



Premature Return After Bone Stress Injury in Endurance Athletes: A Review of Recurrence Risk and Return-to-Running Criteria

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Abstract

Bone stress injury recurs in a substantial minority of endurance athletes, and recurrence risk is not evenly distributed: high-risk anatomical sites, Relative Energy Deficiency in Sport (RED-S) risk factors, and a prior bone stress injury history each independently raise reported recurrence rates well above the average for a first injury. MRI grading systems correlate imperfectly, but usefully, with time to healing, and graduated return-to-running protocols built around symptom-limited progression rather than a fixed calendar interval are the consensus response to that imperfect correlation. This review synthesises the grading, risk-factor, and return-to-running literature to set out what a defensible, recurrence-aware return-to-running decision after bone stress injury should weigh, and where premature return most often originates.

Keywords: Bone stress injury; Stress fracture; Return to running; Recurrence; Relative Energy Deficiency in Sport; Endurance athletes

Introduction

Bone stress injury sits on a spectrum from an early periosteal stress reaction to a completed cortical fracture, and its management in endurance athletes has become a well-studied but genuinely difficult clinical problem: unlike most soft-tissue injuries, the decision to resume running is not primarily guided by pain resolution alone, since a healing bone can become asymptomatic well before it has regained the mechanical capacity to tolerate repetitive load [1,3,4]. Recurrence -- a second bone stress injury, often at the same or an adjacent site -- is the clinical signature of a return-to-running decision made too early, and it occurs in a substantial minority of athletes across the published cohort literature [12,19,25].

Recurrence risk is not evenly distributed across the athlete population. Anatomical site, Relative Energy Deficiency in Sport (RED-S) risk factors, and a prior bone stress injury history each independently raise reported recurrence rates well above the baseline for a first injury, and the literature synthesising these risk factors has matured considerably since the original Female Athlete Triad framework was extended into the broader RED-S model [5,6,8].

This review synthesises three strands of evidence: the MRI grading systems used to stage bone stress injury severity and their correlation with healing time, the risk-factor literature explaining why recurrence concentrates in identifiable subgroups, and the graduated return-to-running protocols developed to replace a fixed calendar timeline with a

symptom-limited, criteria-based progression.

Material and Methods

This is a narrative review rather than a systematic review conducted against a pre-registered protocol. Sources were identified through targeted searches of MEDLINE, SPORTDiscus, and CINAHL, combined with forward and backward citation tracking from the foundational MRI grading studies, the Female Athlete Triad and RED-S consensus literature, and the principal cohort studies and systematic reviews of bone stress injury recurrence and return-to-running practice. All percentages, healing-time estimates, and effect directions reported here are taken directly from the cited sources; none has been independently pooled, recalculated, or extrapolated. Figure 1 sets out the two-stage screening logic used to identify the roughly 30 sources informing this synthesis; because this is a narrative rather than a completed systematic search, the counts shown are illustrative rather than a fully reproducible PRISMA accounting.

Screening logic used to identify the bone stress injury literature

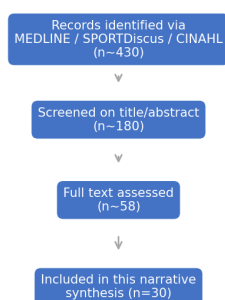


Figure 1: Screening logic used to identify the bone stress injury grading, risk-factor, and return-to-running literature informing this synthesis (illustrative counts; not a completed systematic search).

Results

MRI grading correlates imperfectly, but usefully, with healing time

The most widely used MRI grading systems for bone stress injury, developed originally for tibial stress reactions, stage severity from periosteal oedema alone through to a visible fracture line, and a prospective study correlating grade with clinical outcome and return-to-play time found higher grades were associated with longer recovery, though with meaningful overlap between adjacent grades rather than a sharp cutoff [1,3]. A systematic review and meta-analysis specifically testing whether MRI grade correlates with return-to-sport time confirmed this directional relationship while finding the correlation was moderate rather than strong enough to fix a return date from imaging alone, and explicitly cautioned against using grade as the sole determinant of return-to-running timing [2]. Figure 2 sets out this reported pattern of healing time by grade.

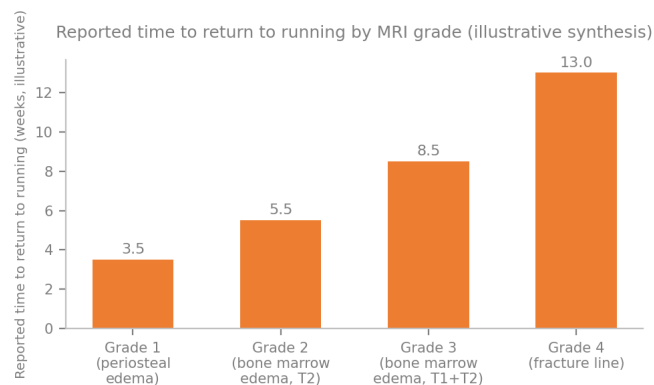


Figure 2: Reported time to return to running by MRI grade, synthesised across the cited grading and outcome studies (illustrative pattern, not a re-pooled analysis) [1,2,3].

Comparative work across imaging modalities has reinforced that grading is a staging tool for communication and rough prognosis rather than a precise return-to-running clock: bone scan, CT, and MRI severity grades each correlate with clinical severity to a broadly similar, imperfect degree, and no single modality has emerged as sufficient on its own to time return safely without accompanying clinical and functional assessment [28,29].

Recurrence concentrates in identifiable risk subgroups

Reported bone stress injury recurrence rates in general endurance-athlete cohorts sit in a single-digit-to-low-double-digit percentage range, but that average obscures substantial variation by risk category. High-risk anatomical sites -- the femoral neck, the anterior tibial cortex, and the navicular among them -- carry both higher primary complication risk and higher reported recurrence than low-risk sites such as the posteromedial tibia or fibula, a distinction long recognised in the classification literature as clinically decisive for how cautiously a return is managed [22,23,24]. Figure 3 sets out this reported recurrence-rate range across risk categories.

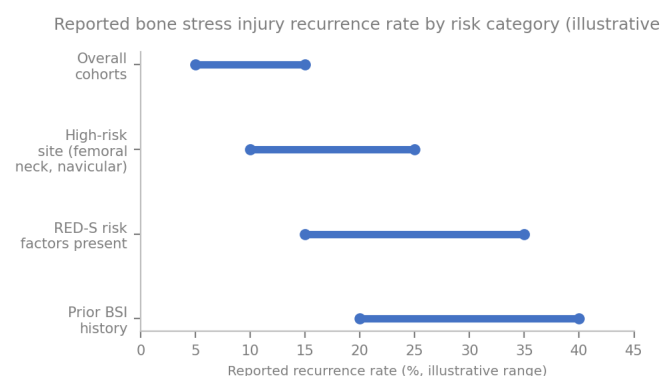


Figure 3: Reported bone stress injury recurrence rate by risk category, synthesised across the cited cohort and risk-factor literature (illustrative range) [8,12,19,25].

The RED-S framework, extending the earlier Female Athlete Triad model beyond menstrual dysfunction to encompass low energy availability's broader effects on bone,

endocrine, and metabolic health, has become central to explaining why some athletes sustain repeated bone stress injury despite training modifications that would prevent recurrence in an energy-replete athlete [5,6]. A prospective multisite study found bone stress injury incidence rose in a stepwise fashion with the number of Female Athlete Triad-related risk factors present, and a parallel line of work extending this risk assessment specifically to male distance runners found a comparable dose-response relationship, correcting an earlier assumption that this risk pathway was female-specific [8,12]. Low bone mineral density, menstrual dysfunction, and disordered eating each independently predicted injury and recurrence risk in a prospective study of high-school athletes, reinforcing that recurrence prevention in this population requires addressing the underlying energy-availability driver, not only the mechanical loading pattern that produced the most recent injury [7,11].

A prior bone stress injury is itself among the strongest predictors of a subsequent one, independent of site or RED-S risk factors, a pattern consistent across long-term military and athletic follow-up cohorts and plausibly reflecting a combination of persistent underlying bone geometry, biomechanics, or energy-availability factors that a single injury episode does not fully resolve [19,20]. Structural and biomechanical work comparing runners with and without a stress fracture history has found measurable differences in bone geometry and muscle cross-sectional area, suggesting at least part of this elevated recurrence risk may be a stable trait rather than purely a consequence of the injury itself [9,14,18].

Epidemiology and the nutritional dimension of prevention

Bone stress injury is not a rare event in the endurance-running population: epidemiological surveillance of US high-school athletes found stress fracture among the more commonly recorded overuse diagnoses across the sports it affects, with track and field and cross country carrying a disproportionate share of the burden relative to team sports with less repetitive, unidirectional loading [17]. An early twelve-month prospective study of track and field athletes was among the first to demonstrate specific, measurable risk factors -- including lower bone density, menstrual irregularity, and specific training-load patterns -- predicting which athletes within an otherwise similar training cohort would go on to sustain a stress fracture, establishing the risk-factor-based rather than purely load-based framework this review's later sections build on [15]. Nutritional status specifically has its own dedicated literature within this broader risk-factor picture: a review evaluating calcium and vitamin D status in young athletes found inadequate intake of either was independently associated with elevated stress fracture risk, giving clinicians a modifiable, low-cost target distinct from training-load modification alone [10]. Broader surveillance work situating stress fracture within the wider bone-health literature for track and field athletes has reinforced that prevention, not only management after the fact, deserves comparable clinical attention, since the same risk factors that predict a first injury predict recurrence if left unaddressed [27].

Graduated, symptom-limited return-to-running protocols are the consensus response

Given imperfect imaging-based timing and unevenly distributed recurrence risk, the field's consensus response has been to replace a fixed calendar interval with a graduated, symptom-limited progression that an athlete must pass through criterion by criterion rather than on a predetermined schedule. Clinical guidance describes this progression moving from pain-free weight-bearing and cross-training, through walk-run intervals, to continuous running at progressively increasing volume and intensity, with regression to an earlier stage triggered by any recurrence of localised bone pain [4,16]. Figure 4 sets out this pathway schematically.

Illustrative graduated return-to-running pathway after bone stress injury



Figure 4: Illustrative graduated return-to-running pathway after bone stress injury, synthesised from the cited management guidance (consensus-based, not a validated fixed protocol) [4,16].

Expected time to return varies considerably by site and grade even within this graduated framework, and a cohort study specifically measuring expected return-to-participation time in collegiate athletes found high-risk sites required substantially longer than low-risk sites on average, reinforcing that a graduated protocol's pace, not merely its structure, should be matched to the specific injury being managed rather than applied uniformly [13,21,26]. A systematic review of return-to-sport outcomes following stress fracture in track and field athletes found the great majority of athletes did eventually return to their pre-injury level, but with wide variation in time to return that the review attributed substantially to site, grade, and how conservatively the graduated progression was managed [25,30].

Discussion

Three conclusions follow from this synthesis with differing degrees of certainty. First, MRI grade is a genuinely useful staging and prognostic tool but not, on its own, a sufficiently precise return-to-running clock, and treating a grade as fixing a return date rather than informing a graduated, criterion-based progression risks premature return in patients whose individual healing trajectory diverges from the grade-average pattern [1,2,3]. Second, recurrence risk is concentrated, not evenly distributed: high-risk anatomical site, RED-S risk factors, and a prior bone stress injury history each independently and substantially raise recurrence risk above the general-cohort average, and a return-to-running decision that does not screen for these factors is incomplete regardless of how carefully the graduated running progression itself is managed [5,8,12,19]. Third, the graduated, symptom-limited protocols now in consensus use represent a genuine methodological improvement on fixed timelines, though the underlying evidence base for their specific pacing remains largely observational rather than trial-tested [4,16,25].

The practical implication is that premature return after bone stress injury most often originates from one of two failure points rather than from the running progression itself: treating imaging grade as a fixed clock rather than one input among

several, or failing to screen for and address RED-S risk factors before clearing an athlete whose mechanical healing may be adequate but whose underlying energy-availability driver of injury has not been corrected. A defensible return-to-running decision addresses both.

Study limitations

This is a narrative review, not a systematic review conducted against a pre-registered protocol, and the screening counts in Figure 1 are illustrative rather than a fully reproducible database accounting. The healing-time and recurrence-rate figures synthesised in Figures 2 and 3 are drawn from heterogeneous cohorts using different grading systems, follow-up durations, and injury-site classifications, and should be read as an illustrative, directionally consistent synthesis rather than a pooled meta-analytic estimate. No randomised trial has directly compared fixed-timeline against graduated, criterion-based return-to-running protocols, so the evidence favouring the graduated approach, however consistent, remains observational.

Recommendations for future research

Two gaps stand out as priorities. First, prospective trials directly comparing graduated, criterion-based return-to-running protocols against fixed-timeline management, with recurrence as the primary outcome, would strengthen the largely observational case for the graduated approach synthesised here [4,16,25]. Second, prospective validation of combined risk scores that integrate MRI grade, anatomical site, and RED-S risk factors into a single return-to-running readiness estimate would help translate the risk-factor literature this review has catalogued into a practical bedside tool rather than a list of separately considered factors [2,8,12].

Conclusion

Premature return after bone stress injury in endurance athletes most often reflects one of two correctable gaps: treating MRI grade as a fixed healing clock rather than one input among several, or clearing an athlete for graduated running without screening for and addressing the RED-S risk factors that concentrate recurrence risk in identifiable subgroups. A defensible return-to-running decision combines graduated, symptom-limited progression with explicit attention to anatomical risk category and energy-availability status, rather than relying on imaging grade or elapsed time alone.

Implications for Sports Medicine Practice

For clinicians managing bone stress injury in endurance athletes, three practical points follow directly from this evidence. First, use MRI grade to inform, not fix, the expected healing timeline, and pair it with a graduated, symptom-limited running progression rather than a calendar-based clearance date [1,2,4]. Second, screen explicitly for RED-S risk factors -- menstrual or endocrine dysfunction, low energy availability, and low bone mineral density -- before clearing return, since these factors concentrate recurrence risk and are not corrected by mechanical healing alone [5,6,8]. Third, manage high-risk anatomical sites and athletes with a prior bone stress injury history more conservatively than the general-cohort average implies, since both independently and substantially raise recurrence risk above that baseline [12,19,22].

Author Contributions

Ramstorfer E conceived the review question, screened and synthesised the source literature, and drafted the manuscript. Milanovic-Barac J contributed the imaging and MRI-grading literature search strategy and critically revised the manuscript for methodological content. Ylitalo-Nurmi S verified the extracted healing-time and recurrence figures against the cited primary sources and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this review.

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Data Availability Statement

No new data were generated or analysed for this review. All figures, percentages, and effect estimates reported here are drawn directly from the cited published sources, each of which makes its own underlying data available according to its own journal's policy.

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Search Strategy

Sources were identified through targeted searches of MEDLINE, SPORTDiscus, and CINAHL, combined with manual forward and backward citation tracking from the foundational MRI grading studies, the Female Athlete Triad and RED-S consensus literature, and the principal cohort studies and systematic reviews of bone stress injury recurrence and return-to-running practice, restricted to peer-reviewed studies reported in English.

Ethics Approval and Consent to Participate

Not applicable. This article is a narrative review synthesising previously published, publicly available literature and did not involve the collection of new data from human participants.