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FEMORAL NECK STRESS FRACTURE IN AMATEUR RUNNERS: NARRATIVE REVIEW AND CLINICAL IMPLICATIONS

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Abstract: Objective: To review and synthesize current evidence regarding the epidemiology, pathophysiology, diagnosis, therapeutic approaches, rehabilitation, prevention, and prognosis of femoral neck stress fractures in amateur and beginner runners. Methods: Narrative review with targeted search in PubMed, Scopus, and Google Scholar until November 1, 2025, using terms such as "femoral neck stress fracture," "bone stress injury," "runner," "RED-S (Relative Energy Deficiency Syndrome in Sports)," and "return to sport." Original articles, systematic reviews, consensus statements, and guidelines were prioritized. Results: Femoral neck injuries are considered high risk because they have a higher rate of complications, such as avascular necrosis and delayed consolidation, with the average time to return to sport being longer than that observed in other overload injuries (approximately 10 to 16 weeks for cases without displacement and up to 24 weeks for surgical cases) [6, 22]. Magnetic resonance imaging plays a central role in diagnosis and severity stratification; the indication for surgery depends on the pattern of the trace (tensional or compressive), the percentage of cortical arch width, and the presence of displacement [14, 20]. RED-S and metabolic factors increase risk and delay recovery; nutritional measures (adequate energy intake, vitamin D, and calcium) and load monitoring are fundamental in prevention [4, 11, 12]. Conclusion: In amateur runners, early evaluation with MRI, metabolic screening, and progressive rehabilitation programs reduce complications and optimize recovery. Finally, a practical algorithm and prevention checklist applicable to sports clinical practice are proposed.

Keywords: Stress fracture; femoral neck; runners; RED-S; rehabilitation.

Introduction

The growing popularity of road running among beginners in physical activity and among new recreational athletes has been accompanied by a higher incidence of overload injuries [1]. Among these, stress fractures of the femoral neck deserve special attention, precisely because of their recurrence and possible serious complications, including avascular necrosis of the femoral head and pathological consolidation [1]. Although classically described in military personnel and high-performance athletes, previous and more recent studies indicate its occurrence in amateur runners, often associated with changes in training load, energy deficiency, and bone risk factors [2,3]. This study aims to critically review the recent literature and propose evidence-based practical recommendations for the management of femoral neck stress fractures in recreational runners.

Methods

This narrative review was conducted through targeted searches in PubMed, Scopus, and Google Scholar databases until November 1, 2025. The following terms were used in combination: "femoral neck stress fracture," "femoral neck stress injury," "bone stress injury," "runner," "return to sport," "RED-S," "vitamin D," and "calcium." Original articles, systematic reviews, consensus statements, and clinical series published between 2000 and 2025 in English and Portuguese were included. Priority was given to publications that specifically addressed femoral neck fractures in athletes or recreational runners and studies that discussed return to sport and associated complications. Isolated reports without descriptive methodology and articles focusing exclusively on other stress fracture topographies were excluded. The final synthesis was qualitative, with extraction of clinical and epidemiological data used in the proposed tables and algorithms [1–3, 6, 20, 22].

Epidemiology and At-Risk Population

Hespanhol Junior *et al.* [5] observed that young adults between the ages of 25 and 45 constitute the main group of new road runners. These amateur runners, especially beginners who were previously sedentary, are the group most susceptible to femoral neck stress fractures [3,6]. Although this injury is rare in absolute terms, accounting for approximately 0.8% to 1.6% of all stress fractures described in runners [26], its clinical impact is significant due to the risk of complications such as avascular necrosis and delayed healing [26]. The use of inappropriate footwear is also associated with an increased risk of this injury [8]. Milner *et al.* [9] demonstrated that shoes with low cushioning or unsuitable for the morphology of the feet can intensify the biomechanical forces transmitted to the joints, including the hip, favoring the development of stress fractures. The literature also indicates a higher prevalence of this injury in women, due to the so-called female athlete triad, characterized by low energy availability resulting from caloric deficit, menstrual dysfunction, and reduced bone mineral density [8]. Currently, this concept has been expanded to Relative Energy Deficiency Syndrome in Sport (RED-S), which covers both men and women and involves a series of physiological, hormonal, and metabolic consequences resulting from insufficient caloric intake in relation to the energy demands of training [25,10]. In addition, this predisposition may be related to relevant metabolic factors, such as vitamin D deficiency and low bone mineral density [11,12].

Biomechanical Mechanisms and Predisposing Factors

The abrupt increase in mileage and weekly training volume, combined with frequent exposure to hard and unstable surfaces and short recovery periods, are predisposing factors for stress fractures of the femoral neck [7]. Fullerton and Snowdy [7] described that excessive cyclic overload and repetitive impact on the bone during running are the main mechanisms triggering this injury. Repetitive mechanical stress compromises the balance of bone remodeling and, chronically, leads to the accumulation of structural microdamage that, in the medium term, culminates in stress fractures. Robertson [8] emphasized that females are particularly vulnerable due to the combination of mechanical overload, marked caloric deficit, amenorrhea secondary to intense exercise, and low bone mineral density, known as the female athlete triad. In addition, individual anatomical factors, such as muscle imbalances and morphological variations in the hip joint, may also contribute to the onset of the injury. Among the predisposing mechanisms, reduced levels of vitamin D, recognized as a possible additional risk factor, also stand out [9,10,11]. Huhtajo et al. [11], in a study of 756 Finnish military recruits, identified an association between low serum levels of

25-hydroxyvitamin D (<75.8 nmol/L) and a higher incidence of stress fractures. Similarly, Marx, Berglund, and Stein [12] observed in a cohort study that athletes with 25-hydroxyvitamin D levels above 40 nmol/L had a lower incidence of stress injuries.

Anatomy and Biomechanics of the Femoral Neck Applied to Running

The hip joint is heavily stressed during road running, being subjected to combined compressive and tensile forces that act directly on the femoral neck [7,8]. This region is particularly vulnerable due to femoral angulation and the shear forces that occur in the support and propulsion phases during the stride, which substantially increases the local mechanical load [9]. Given the abrupt increase in training intensity or volume, associated with insufficient recovery, the balance between microdamage and bone remodeling processes is disrupted. Consequently, there is an accumulation of unrepaired microlesions, which progressively evolve into stress fractures of the femoral neck.

Pathophysiology of Stress Fracture

The pathophysiology of this condition is based on the accumulation of bone microdamage in a context of insufficient remodeling time [7]. Within 6 to 8 weeks of a significant increase in physical load, elastic deformation initially occurs, followed by plastic deformation, manifesting clinically as bone edema [13]. These changes precede the appearance of microfractures, which, if not identified or treated early, can progress to complete fractures. It is important to note that, in the case of stress fractures, the bone repair process differs from the usual one, occurring exclusively through the resorption of the injured tissue and subsequent replacement by new bone tissue. Thus, the association between high overload and insufficient recovery periods favors the development of femoral neck fractures, a critical region in the context of road running [7, 8].

Classification and Clinical Implications

Femoral neck stress fractures are commonly classified according to the criteria proposed by Fullerton and Snowdy [7], which are, in some situations, complemented by Provencher's classification [14]. The classification by Fullerton and Snowdy [7], widely used in clinical practice, is based on radiographic findings and describes three main subtypes of fracture. Type 1 fractures occur at the upper edge of the femoral neck, the region subjected to the greatest stress; type 2 fractures are located on the lower surface, corresponding to the compression zone during the stride; and type 3 fractures are characterized by complete discontinuity between the neck and the femoral shaft [7]. Subsequently, Provencher [14] added a fourth subtype, considered atypical, described as an incomplete fracture located in the region above the femoral neck, a lesion identifiable only by magnetic resonance imaging. The use of this imaging modality also allowed for new findings that were described by Shin and Gillingham [15], who proposed a subclassification of type 2 fractures, compression fractures [7], according to the degree of involvement of the femoral neck, evaluating its size, being less than

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or greater than 50% of its total width [15]. Analysis of the mechanisms involved in the injury is essential for understanding and managing femoral neck stress fractures. Accurate identification of the predominant type of force, compressive or tensile, is essential to guide appropriate clinical management, as it allows assessment of fracture stability, the risk of complete displacement, and, in more severe cases, the possibility of progression to avascular necrosis of the femoral head [7,9]. Assessing the degree of fracture involvement in relation to the width of the femoral neck has important clinical implications. The classification proposed by Shin and Gillingham [15] allows the stability of the injury to be measured and the risk of progression to be estimated. Fractures that compromise more than 50% of the total width of the femoral neck are more likely to displace. Once displacement occurs, bone continuity is interrupted and the blood supply to the femoral head is compromised, which predisposes to avascular necrosis, the main complication associated with this condition [16].

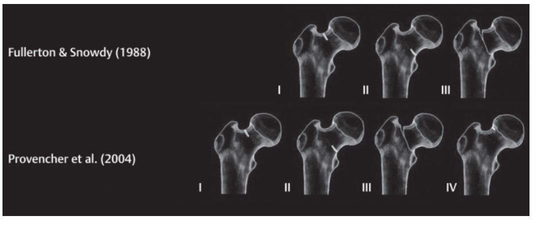

Figure 1. Classifications of stress fractures in the femoral neck.

Source: WALDRON et al. (2018) [17].

Clinical Picture in Road Runners

The clinical picture of femoral neck stress fractures is classically characterized by insidious mild to moderate pain located in the groin or anterior hip, with progressive worsening as the injury evolves [17]. In street runners, it is common to complain of progressive functional limitation and reduced ability to sustain activities due to the gradual worsening of pain [17]. The main warning signs include night pain, exacerbated pain upon initial weight bearing, especially in the first step of the day, and limited weight bearing, often accompanied by limping. The differential diagnosis should include gluteal tendinopathies and pubalgia, conditions that often delay clinical recognition of the fracture. In most cases, the initial examination is a plain radiograph, which may not show changes in the early stages, contributing to diagnostic delay and, consequently, increasing the risk of complications, such as progression to complete fracture or avascular necrosis of the femoral head [18].

Diagnostic Imaging

Femoral neck stress fractures are rarely detected in their early stages by conventional radiography [18]. The absence of initial radiographic changes is a limiting factor for early diagnosis, resulting in many cases in the progression of the injury until complete cortical continuity is compromised. This evolution can culminate in displacement of the fracture and, secondarily, in avascular necrosis of the femoral head, resulting from the interruption of regional vascular supply [18].

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Figure 2. Radiograph of a femoral neck fracture in its initial stage.

Source: SAGE; O'NEILL; HUGHES (2021) [19].

Magnetic resonance imaging is the most sensitive and specific imaging method for the early diagnosis of femoral neck stress fractures and is considered the gold standard in the evaluation of these cases [18,19]. Recent studies describe the use of STIR and T2 sequences with fat suppression, which allow the identification of early bone edema before the fracture line is visible [20,21]. MRI also allows for the evaluation of the tensile or compressive pattern, the degree of cortical involvement, and the stability of the lesion, which are fundamental parameters for guiding therapeutic management [14,15,21].

Figure 3. Magnetic resonance imaging of a femoral neck fracture.

Source: SAGE; O'NEILL; HUGHES (2021) [19].

Conservative Management

Conservative treatment is one of the therapeutic approaches for femoral neck stress fractures, being indicated mainly for cases classified as compression fractures without complete displacement. This approach is based on the immediate suspension of impact activities, such as running, and partial reduction of the load on the affected limb, in order to prevent the progression of the injury [17]. The partial weight-bearing phase usually lasts four to six weeks, followed by gradual reintroduction of full weight-bearing as pain subsides and radiological improvement occurs [22]. Return to sports activities occurs, on average, between 10 and 16 weeks for conservative cases, depending on the degree of injury and clinical response [6, 22]. Physical therapy rehabilitation plays a central role, emphasizing strengthening of the hip abductor and extensor muscles, impact control, and pelvic balance. Multidisciplinary follow-up is essential, involving an orthopedist, physical therapist, and physical education professional, ensuring safe and individualized rehabilitation [22, 23].

Surgical Treatment

Surgical treatment of femoral neck stress fractures is mainly indicated in tension fractures, with deviation or risk of progression, situations in which there is compromise of the upper cortex and possibility of complete displacement of the femoral head [15,17,20]. In these cases, internal fixation with cannulated screws is the most commonly used technique, while the use of the Dynamic Hip Screw (DHS) is reserved for vertical or unstable fractures [7,20]. Postoperative management includes partial weight-bearing restriction for 6 to 8 weeks, with progressive release according to radiographic consolidation and regression of symptoms [18]. The prognosis is favorable when diagnosis is early and treatment is adequate. However, the risk of avascular necrosis can reach 30% in tension fractures treated late, especially when the displacement has already compromised the vascular flow of the femoral head [16,17,20]. Complete rehabilitation and return to sports occur, on average, between 3 and 6 months, depending on the type of treatment and clinical evolution [21,22].

Prevention and Runner Education

The prevention of femoral neck stress fractures requires individualized training planning, with an increase in volume and intensity of less than 10% per week, avoiding cumulative bone overload [3,5]. Biomechanical assessment is essential, including analysis of foot strike, core strength, and neuromuscular control, which are determining factors for the adequate dissipation of impact forces [9,10]. Adequate nutrition is a preventive pillar. Vitamin D and calcium deficiency is directly related to reduced bone mineral density and increased risk of stress fractures [11,12]. In addition, **low energy availability (RED-S)** should be routinely investigated, as early nutritional correction and dietary monitoring significantly reduce the risk of overload bone injuries [4,25]. Strength training and plyometrics performed twice a week demonstrate **improvement in bone mineral density and femoral resistance to mechanical stress** [9,10,22]. Continuous training monitoring and technical correction are essential long-term measures.

Practical algorithm (diagnosis and management)

1. Runner with groin/proximal thigh pain that worsens with weight bearing: targeted physical examination and plain radiographs (AP pelvis and lateral view).

2. If X-ray is negative and clinical suspicion is high or X-ray shows signs of minimal fracture: perform MRI to detect bone reaction, medullary edema, and cortical trace; classify as compressive vs. tensional and by MRI grade.

3. Conservative management: indicated for compressive injuries without displacement — weight-bearing protection (use of crutches/partial weight-bearing for 4–6 weeks depending on pain), rehabilitation with bicycle and progressive eccentric/concentric work, gradual reintroduction of running after 6–8 weeks if pain-free.

4. Surgical indication: tension line, cortical loss >50%, displacement, progression on imaging, or incapacitating pain — internal stabilization (cannulated screws or standard plate).

5. Metabolic screening: in all cases of femoral neck BSI (or in runners with risk factors), request 25(OH)D, complete blood count, thyroid function, reproductive markers as indicated, and assess energy availability and calcium intake.

6. Criteria for return to sport: absence of pain in high-impact activities, recovery of strength and functional endurance, and tolerated progression without recurrence. Consider follow-up MRI in symptomatic or high-risk cases before full return to training.

Intervention	Practical action
Load progression	Avoid increases >10%/ week; prioritize volume increases with a focus on consistency
Strength training	2 sessions/week focused on lower limbs and core
Nutrition and RED-S	Assess energy intake; refer to a nutritionist if LEA/RED-S is suspected
Supplementation	Assess 25(OH)D and supplement according to guidelines; ensure 1000–1500 mg/d calcium
Monitor	Symptom and pain questionnaires; training monitoring (volume, intensity)

Table 2 — Practical prevention checklist for beginner runners

Discussion and Final Considerations

Femoral neck stress fractures represent a clinical challenge due to their potential for silent progression and because they affect recreational runners who are new to the sport [4,17,20]. Early diagnosis, preferably by magnetic resonance imaging, substantially reduces the risk of progression to complete fractures and avascular necrosis [14,21]. Recent evidence indicates that the time away from sports varies from 10 to 16 weeks for mild cases and up to 24 weeks when surgical fixation is necessary, highlighting the functional impact of this condition [6,22]. Optimal management requires a multidisciplinary approach, with an emphasis on progressive functional rehabilitation and monitoring of metabolic factors, especially vitamin D and energy availability [4,11,25]. The literature still lacks prospective studies with robust samples, which is the main limitation at present. However, the body of evidence reviewed reinforces the importance of gradual load planning, metabolic screening, and continuous professional monitoring in prevention. Advances in imaging techniques and load monitoring systems offer promising prospects for early diagnosis and monitoring of runners, reducing both the incidence and severity of these injuries [19,22].

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