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ARTIFICIAL INTELLIGENCE IN MUSCULOSKELETAL ULTRASOUND FOR SPORTS INJURIES: DIAGNOSTIC ACCURACY, CLINICAL UTILITY, AND IMPLEMENTATION CHALLENGES (2022-2026): A NARRATIVE REVIEW

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ABSTRACT

Background: Musculoskeletal Ultrasound (MSK-US) is a popular tool among Sports Medicine professionals due to its portability, repeatability, no radiation exposure, and ability to provide dynamic, point-of-care assessments. However, MSK-US also has an operator dependent component of accuracy.

Objective: This Review will summarize the current literature from 2022-2026 regarding Artificial Intelligence (AI) in MSK-US specifically with respect to its use in assessing sports injuries, including its diagnostic accuracy, utility and readiness.

Methods: The search engines PubMed, Google Scholar, and Reference Chaining were utilized to identify peer-reviewed publications that contained information related to AI; MSK Ultrasound; Sports Medicine; Tendons; Muscle Injuries; Rotator Cuff Injuries; Point-of-Care Imaging.

Results: Potential uses of AI in MSK-US are based on pattern recognition, automated measurements, segmentation, and as an aid to second readers, particularly when assessing injuries to tendons, muscles, or the rotator cuff. AI can potentially help reduce variability and enable consistent monitoring. The quality of the available evidence was limited by studies using retrospectively collected data; curated databases; heterogeneity of study design; lack of external validity; and limited examination of outcomes relevant to patients.

Conclusion: AI-assisted MSK US appears to be a promising technology; however, at present it is not ready for unqualified clinical application. The most likely near term use of AI-assisted MSK US would be as a form of supervised decision support for trained health care providers.

KEYWORDS

Artificial Intelligence, Musculoskeletal Ultrasound, Sports Injuries, Point-of-care Ultrasound, Sports Medicine, Tendon Injury, Muscle Injury, Diagnostic Imaging.

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1. Introduction

Sports medicine is increasingly relying upon imaging methods which are capable of being performed quickly; thus enabling these assessments to be repeated as changes occur in the clinical decision-making process. Musculoskeletal (MSK) ultrasound has been identified as an ideal diagnostic tool for assessing musculoskeletal injuries dynamically; comparing both sides of the body; and providing non-invasive assessments longitudinally throughout the continuum of care — i.e., from initial injury to return to play. Additionally, MSK ultrasound typically does not result in delays similar to those encountered via the use of static imaging referrals. Recent literature reviews have made connections between sports medicine, point-of-care ultrasound and other technologies (AI), and how they relate to the delivery of athlete care. (Koziak et al., 2025; Bolek et al., 2025; Park et al., 2024).

Use of musculoskeletal ultrasound (MSK US), is increasing with its limitations being exposed. Accuracy of diagnosis will depend upon the experience of the operator in obtaining and interpreting images, their knowledge of sport specific injury patterns, as well as their ability to identify very small grayscale and Doppler changes. This becomes particularly significant in the field of sports medicine. Clinicians have the need to differentiate pathologic conditions due to repetitive load (for example; patella tendonitis, achilles tendonitis, rotator cuff pathology) from adaptive changes and to understand the clinical implications of abnormalities which are identified prior to a patient having symptoms, continue after symptoms resolve, or exist in patients who have no current symptoms.

AI can aid in addressing several of those mentioned as areas of limitation. In this regard, there have been a variety of applications for AI in medical imaging (e.g., segmentation; pattern recognition; triage support; automated measurement; and structured reporting). Similarly, recent review articles suggest that both machine learning and deep learning may be useful in musculoskeletal radiology to assist in fracture detection, osteoarthritis staging, ligament injury assessment, body composition analysis and characterization of tendons or muscles (Shariatnia et al., 2025; Oettl et al., 2025; Longo et al., 2025; Mercurio et al., 2025; Prudnikov et al., 2024).

While musculoskeletal ultrasound provides valuable diagnostic information to determine soft tissue injuries related to sport, it represents a particularly difficult modality in which to develop AI applications due to the strong dependence of image quality upon both the techniques employed by the operator as well as several other physical factors specific to ultrasound (such as anisotropy, transducer pressure, and angle of incidence). Therefore, this particular challenge also presents opportunity.

AI can be used in sports medicine to analyze image patterns, but most importantly, AI can help clinicians make decisions quickly and provide continuous evaluations through various forms of data collection. Thus, the primary goal of this review was to synthesize the available literature on AI-based MSK-US for diagnosing sports-related injury and to find out which applications are the closest to being translated into an appropriate clinical environment.

The intent of this review is not to duplicate other reviews on AI in sport or the use of musculoskeletal imaging. Rather, it will take a targeted approach to synthesizing clinical diagnostic pathways related to sports injuries and highlight the significant gap in translating potentially useful algorithms into common clinical practices.

Research Objective. To critically synthesize the 2022-2026 evidence on AI-assisted musculoskeletal ultrasound in sports injuries, with emphasis on diagnostic accuracy, clinical usefulness, and implementation readiness.

Research Problems. Which sports injury applications currently show the strongest evidence for AI-assisted MSK US? Where does AI improve diagnosis, workflow, or longitudinal monitoring, and where do methodological limitations still dominate?

Research Hypotheses. First, AI-enhanced MSK US improves selected diagnostic tasks compared with conventional reading alone, especially where pattern recognition is repetitive and visually well-bounded. Second, the clinical translation of these models remains limited by heterogeneous datasets, incomplete external validation, and persistent dependence on high-quality image acquisition.

Research materials and methods

Participants.

As this is a narrative review, no human participants were enrolled directly. The unit of analysis was the published scientific literature concerning AI applications in MSK ultrasound and sports-related injury diagnostics.

Procedure / Test protocol / Skill test trial / Measure / Instruments.

A clinical practice focused narrative literature review was undertaken. PubMed and Google Scholar were both independently searched with a combination of the following search terms to identify articles on the topic: artificial intelligence, machine learning, deep learning, musculoskeletal ultrasound in sports medicine/sports injury; tendon/muscle/rotator cuff; and point-of-care (POC) ultrasound.

2.3. Data collection and analysis / Statistical analysis.

Titles & Abstracts (which were then used to determine which studies would be relevant) related to Sports Medicine Ultrasound Musculoskeletal Image Analysis Tasks were initially assessed. The full texts of articles that indicated an association with using Artificial Intelligence in Musculoskeletal US image analysis as well as the ability to improve diagnostic accuracy, support workflow, assist in educating operators, or implement in a sports medicine setting were then evaluated. A priority was given to publications written in English language by peer-review journals from 2022-2026. Studies that were excluded were those that had no relation to MSK-US, focused solely on non-sports indications, or provided no information regarding diagnostic accuracy, clinical utility or the use of the technology in practice.

2.3.1. Statistical Software.

No de novo statistical analysis of pooled data was performed. When original studies reported diagnostic accuracy metrics such as sensitivity, specificity, area under the curve (AUC), Dice score, interobserver reliability, or agreement against expert reference standards, these metrics were described qualitatively and compared across studies where appropriate.

2.3.2. Ai.

AI tools were employed solely in improving clarity, refining vocabulary (language) and organizing content for ease of reading; all other aspects of science — including selecting sources, synthesizing data/evidence, drawing conclusions, etc., as well as approval of said science, was done entirely by the authors. No AI tool generated a single recommendation concerning care of patients based on clinical decision-making, created references that did not exist prior to their generation or replaced the human scientist's role in determining what constitutes good scientific practice and/or making individualized patient-based medical decisions.

2.3.3. Statistical Methods.

The current research examined the published works on the topic by way of both a methodologically and clinically oriented review process as opposed to a meta-analytically based (quantitative) summary. All published articles were evaluated for their applicability in sports medicine, whether they appropriately addressed an appropriate target for imaging, the level of development of the AI used, the level of detail regarding the reference standard utilized, if the data was externally validated; and how each could be potentially incorporated into an actual workflow for MSK-US.

Research results**3.1. Why musculoskeletal ultrasound is particularly relevant for sports injuries**

MSK ultrasound has a significant role to play in sports medicine. It provides an advantage over radiography by allowing clinicians to directly assess soft tissue. Additionally, when comparing to MRI, MSK ultrasound is more readily available; less expensive; can be used repeatedly at the bedside and can assist clinicians in making immediate decisions regarding patient care. The recent literature also highlights MSK ultrasounds utility in assessing movement dynamically; providing a means of triaging patients in the clinic or on the field; as well as performing repeated assessments on athletes (Koziak et al., 2025; Park et al., 2024; Palermi et al., 2025).

As an example, while the concept of using AI to detect tears based upon ultrasound has received attention, the technical challenges have proven to be significant. These challenges range from issues related to consistency across different machines and probes to difficulties with identifying lesions and distinguishing them from artifacts.

Table 1. Clinically relevant domains of AI-assisted musculoskeletal ultrasound in sports medicine (2022-2026).

Domain	Typical sports use case	Potential AI contribution	Main current limitation
Rotator cuff and shoulder US	Rapid identification of full-thickness tears, dynamic impingement assessment, subacromial pathology	Lesion classification, segmentation, second-reader support, workflow standardization	Small datasets, variable acquisition angles, limited external validation
Tendon imaging	Achilles, patellar, common extensor, and supraspinatus tendinopathy or tear assessment	Automated thickness and echotexture measurement, abnormality detection, monitoring support	Difficulty distinguishing adaptive change from clinically important pathology
Muscle injury imaging	Acute strain detection, grading, hematoma follow-up, return-to-play monitoring	Symmetry-based lesion detection, automated region proposal, quantitative follow-up	Lack of consensus labels and inconsistent injury reference standards
Quantitative ultrasound	Serial rehabilitation monitoring and body composition related tasks	Measurement automation, reproducibility enhancement, reduced time burden	Few prospective studies showing improved decisions or outcomes
Education and access expansion	Use by non-radiologist sports clinicians and trainees	Real-time guidance, image-quality feedback, safety prompts	Human factors, liability, overreliance, unclear regulatory pathways

3.2. What AI currently does in musculoskeletal ultrasound

At present, the systematic review by Getzmann et al. provides one of the clearest summaries of AI in musculoskeletal ultrasound. The authors concluded that AI could be integrated into MSK US for diagnostic purposes, but they also emphasized substantial heterogeneity in both the anatomical regions studied and the tasks performed. Most published work has focused on image segmentation, image classification, automated measurements, or workflow support rather than full clinical pathway implementation (Getzmann et al., 2024; Shin et al., 2021).

AI can have many practical applications in MSK-US and they can be categorized based on their function. There are five different types of functions of these practical applications. These include; Classification (i.e. is the tendon ruptured or intact); Segmentation (i.e. outlining the boundaries of tendons or muscles for better measurement reliability), Measurement Automation (e.g. measuring tendon thickness, echotexture, or side-by-side comparisons); Acquisition Support (e.g. providing operator guidance or scan quality feedback) and Workflow Support (e.g. triaging images, creating structured reports, tracking longitudinal changes). The most important limitation is that demonstrating a high level of performance within a small, curated image set may not demonstrate a potential to enhance clinical decision-making when using the tool in a full clinical examination. Thus, there may be significant "translational gaps" between achieving an accurate diagnosis at the imaging level and improving clinical outcomes at the pathway level. Translational gaps are particularly relevant in MSK-US since the clinical application of ultrasound examinations are highly dependent upon; the acquisition technique used by the clinician, the clinical context in which the examination was performed and the clinicians' experience with performing and interpreting MSK-US examinations.

3.3. Evidence by injury type and sports medicine scenario

The Shoulder & Rotator Cuff provides an excellent example of how AI can aid MSK-US. Injuries to the Rotator Cuff occur with regularity in active individuals and have enough anatomical consistency to allow image based classification of such injuries. Wu et al., demonstrated through attentional deep learning that both diagnostic accuracy & Inter-Observer Reliability were significantly increased for detecting tears in the rotator cuff, thereby supporting a secondary reader position for AI vs. Autonomous Diagnosis.

Imaging Tendons is a high priority in Sports Medicine due to the necessity for Clinicians to Diagnose Injury, Assess Progression of Injury and Make Return-To-Load Decisions. Additionally, this represents a significant Sports-Med Paradox; Ultrasound Abnormalities may be seen in Asymptomatic Athletes; Continue to be present after Symptom Resolution; or be Adaptive vs. Pathological Change. Thus, Clinical Judgment

must remain paramount when evaluating AI Outputs in conjunction with Symptoms, Function, Training Load and Physical Examination.

Although Imaging Muscular Injuries has the Potential to be One of the Most Appealing Clinical Applications for AI-Assisted MSK-US, there are currently Methodological Challenges. Muscular Strains are a Common Injury to Football Players, Field Sport Players and Track & Field Athletes who utilize Ultrasound for Rapid Localization and Follow-Up. While Ultrasound is Less Sensitive Than MRI for Detection of Subtle Edema and Low Grade Injury, AI Should Be Viewed as a Support Tool for Selected Image Recognition Tasks and Monitoring vs. Replacing Clinical Judgment.

Table 2. Representative recent studies relevant to AI-assisted musculoskeletal ultrasound in sports injuries.

Study	Design	Target	Main finding	Clinical significance
Getzmann et al., 2024	Systematic review	AI in MSK US overall	Promising but heterogeneous evidence; most studies remain early-stage	Good overview of current maturity and gaps
Wu et al., 2025	Original deep learning study	Rotator cuff tear detection on US	Improved diagnostic accuracy and interobserver reliability	Supports second-reader use in shoulder imaging
Ghosh et al., 2024	Original AI tool study	Full-thickness rotator cuff tear classification	Automated approach feasible on shoulder US images	Potential access expansion beyond expert readers
Zhu et al., 2025	Original deep learning study	Muscle strain detection using bilateral US	Symmetry-aware model improved lesion detection in curated dataset	Highly sports-relevant proof of concept for muscle injuries
Cushman et al., 2025	Prospective observational study	Preseason tendon/fascia sonographic abnormalities	Abnormal findings associated with later time-loss injury	Shows prognostic importance of standardized US interpretation
Koziak et al., 2025	Narrative review	POCUS in sports medicine	US valuable for rapid diagnosis, monitoring, and procedures	Confirms strong clinical niche for tools that enhance ultrasound consistency

3.4. Diagnostic accuracy, clinical utility, and the translational gap

Diagnostic capability in a curated dataset does not guarantee that an algorithm will have utility for sports medicine professionals in their clinics. Clinicians need to know if a lesion is identified on imaging, and then they need to know if it accounts for the patient's symptoms (pain), limitations of function, intolerance to load, or risk of returning to play. Therefore, when evaluating AI-assisted musculoskeletal ultrasound, we suggest that you use meaningful outcomes based on what matters in a clinical environment rather than only relying upon measures of image level accuracy.

Currently, the most compelling evidence supporting clinical relevance exists for very narrow assistance applications. The current examples are: the automatic identification of full-thickness tendon tears, consistent and accurate measures of tendons, consistency of segmenting images of tendons, and assisting inexperienced operators with reviewing images. Conversely, there is no strong evidence to suggest that clinical outcomes are enhanced through use of this technology; including better return-to-play decision-making, fewer injuries after returning to competition, lower cost associated with treatment or rehabilitation, or a shorter time frame from the onset of an injury to receiving a formal diagnosis. It is not suggesting that the field is devoid of value. Rather, the field currently consists primarily of pre-implementation data. (Staszkievicz et al., 2025).

Another translational issue is the quality of the reference standard. Many AI studies in MSK US compare model output with expert ultrasound labels rather than with composite clinical endpoints, surgical findings, or

MRI in all cases. That approach may still be useful when the goal is consistency, but it limits the strength of diagnostic claims. If the training labels embed observer subjectivity, the model may learn expert convention rather than objective disease status. This distinction is crucial in sports medicine, where imaging findings must always be interpreted alongside symptoms, mechanical load, timing, and functional status.

Model explainability is also important. Clinicians are more likely to use AI when they can understand why the model highlighted a region and when the output is presented as decision support rather than as an absolute answer. Heat maps, segmentation overlays, confidence ranges, and quality flags are therefore more clinically acceptable than unexplained black-box yes/no classifications.

3.5. Implementation challenges: data quality, workflow, ethics, and education

Several barriers currently limit widespread adoption of AI-assisted MSK US in sports medicine. The first is data heterogeneity. Ultrasound images vary substantially according to device, transducer, preset, operator technique, patient habitus, motion, and pathology chronicity. A model trained on one shoulder protocol or one tendon clinic population may perform worse in other environments. This is particularly problematic in sports medicine, where the population includes adolescents, elite adults, female athletes, para-athletes, and recreational exercisers with very different exposure histories and body compositions.

Ultrasound technology has both an "acquisition" phase, when images are collected, and an "interpretation" phase. The output of the "algorithm", regardless of its strength, can be unreliable if the input (images) were poorly collected. Consequently, commercially viable AI systems for medical ultrasound will probably require to have some form of acquisition aid, scan quality assessments or scanning quality advice before producing diagnostic results.

There are additional barriers to the development of AI based applications in sports imaging; most importantly, there does not yet exist a well developed regulatory/ethical framework for making performance claims regarding new technologies. Developers of these technologies typically make performance claims prior to developing adequate mechanisms for integrating their devices into clinical environments, tracking changes in versions of their software (model drift), establishing liability for errors produced by their products, providing appropriate data management practices, and creating processes that allow them to update their algorithms after they have been deployed.

4. Discussion

Current evidence suggests that AI-assisted MSK ultrasound is not being developed entirely apart from real-world sports medicine needs. Credible technical applications already exist for selected tasks, including tendon pathology detection, muscle injury support, and workflow standardization. The appeal of this field lies in its alignment with core sports medicine needs: rapid assessment, repeated follow-up, and reduction of inter-observer variability across clinicians.

Although this area has distinct disadvantages. There is a great deal of evidence that strong AI performance has been consistently demonstrated in retrospective image-level analysis as opposed to prospectively evaluating pathways. In addition to many examples of how AI can enhance individual isolated ultrasound images, there are very few studies demonstrating if AI enhances treatment choices, improves patient health results, or reliably shortens time to diagnose.

AI could help improve the role of ultrasound at the bedside in sports medicine by helping with the quality of images (and) guiding the operator; providing standardization of measurement; and also provide calibrated assistance from a second reader. However, Ultrasound is still very prone to variation in data collection; probe positioning; and operator ability. Therefore, there will be an increased need for development of standard operating procedures prior to widespread use in a clinical setting.

A focused narrative review on AI in MSK US for sports injuries provides a clear clinical niche and stronger coherence than a broad review of AI in medicine or AI in sport. It also addresses a topic that is highly relevant to sports medicine, rehabilitation, and implementation-oriented imaging practice.

Future work should focus on several priorities. First, multicenter datasets should be developed with anatomical specificity and representation of real-world sports populations. Second, labels should incorporate clinically relevant reference standards rather than expert opinion alone. Third, AI studies in MSK-US should transparently report acquisition protocols, device characteristics, external validation, and clinically meaningful endpoints.

Table 3. Priority actions needed before AI-assisted MSK ultrasound can become routine in sports medicine.

Domain	What is needed next	Why it matters in sports medicine
Standardized acquisition	Consensus scanning planes, labeling standards, and quality-control rules	AI performance depends heavily on image consistency
External validation	Testing across devices, operators, sports, and patient subgroups	Essential to avoid overfitting to one site or protocol
Integration studies	Prospective studies assessing time to diagnosis, referral patterns, return-to-play decisions, and clinician confidence	Shows whether AI changes meaningful practice rather than image metrics alone
Education	Structured training so clinicians understand both ultrasound limitations and AI limitations	Reduces overreliance and supports safe adoption
Governance and ethics	Clear rules on responsibility, athlete consent, data access, and post-deployment monitoring	Sports settings often involve sensitive performance and employment implications

Beginning with a practical research agenda that will determine the next level of advancement in this area for future prospective testing of AI-based systems in actual clinical assessment settings as opposed to only utilizing large retrospective images, outcomes should move beyond image accuracy to reflect a variety of other factors such as; diagnostic confidence, time to diagnosis, referrals, rehabilitation decisions, return to play planning and patient safety.

A hybrid model is the most likely first application of AI-assisted ultrasound in sports medicine. This model would allow the clinician to continue performing/interpreting the examination while utilizing an AI system to create standard views; identify potential issues with image quality; quantify anatomical structures; enable direct comparisons of each side of the body; and indicate regions where the clinician may want to further examine. While completely autonomous diagnostic systems may eventually occur, the current hybrid model is a more realistic model of how sports imaging occurs in the context of all other aspects of an athlete's medical evaluation.

4.1. A practical research agenda for 2026 and beyond

While there are some shortcomings with this review. For example it is a narrative synthesis as opposed to either a systematic review or meta-analysis. The available evidence that was analyzed in this review is also very heterogenous (i.e., different areas of the body were examined using various types of imaging protocols, different architectures of models and various reference standards). In addition, several clinically relevant studies examining sports ultrasound and musculoskeletal artificial intelligence were included in this review due to their conceptual relevance even though they did not directly investigate the use of artificial intelligence in sports related musculoskeletal ultrasound.

The focused nature of this review can be seen as one of its strengths; specifically that this review addressed clinically relevant issues. This review linked the performance of algorithms to clinically relevant questions in sports medicine: Which injuries would benefit from the assistance of an artificial intelligence-based ultrasound? What outputs from the system will be useful to clinicians? And what are the barriers that need to be overcome prior to implementing these systems?

Future narrative syntheses and original research articles should make every effort to distinguish performance based upon the concept versus readiness for implementation.

5. Conclusions

AI-Assisted Sports-Related Musculoskeletal-Ultrasound (MSK-US) is both timely and has significant clinical relevance. The current literature indicates that AI may be able to assist in selected aspects of sports medicine such as rotator cuff tear diagnosis, symmetry based analysis of injury to muscles, and measurement/standardization of tendons and muscles. A large portion of this data still exists as preliminary, and there is no current evidence demonstrating an autonomous diagnostic capacity for routine use in sports medicine.

Practical implications for sports clinicians

Future articles in this area need to be far more than just excited descriptions of technology; they need to have a defined clinical problem, describe their methodology openly, provide clinically applicable results, and describe how AI alters the work of the sports medicine staff at the practical level. AI has the potential to assist the smaller centers and/or inexperienced users of ultrasound with reducing the difference between access to equipment and expertise by being utilized responsibly. However, it will not be responsible for encouraging interpretations of scans beyond what a clinician can do on his/her own. In addition, AI will serve as a supervisory safety net for reinforcing anatomically based techniques, identifying areas of uncertainty, and facilitating appropriate escalation when expert review is necessary. There are many uses for AI enhanced ultrasound in rehabilitation. While there are times when clinicians will have to scan athletes multiple times in a row (i.e., over several days/weeks) to assess changes in hematoma, tendons, fascia, and muscles; there will be significant variability among those assessments due to inconsistency from one assessment point in time to another. Therefore, software that enhances the reproducibility of planes, assists side-by-side comparisons of each limb, and provides quantitative measures of longitudinal changes may also be very beneficial during both rehabilitation and return-to-sport evaluations.

The authors declare that this manuscript is an original narrative review prepared for scholarly purposes and that it has not been published previously or submitted elsewhere.

Author Contributions:

Conceptualization: Victoria Stielow and Michał Marusza; literature review and evidence synthesis: Victoria Stielow, Antonina Zatyka, and Aleksander Krupski; drafting of the manuscript: Victoria Stielow; critical revision and supervision: Michał Marusza and Aleksander Krupski; final approval: all authors.

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