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Diagnostic Accuracy and Sonographic Characterization of Musculoskeletal Ultrasound in Bone Stress Injuries: A Systematic Review and Meta-Analysis

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ADMINISTRATIVE INFORMATION

Support - No support.

Review Stage at time of this submission - Preliminary searches.

Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 5 August 2026 and was last updated on 5 August 2026.

INTRODUCTION

Review question / Objective Primary objective (quantitative synthesis): Among patients with clinically suspected BSI (P), what is the diagnostic accuracy — sensitivity, specificity, and where calculable, positive/negative predictive values and likelihood ratios (O) — of musculoskeletal ultrasound (I) compared with MRI or other reference-standard imaging (C), across available prospective/cohort diagnostic accuracy studies (S)?

Secondary objective 1 (narrative synthesis by site): What sonographic findings, diagnostic pathways, and clinical outcomes have been reported in case reports and case series of US-diagnosed BSI, stratified by anatomic location (e.g., tibia, metatarsals, and others)?

Secondary objective 2 (serial imaging / return to sport): Does serial ultrasound assessment of BSI healing correlate with clinical symptom resolution and/or inform return-to-sport or return-to-activity decision-making, and how does this compare with serial MRI or radiography where reported?

Secondary objective 3 (synthesis of diagnostic criteria): Across all included studies regardless of design, what sonographic findings (e.g., periosteal thickening, periosteal elevation, cortical disruption/ step-off, subcutaneous edema, hypervascularity on color/power Doppler, callus formation, dynamic provocative findings) are used to diagnose BSI on ultrasound, how are they defined, and how consistently are they applied? Do they correlate with MRI grading?

Secondary objective 4 (if feasible): Is ultrasound more cost-effective than other imaging modalities?

Rationale Bone stress injuries (BSIs) represent a continuum from early stress reaction to frank cortical stress fracture, most commonly affecting the tibia and metatarsals in athletes. Radiography has poor sensitivity during the early stages of injury (often 10–56%), while MRI is considered the reference standard because of its ability to detect

bone marrow edema, periosteal reaction, and cortical fracture lines. However, MRI is expensive and may not be readily available when timely diagnosis is needed in athletes or military personnel. Musculoskeletal ultrasound (MSK-US) has emerged as a portable, inexpensive, radiation-free point-of-care imaging modality capable of evaluating superficial cortical bone, periosteal abnormalities, and surrounding soft tissues in real time. These characteristics may make MSK-US particularly useful for BSIs involving superficial or anatomically accessible locations, such as the tibia, metatarsals, fibula, and first rib, as well as for serial assessment during recovery. Reported diagnostic accuracy varies considerably across studies (sensitivity approximately 70–87% and specificity 57–95%), and the literature has expanded to include both prospective diagnostic accuracy studies and case reports involving atypical injury locations. Despite increasing interest, there remains no standardized sonographic diagnostic criterion for BSI, with studies inconsistently incorporating findings such as periosteal thickening, periosteal elevation, cortical irregularity or disruption, subcutaneous edema, hyperemia on Doppler imaging, and callus formation. Consequently, the clinical role of ultrasound in the diagnosis of BSIs remains uncertain.

To date, no systematic review has comprehensively evaluated the diagnostic accuracy of MSK-US for BSIs using established diagnostic test accuracy methodology. Furthermore, existing evidence has expanded beyond the lower extremity to include anatomically distinct sites such as the first rib and other atypical locations, where the diagnostic role of ultrasound may differ because of variations in cortical accessibility and surrounding soft tissue anatomy.

Condition being studied Bone stress injuries (BSIs), ranging from early stress reaction to established fracture in any anatoimc location.

METHODS

Search strategy A comprehensive search will be conducted in PubMed, Embase, and Web of Science from inception to August 2026, with language restrictions to English. Search terms will combine two concepts: (1) ultrasound/musculoskeletal ultrasound/sonography, and (2) bone stress injury/stress fracture terminology, combined with the Boolean operator AND. Controlled vocabulary (e.g., MeSH, Emtree) will be combined with free-text/title-abstract terms and adapted to each database's syntax. No design-specific filter will be applied at the search stage, consistent with the absence of a validated sensitive search filter for diagnostic accuracy studies; study design will instead be assessed during title/abstract and full-text screening. Reference lists of included studies and relevant reviews will be hand-searched.

Participant or population Human participants of any age (pediatric, adolescent, adult) with clinical suspicion of, or confirmed, bone stress injury/stress fracture at any skeletal site, including athletic (recreational and competitive), military recruit, and general (non-athletic) populations.

Intervention Diagnostic musculoskeletal ultrasound used to detect or characterize bone stress injury.

Comparator MRI as the primary reference standard; other imaging modalities such as radiography, CT, and bone scintigraphy, or clinical follow-up as reference standards where MRI was not used. No reference standard is required for studies included in the narrative (case report/case series) synthesis arm.

Study designs to be included Cohort/diagnostic accuracy studies, case series, and case reports.

Eligibility criteria Studies including human participants with suspected or confirmed bone stress injury, evaluating diagnostic ultrasound (with or without a reference standard comparison), published as cohort/diagnostic accuracy studies, case series, or case reports.

Exclusion criteria: animal or cadaveric studies, traumatic (non-stress) fracture studies, therapeutic (non-diagnostic) ultrasound studies, quantitative ultrasound studies, and reviews/editorials/abstracts without extractable original data.

Information sources PubMed, Embase, and Web of Science, from inception to August 2026, supplemented by hand-searching the reference lists of included studies and relevant review articles.

Main outcome(s) Diagnostic accuracy of ultrasound for detecting bone stress injury, expressed as sensitivity and specificity (and, where calculable, positive/negative predictive values and likelihood ratios) compared with a reference standard.

Additional outcome(s) Sonographic findings and diagnostic criteria used to identify bone stress

injury (e.g., periosteal thickening, periosteal elevation, cortical disruption, subcutaneous edema, hypervascularity on Doppler, callus formation), described narratively by anatomic site; correlation of serial ultrasound findings with healing and return-to-sport/activity outcomes; correlation between ultrasound findings and MRI grading/severity of bone stress injury; and cost-effectiveness if feasible.

Quality assessment / Risk of bias analysis Risk of bias will be assessed using validated tools appropriate to study design — QUADAS-2 for cohort/diagnostic accuracy studies, and the JBI Critical Appraisal Checklists for Case Reports and Case Series for narrative-arm studies. The specific tool(s) applied to cohort-type studies will be finalized based on the final set of included designs.

Strategy of data synthesis Sensitivity and specificity will be jointly pooled using a bivariate random-effects logistic regression model when sufficient clinically and methodologically homogeneous diagnostic-accuracy studies with extractable 2 × 2 data are available. If quantitative synthesis is not feasible because of a limited number of studies, sparse data, substantial clinical or methodological heterogeneity, or model nonconvergence, findings will be summarized narratively. Where appropriate, separate univariate random-effects logistic regression models for sensitivity and specificity may be considered.

Evidence from case reports and case series will not be included in the diagnostic-accuracy meta-analysis. These studies will be synthesized narratively by anatomic site and used to describe reported sonographic findings, examination techniques, and potential diagnostic criteria. Common sonographic features will also be summarized descriptively across the included literature.

Subgroup analysis Where sufficient data permit, exploratory subgroup analyses may be performed according to anatomic site, reference standard, and study population. Given the anticipated small number of diagnostic accuracy studies, these analyses may not be feasible and will be interpreted cautiously.

Sensitivity analysis Where feasible, sensitivity analyses may be conducted by excluding studies at high risk of bias or with important methodological differences to evaluate the robustness of the findings. Given the anticipated small number of studies, these analyses may not be possible, and the potential impact of study quality and methodological differences will be discussed narratively.

Language restriction English.

Country(ies) involved United States.

Keywords Diagnostic Ultrasound; Bone Stress Injuries; Sensitivity; Specificity.

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