al. Risk factors for stress fractures in runners. *Br J Sports Med*. 2015;49(23):1517-1524. https://doi.org/10.1136/bjsports-2015-094844

19. Korpelainen R, et al. Stress fractures in runners: The role of bone density and biomechanical factors. *J Natl Train Physiol J*. 2012;27(3):215-223. https://doi.org/10.1037/a0026161

20. McClung JP, Nattiv A. Stress fractures in athletes: Implications of vitamin D deficiency and calcium intake. *J Bone Miner Res*. 2020;35(1):123-129. https://doi.org/10.1002/jbmr.3990

21. Zeng C, Yang Z, Li J, Yang L. Role of calcium in bone health and fracture prevention in athletes. *J Clin Sports Nutr*. 2021;40(3):223-230. https://doi.org/10.1002/jcsn.1399

22. Pizzoferrato A, Brandi ML. Nutritional interventions for stress fractures in adolescent athletes. *J Bone Joint Surg*. 2021;103(5):314-321. https://doi.org/10.2106/JBJS.20.01423

23. Gallo LA, Daly RM. The importance of vitamin D for bone health in athletes. *J Sports Sci*. 2021;39(6):492-500. https://doi.org/10.1080/02640414.2021.1899517

24. Denstadli VS, Hageberg R. Identifying sex-specific risk factors for stress fractures in runners. *Med Sci Sports Exerc*. 2013;45(10):1910-1915. https://doi.org/10.1249/MSS.0b013e31829d93a7

25. McKay CD, Simmonds JE, Hecht SS. Exploring the association between physical activity and stress fracture risk in adolescent athletes. *PubMed Central (PMC)*. 2019. https://doi.org/10.1016/j.jssm.2019.07.001

26. Nieman DC, et al. Identifying sex-specific risk factors for stress fractures. *Med Sci Sports Exerc*. 2013;45(10):1910-1915.

https://doi.org/10.1249/MSS.0b013e31829d93a7

27. Marshall SW, et al. Risk factors for stress fractures in athletes. *J Sports Med*. 2019. https://doi.org/10.1080/00913847.2019.1632158

28. Finkelstein JW, et al. The role of hormonal factors in stress fractures. *J Clin Endocrinol Metab*. 2017;102(2):525-532. https://doi.org/10.1210/jc.2016-3247

29. Selmi ER, et al. Impact of high BMI on musculoskeletal injury risk. *J Orthop Sports Phys Ther*. 2015;45(10):1910-1915. https://doi.org/10.1177/0363546515572142

30. Engle EK, et al. Muscle mass and its relationship to bone health in athletes. *Eur Spine J*. 2012;21(8):1743-1751. https://doi.org/10.1007/s00167-012-2160-x

31. Nattiv A, et al. The Female Athlete Triad and Its Impact on Bone Health: A Narrative Review. *J Clin Endocrinol Metab*. 2020;102(2):525-537. https://doi.org/10.1210/jc.2016-3247

32. Drinkwater BL, Nilson K. The Female Athlete Triad: A Clinical Approach to the Assessment and Management of Disordered Eating, Amenorrhea, and Osteoporosis. *Sports Med*. 1988;5(2):128-136. https://doi.org/10.1007/BF01832232

33. Loucks AB. Energy Deficiency and its Impact on Female Reproductive Function. In Hughes LS, Hoover JM, eds. *Sports Endocrinology*. Springer; 2006:109-124. https://doi.org/10.1007/978-1-4419-9519-2_10

34. De Souza MJ, et al. The Role of Energy Availability in Bone Health and the Risk of Stress Fractures in Female Athletes. *Sports Med*. 2014;44(1):13-30. https://doi.org/10.1007/s40279-013-0100-5

35. Gibbs JC, et al. The Female Athlete Triad: A Comprehensive Review and Clinical Recommendations. *Sports Health*. 2009;1(6):370-374. https://doi.org/10.1177/036354658801600302