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REVIEW ARTICLE

Discrepancies in the prevalence, risk factors, diagnosis, and treatment of stress fractures between long-distance runners and sprinters: A qualitative review of systematic reviews

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Abstract

This qualitative review of systematic reviews consolidates current knowledge on stress fractures among endurance athletes and sprinters, including epidemiology, risk factors, diagnosis, and treatment strategies. A search across PubMed, Web of Science, SCOPUS, Science Direct, and Google Scholar, limiting results to articles published within the last year, yielded 90 relevant articles. Initial search results were narrowed down to 56 articles following abstract screening, with an additional article obtained through direct author correspondence. Stress fractures, a subset of bone stress injuries, result from persistent mechanical pressure surpassing bone regeneration capacity. They predominantly affect lower extremities, notably the tibia and metatarsals in endurance runners, and the toe phalanx in sprinters. Various risk factors contribute to stress fracture susceptibility, including gender, nutritional deficiencies, biomechanical factors, and psychological aspects like perfectionism and fear of failure. Diagnosis involves detailed patient history, clinical examination, and imaging modalities such as MRI, which remains the gold standard. Treatment emphasizes rest, gradual return to activity, and addressing underlying risk factors. Surgical intervention is reserved for high-risk fractures or cases of non-union. Preventive measures encompass nutritional optimization, biomechanical assessment, appropriate footwear, and psychological support. Notably, strategies targeting the Female Athlete Triad and ensuring adequate energy availability are crucial in both endurance and sprinting athletes. While more research directly comparing distance runners to sprinters is warranted, along with more sprinting-related research in general, this review provides a comprehensive understanding of stress fractures in endurance athletes and sprinters, aiding clinicians in diagnosis, management, and prevention strategies to optimize athlete health and performance.

Keywords: long-distance running · sprinting · stress fractures · bone stress injuries · overuse injuries

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1. Introduction

Running has become a popular form of physical activity and recreation for many due to its low economic cost, adaptability, and versatility, as well as the numerous health benefits it provides such as a positive impact on mental health, bone health, and overall physical fitness and a boon to academic growth and social relationships. However, alongside such health benefits, running also presents a risk for injury. Such injuries can range from sprains, muscle injuries, and dislocations to stress-related injuries (SRI) which include bone stress injuries which are more commonly known as stress fractures (Armento et al., 2023; Ross et al., 2023). Stress fractures represent a common and burdensome source of pain and discomfort in athletes. Such injuries usually require a longer period of reprieve from physical activity in order to achieve optimal healing, which can have a profoundly negative social and economic well-being on injured athletes with otherwise physically demanding work or other occupations (Abbott et al., 2023; McDaniel et al., 2023).

Stress fractures are disproportionately more prevalent in female athletes than in males, which has been shown to also be the case in female military recruits undergoing basic training – a stressful and physically demanding period of activity that reflects training regimes from both elite athletes as well as regular athletes attempting to undertake increased difficulty training not in line with the recommended step-wise increases in exercise progression (Abbott et al., 2023). The prevalence of stress fractures in females is attributed to the female athlete triad, lower body weight or BMI as well as to hormonal effects which can be a result of distinct endocrinological pathologies or disturbances such as amenorrhea. An analogous pathology to the female athlete triad has been described in males, which has thus been named the male athlete triad (Abbott et al., 2023; Armento et al., 2023; Chen et al., 2023; Kaiser et al., 2023).

In light of this, we've decided to conduct a qualitative literature synthesis of the most recent systematic reviews available on stress fractures in long-distance runners and sprinters and compare the epidemiology, clinical presentation, and diagnosis, as well as modern treatment options available to such athletes, in order to reduce their recovery times and expedite their return to optimal physical activity.

2. Method

The search for literature was conducted on March 26th, 2024. The databases searched for existing literature were PubMed, Scopus, Web of Science, Science Direct, JSTOR, and Google Scholar. For literature pertaining to stress fractures in long-distance runners, we used the Boolean operators "stress fracture" AND "long-distance running" OR "distance running" OR "marathon running". For literature about stress fractures in sprinters, we used the Boolean operators "stress fracture" AND "sprint" AND "athlete" OR "athletics" NOT "Football" OR "Soccer" OR "rugby". To obtain the most recent, up-to-date knowledge pertaining to our research question, we limited the date of publication to within 1 year of the time of the search. The language was limited to English, and the accessibility to open access. We limited the search to review articles on every database except for PubMed, where we expanded the search to include meta-analyses along with reviews. Because Science Direct and JSTOR offer a wider range of subject areas, we limited the search in those two databases to medicine, biochemistry, and public health. This search provided a total of 90 results, broken down by topic and database in Table 1.

Table 1. Results of the initial search through PubMed, Web of Science, SCOPUS, Science Direct, and Google Scholar, sorted by individual database and broad topic.

	Number of articles	
Journal	Long-distance running	Sprinting
PubMed	2	1
Web of Science	2	9
Scopus	1	17
ScienceDirect	19	4
Jstor	0	0
Google Scholar	22	9
Total	50	40

After collecting the initial articles, we performed a first-pass elimination of the results based on each abstract. After excluding 1 duplicate, 6 limited access articles that bypassed the search filters, and articles irrelevant to the topic of this review (articles only discussing injuries other than stress fractures or only discussing stress fractures unrelated to running), we limited the number of articles to 56. One formally limited-access article was kindly granted to us from its author in response to a formal request, increasing the number of articles to 57. References listed in the acquired articles were also utilized for relevant information, explanations, and context as needed; as a result, twelve references in this review are older than one year.

3. Stress Fractures

3.1 Etiology

Stress fractures are considered a continuation of bone stress injuries (BSI). These are defined by an imbalance in bone tissue brought on by persistent mechanical pressure that is greater than the bone's ability to regenerate. If left untreated, this imbalance might cause localized microscopic damage that could progress to fractures. These microscopic fractures can lead to complete fractures if excessive strain on the bone continues uninterrupted (Coslick et al., 2024). In cases where sports activity is not properly adjusted upon first signs of pain or discomfort, the microscopic stress damage may compound and result in a spectrum of injuries ranging from reactive bone oedema, which can only be seen with the use of MRI, to incomplete or full fractures, which can be either displaced or nondisplaced and visible on certain imaging methods or plain radiograph respectively (Kaiser et al., 2023). While physical activity typically contributes to increased bone density due to moderate stress stimulating osteoblast activity and bone formation, excessive repetitive stress without adequate periods of rest disrupts this benefit by not allowing the bone the time necessary to form new bone and strengthen its structure (Hart et al., 2020). Stress fractures were first described with the name “march fractures“, dating back to the Prussian military in 1855. They appeared in the form of metatarsal fractures in military recruits after long-distance marches, an activity that involves long bouts of repetitive stress on the metatarsals and heels (Hadjispyrou et al., 2023).

In general, stress fractures tend to be described as “overuse injuries“ due to the repetitive mechanical loading that contributes to their formation, along with their high occurrence in athletes with high training workloads and in those who suddenly increase the intensity or frequency of their physical activity. These are also classified as fatigue fractures (Milner et al., 2023).

Bone stress injuries can also occur due to impaired bone remodeling relative to normal physiologic load; these often accompany low bone density due to age or hormone-related osteopenia, and are referred to as insufficiency fractures. Other diseases that can cause insufficiency fractures are osteogenesis imperfecta, Paget's disease, osteomalacia, rickets, hypophosphatasia, rheumatoid arthritis, hyperthyroidism, poliomyelitis, and osteomyelitis (Oh et al., 2021). Malignancies, either primary or metastatic tumors, can also lower the activity threshold for bone stress injuries (Coslick et al., 2024). Along with benign bone cysts, tumors are a common hot spot for stress fractures (referred to as pathologic stress fractures); these fractures are often the first clinical manifestation of benign or malign tumors in the bone (Oh et al., 2021).

3.2 Clinical features

When a stress fracture occurs, a subject may experience swelling or pain upon weight bearing or palpation following a recent increase in activity or after performing a certain activity repeatedly with little to no rest (Romero-Morales et al., 2024). The onset of the pain is insidious, not following one specific traumatic event or memorable injury, and is most often located on the tibia or the second metatarsal (Tingan et al., 2024). Patients feel point tenderness over the metatarsal shaft in the case of a metatarsal stress fracture, pain on the navicular tuberosity for navicular stress fractures, and heel pain or pain at the Achilles tendon insertion point for calcaneal stress fractures (Touzell, 2024). In smaller, initial stress fractures, the pain appears during exercise and dissipates during rest, and it is dull in character; if the athlete does not rest and the fracture progresses, they can experience pain at rest, as well. Palpation of the affected area of the bone results in sharp pain, localized to the point of the fracture, as well as activation of the surrounding muscles (Coslick et al., 2024).

3.3 Diagnosis

Diagnosis of stress fractures begins with a detailed patient history and clinical examination. It is especially important to get an objective account of the patient’s exercise habits, including the frequency of physical activity, intensity and duration of individual sessions, past injuries, and overall nutrition (Hadjispyrou et al., 2023). Stress fractures appearing at the fibula, tibial shaft posteromedially, calcaneus, cuboid, and cuneiform bones, as well as at the shaft or neck of metatarsal bones are termed low-risk stress fractures. High-risk stress fractures have a propensity for non-optimal healing and encompass fractures of the anterior tibial shaft, metatarsal bases of the second, third, and fourth metatarsal bone, sesamoid bones of the hallux and the talus, navicular bone, and the medial malleolus (Kaiser et al., 2023). It is important for the clinician to not forget clinical manifestations of similar etiology which also affect athletes who partake in intensive physical activity. One such example would be chronic exertional compartment syndrome (CECS) which may affect both the upper and lower limbs. CECS manifests as increased pressure inside the fascial compartments and may present as muscle weakness and cramping, pain, tightness in the limbs, and even paresthesia (Tarabishi et al., 2023).

Besides exploring the clinical features listed above, the hop test and fulcrum test are also utilized to evaluate bone stress injuries (Tingan et al., 2024). In this test, the goal is to jump as far as possible on one leg while maintaining balance and landing solidly. The distance is measured from the starting line to the heel of the landing leg. The goal is to have a hop distance differential of less than 10% between the injured and unaffected limbs (Nussbaum et al., 2021). The fulcrum test is used to evaluate femoral stress fractures, albeit much rarer than tibial stress fractures. The patient sits on the examination table, lower legs dangling. The examiner puts an arm beneath the symptomatic thigh. The examiner's arm serves as a fulcrum under the thigh, moving from distal to proximal as the opposite hand applies mild pressure to the dorsum of the knee. In patients with femoral stress fractures, gentle pressure on the knee near the stress fracture's fulcrum results in increased discomfort, which was frequently reported as sharp pain and apprehension to continue (Kiel & Kaiser, 2024).

While radiographs are typically used to rule out acute fractures and primary or metastatic malignancies, they do not confirm the diagnosis of a stress fracture, as early stress fractures are not yet visible in a plain radiograph, and the symptoms predate visible radiographic pathology (Dutton, 2021). MRI is considered the gold standard for stress fracture evaluation, as it is used in imaging of both the bone and the surrounding soft tissue, including swelling and local inflammation that can be detected in the early stages of a fracture. It can also be used to evaluate the progression of stress fracture healing over time (Tingan et al., 2024). However, despite the MRI imaging sensitivity, it was found that the MRI severity grade was usually not significantly associated with the rate of recovery nor the rate at which patients returned to their physical activity. Despite this, a recent study found that higher grade based on MRI imaging was significantly associated with an increase in the time taken to return to physical activity (Armento et al., 2023).

4. Long-distance runners

4.1 Epidemiology

Stress fractures are predominantly handled in sports medicine, as they make up 20% of sports-related injuries. In distance runners, 95% of those stress fractures occur on the lower extremities, with the most common location being the tibia (George et al., 2022). While the specific ratios differ in the literature, tibial stress fractures have been observed to take up between 25% and 59% of reported incidents, metatarsal stress fractures between 10% and 25%, fibular stress fractures between 7% and 23%, tarsal navicular stress fractures between 1% and 3%, femoral stress fractures between 2% and 11%, pelvic stress fractures between 1.3% and 7%, patellar stress fractures approx. 3%, and calcaneal stress fractures between 1.3% and 5.7% (Vasiliadis, 2017). Rare stress fracture locations, like the femur, can misdirect clinicians in terms of clinical presentation and imaging results, which can result in misdiagnosis and improper management (Koutserimpas et al., 2023); Koutserimpas et al. (2023) particularly emphasize the importance of proper diagnosis and classification of rare stress fracture manifestations as well as common ones, which they demonstrate with their novel classification of bilateral fatigue femoral fractures, an extremely rare diagnosis.

4.2 Risk factors

Relative Energy Deficiency in Sport (RED-S), previously known as the Female Athlete Triad, is a state in which there is inadequate energy intake compared to expenditure, resulting in negative physiological repercussions. The triad itself is comprised of energy deficiency, low bone mass, and menstrual disturbance (Melin et al., 2024). Insufficient energy availability in long-distance runners, particularly female athletes, can harm bone health by disturbing hormonal balance, lowering bone density, and deteriorating bone structure; decreased estrogen secretion is an especially important predictive factor for deteriorating bone health. Inadequate energy intake can result from purposeful calorie restriction, strenuous exercise programs, or disordered eating habits, all of which raise the risk of stress fractures (Heikura et al., 2022).

Stellingwerff et al. (2021) highlighted an important connection between RED-S and overtraining syndrome (OTS). Both syndromes are referred to as diagnoses of exclusion, as neither of them has a single proven universal identifier, and both have a broad symptomatic range consisting of performance decline and psychological, immunological, and endocrine deficits. Because of these significant close parallels, the authors postulate that negative outcomes of an overtraining syndrome are often actually misdiagnosed under-fueling in the context of RED-S (Stellingwerff et al., 2021).

Low bone density, often attributed to factors like inadequate calcium and vitamin D intake, further amplifies the risk of stress fractures. Calcium is essential for bone mineralization, while vitamin D facilitates calcium absorption and bone remodeling (Capozzi et al., 2020). Deficiency in these vital nutrients therefore further increases stress fracture susceptibility (Tingan et al., 2024).

Gender plays a significant role in stress fracture susceptibility, with female runners being at greater risk due to hormonal fluctuations and lower bone density compared to males. Fluctuations in estrogen levels, such as those occurring during the menstrual cycle or as a result of hormonal disorders, can compromise bone integrity, predisposing female runners to stress fractures (George et al., 2022).

Increased physical activity, along with sudden changes in running routine, such as quickly increasing mileage or intensity, can exceed the body's ability to adjust, putting undue strain on bones and raising the risk of a stress fracture. Abrupt increases in training load without proper recovery intervals alter the equilibrium of bone production and resorption, increasing the risk of injury. A training load greater than 32 km per week also increases the chances of long-distance runners suffering a stress fracture by a factor of two or even three (Hadjispyrou et al., 2023).

In addition to the previously established risk variables, recent research has discovered new genetic predictors of stress fracture occurrence in long-distance runners. Genetic variables, including variations in bone remodeling and collagen synthesis, have been linked to stress fracture susceptibility. Understanding the genetic basis of stress fractures may allow for more individualized risk assessments and tailored therapies to reduce injury risk in sensitive people (Moreira et al., 2021).

Psychological issues such as perfectionism and fear of failure have also been identified as possible risk factors for stress fractures in sports. Not only are psychological patterns of perfectionism and disordered eating more common in female athletes than female non-athletes, but athletes with high levels of perfectionism were also more likely to feel psychological distress and engage in maladaptive training habits, making them more susceptible to overuse injuries such as stress fractures. Addressing psychological, biomechanical, and physiological components is critical for comprehensive injury prevention techniques (Petisco-Rodríguez et al., 2020).

Irregular or slanted running surfaces increase biomechanical stress on the lower limbs, affecting stride patterns and dispersing forces unevenly. Uneven terrain can cause recurrent microtrauma, especially in weight-bearing bones like the tibia and metatarsals, predisposing runners to stress fractures (Kahanov et al., 2015). In a recent systematic review, Milner et al. (2023) analyzed possible correlations between changes in lower limb biomechanics and tibial stress fractures. While 25 kinematic variables were identified across 14 studies, most of these variables either had no effect, or the effect was not statistically significant enough to claim a correlation between these variables and tibial stress fracture incidence. However, a significant correlation was established between a higher incidence of tibial stress fractures and peak feet eversion angle, peak hip adduction angle, and early stance knee stiffness in the sagittal plane, as well as peak anterior tensile stress and peak posterior compressive stress at the distal third of the tibia (Milner et al., 2023). Another important biomechanical variable is the duty factor, defined as the ratio between the runner's foot-to-ground contact time and their total step time (Lussiana et al., 2019). Current theories suggest that lower duty factors result in greater muscle contraction at the time of contact; these runners experience higher external forces than those with higher duty factors, even while running at the same speed. These external forces increase the risk of overuse injuries, particularly in runners with an unbalanced load-bearing capacity in relation to load exposure (Ruiz-Alias et al., 2023).

The topic of footwear has also gained traction in the realm of sports medicine research. Running in inappropriate footwear with insufficient stability, cushioning, or support can increase impact forces and put more strain on the bones and soft tissues. Shoes that fit wrong or have worn-out soles cannot absorb enough shock from individual foot strikes, which increases the risk of stress fractures by applying excessive strain to the skeletal system (Touzell, 2024). In light of this, different aspects of shoe model design cater to different athletic functions; while longitudinal stiffness and the weight of the shoe itself can be adjusted to increase running economy (i.e. the oxygen requirement at a specific running speed (Herzog, 2022)), thinner midsoles and lower drops from heel to toe can reduce injury risk (Hoitz et al., 2020). In an extensive systematic review, Ruiz-Alias et al. (2023) synthesized analyses of 61 different shoe models, emphasizing their effects on running economy, running performance, ground reaction forces, plantar pressure, joint stiffness, tibiofemoral load, and joint coordination. While some shoe models increased stride length and reduced contact time in runners, others showed a mixed effect of increasing or even decreasing stride length in comparison to barefoot running. As such, the authors' conclusion emphasizes the importance of an individual approach to footwear in distance runners; as demographic factors such as sex and age can influence biomechanical variables like the force-velocity profile of the plantar flexor muscles, it is essential to cater to the individual needs of the runner while assessing footwear, as a "once size fits all" solution has not yielded replicable results of improvement (Ruiz-Alias et al., 2023). A systematic review by Hoitz et al. (2020) also found individual variability in the effect of forefoot longitudinal bending stiffness on running economy, where factors such as ground reaction forces, ankle extensor length, running speed, and body weight influenced the change in running economy for runners at three different skill levels (Hoitz et al., 2020).

4.3 Treatment

Treatment methods for stress fractures in long-distance runners typically aim to alleviate symptoms, promote bone healing, address underlying risk factors, and facilitate a safe return to running. Rest remains the cornerstone of stress fracture management, allowing injured bones time to heal and reducing the risk of progression to complete fracture (Hadjispyrou et al., 2023) A widely adapted treatment protocol involves dividing the rehabilitation process into two phases (Kahanov et al., 2015); phase one focuses on rest, gradual increase of weight-bearing and activity modification, which involves temporarily reducing or modifying running activities to minimize the impact on the affected bone while maintaining cardiovascular fitness through cross-training modalities such as swimming or cycling (Miller et al., 2018). Phase two begins once the athlete has been pain-free for two weeks with absent point tenderness, focusing on a gradual return to running. This phase utilizes muscular endurance and stability training, along with a gradual progression to pre-injury running over the course of three to six weeks (Kahanov et al., 2015). George et al. (2023) list walk-run progression as an alternative rehabilitation method, which involves gradually replacing walking with increasing increments of running. They also recommend avoiding hard surfaces and hills in order to minimize tibial loading and reinjury probability (George et al., 2022).

Before deciding on and implementing a treatment method, clinicians must recognize risk factors in each individual patient (such as age, menstrual or hormonal irregularities, and nutritional deficiencies) that can be modified or removed in order to prevent future stress fractures or delayed healing (Kahanov et al., 2015).

Low-risk stress fractures like those in the posteromedial tibia, metatarsals, and the fibula, typically require 2 – 6 weeks of conservative treatment. High-risk stress fractures, such as the sesamoid, anterior tibia, and femoral neck, often require surgical treatment, especially in cases of delayed union or nonunion (Kahanov et al., 2015). Each individual case, however, can have its own treatment requirements and complications, both operative and non-operative treatments carrying advantages and disadvantages; A systematic review by Schundler et al. (2023) weighed the pros and cons of both methods by comparing surgical treatment with conservative treatment in terms of return-to-sport rates and complication rates. They established a 91.2% - 100% return-to-sport rate for conservative treatment and a 75.5% - 100% rate for surgical treatment. Recurrent fracture was the most common complication of conservative management in a range of 0% - 33,3% of patients, and the failure rate of conservative treatment was 0% - 25% vs. 0% - 6% for surgical treatment. The authors concluded that while conservative treatment carries higher return-to-sport rates, surgical treatment carries fewer complications over time (Schundler et al., 2023).

Another crucial factor in promoting fracture healing is adequate nutrition, which involves addressing nutritional deficiencies, eating disorders, food intolerance, and alcohol consumption. If RED-S was a relevant contributor to the athlete's stress fracture, increasing caloric intake and evaluating possible vitamin and mineral deficiencies is crucial in maintaining proper bone healing and preventing re-injury (Touzell, 2024). As endurance sports have a higher concentration of low energy availability in athletes due to either a perceived performance benefit or a requirement for competition, proactive monitoring of energy availability can significantly reduce stress fracture risk, particularly in female athletes. Maintaining energy availability at a minimum of 45 kcal kg-1 FFM day-1 (FFM = fat-free mass) is recommended (Holtzman & Ackerman, 2021). While specific recommendations in regard to macronutrient ratios differ on an individual level, it is generally recommended to ensure that glycogen stores are fully repleted in order to maximize performance, which can be achieved by habitually consuming 7 – 10 g kg-1 day-1 (Burke et al., 2011). Fats should constitute at least 20% of an athlete's daily caloric intake to prevent deficiencies in fat-soluble vitamins (A, D, E, K) and essential fatty acids. Though ideal protein intake varies by sex, vegans and vegetarians should be specifically cautious about consciously including protein-rich foods in their diets (Holtzman & Ackerman, 2021) Levels of vitamin D and calcium are particularly important for adequate bone formation and fracture healing (Hadjispyrou et al., 2023).

In complicated cases with delayed union or nonunion, teriparatide is a recent topic of discussion; a systematic review by Puvvada et al. (2023) has shown that teriparatide can safely and effectively assist in establishing clinical union in previously complicated fracture patients (Puvvada et al., 2023).

Since specific gaits can predict running injuries, monitoring and adapting running kinematics is an effective method of reducing tibial load and preventing re-injury. Gait retraining is a novel method of reducing running movement patterns that carry higher injury risk, particularly those with a high sudden impact of the lower limbs and high vertical impact peak load rates, which have been associated with rear-strike gait patterns (Friedl & Looney, 2023). In a systematic review and meta-analysis, Mousavi et al. (2024) evaluated the effectiveness of gait retraining on foot pronation, as foot pronation during running also contributes to a wide range of lower extremity injuries (Mousavi et al., 2024). Multiple gait retraining methods, such as speed control using a metronome, instruction to run softer using visual biofeedback, and forefoot strike training, were evaluated. Increasing step width was shown to cause a change in pronation angle, and increasing step rate by 5% - 10% decreased peak rearfoot eversion significantly (Mousavi et al., 2024)

Running-induced fatigue can also cause subtle gait changes that result in higher peak accelerations, which bring higher impact forces and can increase overuse injury risk. When runners experience fatigue, they can subconsciously adopt a stiffer gait (decreased shock attenuation, decreased joint flexion angles); this gait saves energy but comes at the cost of higher impact forces on the lower limbs. This change is less significant in experienced runners, as they are more accustomed to running-induced fatigue than novice runners (Zandbergen et al., 2023).

5. Sprinters

5.1 Epidemiology

Due to the scarcity of research found that focuses on the sprinter athlete as a focal entity for stress fractures, the epidemiology of such fractures is, in comparison with the epidemiology of distance runner-related stress fractures, less well described. The reviewed literature was inconclusive with regards to whether the following statistics are representative of both sprinters and long-distance runners combined or if both groups incidentally share the same stress fracture occurrence rate. In the study conducted by Robertson et al. Return to sport following toe phalanx fractures: A systematic review and in the study focusing on stress fractures in the female military recruit published by Abbott et al. it was noted that stress fractures disproportionately affect the female sex over the male sex (Abbott et al., 2023; Robertson et al., 2023). In general, stress fractures occurring in the ankle and foot skeletal regions represent approximately 10% of sports-related injuries in competitive and recreational athletes (Kaiser et al., 2023). Hip and groin-related stress fractures are a rare entity encountered in the clinical setting when compared to running-related injuries in other anatomical locations. A study comparing sex-related differences in hip and groin running-related injuries found that these make up less than a fifth of all running-related injuries and include, alongside stress fractures, acetabular labral tears, strains of the adductor muscle and greater trochanter pain syndrome (Ross et al., 2023). Robertson et al. have also put forward that while a big part of stress-related fractures to the toe phalanx is related to sports activities such as sprinting, soccer, and long-distance running, the current available literature on this injury type mainly consists of a small number of case series and case reports (Robertson et al., 2023).

5.2 Risk factors

The female gender represents an intrinsic risk factor for more frequent high-risk stress fracture occurrences compared to the male athlete and is more likely to have difficulties in the healing process (McDaniel et al., 2023). Metatarsal stress fractures, particularly diaphyseal fractures of the distal shaft of the second metatarsal bone, are injuries which dancers, military recruits, and athletes active in running sports are at increased risk for, as the loading forces on the front part of the foot are similar between these activities (Kaiser et al., 2023). Sprinting and similar short-distance explosive movements are a shared point of interest between sprinters, military recruits taking part in basic training and dancers repeatedly rehearsing complex choreography. Navicular stress fractures are commonly found among Track & Field athletes. Explosive propulsion in these events applies compressive forces by the medial column of the foot and tensile forces of the spring ligament and posterior tibial tendon help to compound the effect and significantly increase the risk of stress fracture of the navicular bone (Kaiser et al., 2023). Sprinting, long-distance running, and soccer all present a significant risk factor for stress fractures of the toe phalanx (Robertson et al., 2023).

Anatomical deformities such as hallux valgus present a risk factor for toe phalanx fracture due to increased shear forces during exercise that stem from the medial collateral ligament and the abductor hallucis. Together with the valgus deformity of the big toe, these structures provide adverse traction forces, which potentiate the aforementioned shear forces, leading to the propagation of the stress fracture across the phalanx. In line with this, tight footwear which exacerbates the appearance of such deformities should be classified as a risk factor and thus avoided (Robertson et al., 2023).

Track and field sprinters are at greater risk for hip and groin-related running injuries when compared to long-distance runners. The former has been reported to display a prevalence of 10.8% of hip and groin injuries out of all running-related injuries, while the latter only had a reported prevalence of 5.7% (Ross et al., 2023).

5.3 Treatment

Treatment of bone stress injuries in sprinters is much the same as treatment of these injuries in long-distance runners. The primary approach to managing a patient with a stress injury of the bone is a conservative approach that initially involves cessation of physical activity and allowing the affected bone to heal. This can be done with limited load-bearing of the affected limb without immobilization or with immobilization of the affected area coupled with either load-bearing casts or non-load-bearing casts and crutches (Robertson et al., 2023). In cases where primary conservative management fails or the patient initially presents to the clinician with a delayed fracture presentation and confirmed non-union of the fractured area, surgical interventions remain an option. Primary surgical intervention would be used in cases of delayed presentation and confirmed non-union as well as in cases of early presentation but with accompanying significant deformities, such as hallux valgus in patients with phalanx fractures. Surgical intervention aimed at bone fixation is used in order to establish bone union in complex fractures or in high-risk stress fractures that present with non-union after primary conservative intervention (Kaiser et al., 2023; Robertson et al., 2023).

Other non-invasive treatment options have historically included bone stimulation treatment, orthotics, extracorporeal shock wave therapy, and pulsed ultrasound. These treatment modalities supposedly offer an increase in bone healing rates and a reduction in stress fractures, however, only Low-Intensity Pulsed Ultrasound (LIPUS) therapy has insofar shown a potential application in early onset treatment of bone stress injuries, with an occasional decrease in time-to-heal and time-to-return to physical activity (Kaiser et al., 2023; McDaniel et al., 2023). More research is needed to verify the efficacy of such adjuvant therapies in the management of bone stress injuries.

Prevention tactics and management of extrinsic risk factors such as the Female Athlete Triad and its male counterpart, as well as Vitamin D and calcium deficiency, have been described in the treatment section in the LONG-DISTANCE RUNNERS segment of this article. The described interventions and prevention measures do not differ between long-distance runners and sprinters.

6. Discussion

Stress fractures represent a consistent source of pain, discomfort, and stress for athletes, particularly for elite athletes or overly ambitious athletes who take on training regiments that are not properly adjusted for the individual with respect to their performance capabilities and both intrinsic and potential extrinsic risk factors (Abbott et al., 2023; Hadjispyrou et al., 2023). In the past year, published literature that focused on stress injuries in athletes was concise and accurate in its description of risk factors that predispose physically active individuals to bone stress injuries. Among non-modifiable risks were the female gender, bone density and body composition, and BMI. Modifiable risks included athlete fitness, training regime adjustment, and vitamin D and calcium deficiency, with treatment options spanning a spectrum of conservative and surgical approaches. The occurrence of stress fractures in long-distance runners was well studied in the literature, with reviews covering all the aforementioned risk factors and treatment options readily available.

Despite this, several limitations persist in the literature. Many studies suffer from small sample sizes and lack direct comparisons between long-distance runners and sprinters. This limitation hinders our ability to draw definitive conclusions about the unique risk factors and injury mechanisms specific to each group. Future research endeavors should aim to address this gap by conducting larger-scale studies that directly compare stress fracture rates and risk factors between long-distance runners and sprinters.

Furthermore, the scarcity of literature on stress fractures in sprinters published in this review's allotted timeframe also hindered our ability to conduct an in-depth analysis of potential similarities or differences between the sprinter group and the long-distance runner group of athletes. From the information that was available to us, we can speculate that due to the difference in biomechanical loading of the foot during sprinting and the difference in applied total force during activity, sprinters are potentially more at risk for stress fractures of the toe phalanx and high-risk fractures of the navicular bone as well as the shafts and bases of metatarsal bones. Anatomical deformities also seem to play a part in whether the fracture can be treated conservatively with rest and cessation of activity or if the patient will need to undergo surgical intervention with bone fixation and deformity reconstruction. Another possible explanation for this discrepancy in literature availability is the sheer volume of athletes who engage in distance running as opposed to sprinting, both on an amateur and professional level; events like the Boston Marathon attract tens of thousands of participants each year, with many local races taking place worldwide. Such events for sprinting are fewer in number and are mostly limited to professional sports and athletics competitions (A, 2024).

Several published studies that were initially included in the search results for this review included sprinting as a part of soccer, football, and other sports. However, because soccer, football, and similar activities do not exclusively consist of sprinting as an athletic discipline, the literature was not included. The reason for this separation of sports activities was because football and soccer include repetitive motions of hitting or striking an object or another player which introduces a completely different set of biomechanical loading that may lead to bone stress injuries that would otherwise not happen or happen less often in athletes that only engage in sprinting. We propose the need for further study of sprinters as a separate entity in bone stress injury diagnosis and management in order to determine whether there are significant differences in BSI location and severity and whether the risk factors for BSI involve different development of muscle groups specific to the type of activity, long-term repetitive loading or short-term heavy loading in long-distance runners and sprinters, respectively.

Additional research is also needed to determine the efficacy of non-invasive adjuvant treatment methods that could potentially reduce the time it takes for athletes to recover from injury and return to their regular activities. Further research on the efficient management of sports injuries is of vital importance for the health of anyone engaging in sports, whether as a hobby or as a professional career.

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