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Review Article

Effectiveness of Diagnostic Musculoskeletal Ultrasound in Orthopedic Physical Therapy: A Systematic Review

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Abstract: ***Background*:** Musculoskeletal ultrasound (MSK-US) has become an increasingly popular tool in diagnosing and managing musculoskeletal disorders due to its non-invasive, cost-effective, and real-time imaging capabilities as a practical alternative to conventional methods like MRI. ***Methods*:** This systematic review evaluates the effectiveness of MSK-US in orthopedic physiotherapy, adhering to PRISMA guidelines and using the PICO framework. Databases, including PubMed, Cochrane Library, ScienceDirect, ClinicalTrials.gov, Google Scholar, and PEDro, were searched for studies published between January 2001 and September 2024. ***Results*:** Nine studies, comprising case reports, clinical trials, and observational studies, were included. MSK-US demonstrated a significant reduction in repeat reduction rates (9.2% vs. 24.6%; P = .019) and improved volar tilt measurements (7.6° vs. 3.7°; P = .000). Its use was also effective in imaging muscle tears and treating hemiplegic shoulder pain, with high sensitivity and specificity in diagnosing fractures, although accuracy varied depending on the fracture site. ***Conclusion***: Most studies presented a low to moderate risk of bias, according to quality assessments. MSK-US provides high diagnostic accuracy, with sensitivity and specificity rates of 87.3% and 96.4%, respectively, alongside therapeutic benefits and noninvasiveness. These attributes make it a valuable tool in orthopedic physical therapy. However, its effectiveness is highly operator-dependent and condition-specific. Further high-quality randomized controlled trials are necessary to fully validate these findings and confirm MSK-US as an integral tool in orthopedic practice.

Keywords: Diagnostic Imaging, Fracture Management, Musculoskeletal Ultrasound, Orthopedic Physical Therapy.

1. INTRODUCTION

Ultrasound (US) imaging significantly influences the assessment and management of musculoskeletal (MSK) disorders and has become an increasingly popular imaging modality in the field of MSK and neuromuscular rehabilitation for visualizing soft tissue structures as a diagnostic aid. MSK-US enables clinicians to visualize both static and dynamic anatomical structures in real time and exhibits comparable specificity and sensitivity to magnetic resonance imaging (MRI) for both partial and full-thickness rotator cuff tears [1, 2]. Traditional US imaging has been supplemented by various quantitative tools provided by US systems [3], making it a valuable diagnostic instrument that can visually define anatomy and pathophysiology, complementing the physical examination [4].

The potential of MSK-US has been adopted by the medical profession for a variety of pathologies and specialties [5]. A recent review identified numerous indications for MSK-US in geriatric care and rehabilitation across various patient presentations, injuries, and diseases [6]. This method simplifies diagnostics by enabling practitioners to rapidly and precisely evaluate structures in a single step, facilitating early detection, reducing costs, and shortening diagnostic times by optimizing resource utilization. As clinicians become more proficient in its use, MSK-US is expected to be more widely adopted in various MSK evaluations, providing detailed insights into MSK anatomy that can improve patient care and outcomes, enhance patient comfort, and reduce radiation exposure through its rapid scanning process [7].

MSK-US has also been recognized for its capacity to dynamically visualize muscle structure and movements, regardless of whether they are in motion or at rest and is expanding rapidly as a non-invasive and secure method of

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evaluating MSK structures such as bones, muscles, tendons, and ligaments, avoiding the need for costly or potentially harmful studies like MRIs, radiographs, and computed tomography (CT) [8]. High-frequency sound vibrations employed in MSK-US help image bodily soft tissues and bony structures for pathological diagnosis or real-time interventional procedure guidance. As a result, MSK-US has been incorporated into the practices of an increasing number of practitioners to improve patient care.

In clinical medicine, the proliferation of US is being driven by technological advancements, reduced costs, and enhanced portability [9]. Understanding physical therapy practices is crucial to identifying discrepancies in empirical evidence and emphasizing the need for training [10]. MSK-US gives clinicians a non-invasive way to view tissues like muscles, bones, tendons, and ligaments beneath the skin and supports physical therapy diagnoses and targeted treatment plans by assessing structural integrity and detecting inflammation [11]. However, MSK-US may not be comparable to MRI for various MSK injuries, such as distal biceps tendon avulsions and plantar plates [12], though it has been utilized for acute athletic injury evaluations [13].

Despite these applications, research on orthopedic physical therapy, particularly for fracture diagnosis, shows promising results but lacks comprehensive coverage. While the meta-analysis by Douma-den Hamer *et al*., [14], highlighted the reliability of US in diagnosing pediatric forearm fractures, the overall evidence remains limited. Studies have suggested that the multi-planar imaging capabilities of MSK-US may surpass radiological methods in detecting stress fractures, especially those that are radiographically hidden [15, 16]. However, most research has focused on specific cases such as pediatric forearm fractures, lower extremity stress fractures, acute extremity fractures, and long bone fractures.

Ultrasonography is a non-invasive imaging technique that is entirely safe and reliable. Unlike CT and X-rays, it does not produce ionizing radiation. It is considered safe for all patients, including those with cardiac pacemakers and metallic implants, unlike MRI. Further, its ability to distinguish structures based on their echo characteristics results in exceptional pictorial representation [17]. The use of US in diagnosing fractures in the head and shaft of the humerus, particularly the greater tuberosity, and in detecting osteolytic lesions of the proximal humerus, is well-documented [18]. Additionally, MSK-US benefits the diagnosis of ankle pathologies, such as tendon and ligament ruptures and tendon sheath inflammation [19], and improves the early detection rate of hip abnormalities through static and dynamic examinations [20]. In recent years, MSK-US has also been recognized as an excellent imaging tool for diagnosing and following up with patients diagnosed with rheumatic diseases [21].

While MSK-US has proven valuable for assessing soft tissue injuries, particularly in sports injuries, and is most practical in evaluating tendon structures, articular pathologies, and dynamic examinations during motion, a need exists to consolidate current findings to better understand its role in orthopedic physical therapy. This includes evaluating its effectiveness across various conditions and its potential to enhance patient outcomes through targeted interventions.

The purpose of this systematic review is to provide an overview of the available research on MSK-US applications, identify areas where MSK-US has shown the most and least promise, and point out future research directions for improving its role in diagnostics and treatment planning in physical therapy.

2. MATERIALS AND METHODS

2.1. Study Design

The current systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement criteria. Furthermore, the study met the population, intervention, control, and outcome (PICO) criteria. The PICO statement for this study is as follows: P: Patients with orthopedic involvement undergoing physical therapy who require diagnostic US imaging before rehabilitation; I: MSK diagnostic ultrasonic imaging; C: comparison between the control group and US group; O: measuring the accuracy of diagnostic rate and application of physical therapy intervention.

2.2. Inclusion and Exclusion Criteria

The inclusion criteria were as follows: (1) original research articles, clinical studies, randomized controlled trials, prospective and retrospective cohort studies, studies reporting on the efficacy of MSK-US in orthopedic conditions, studies with adequate details like sensitivity, specificity, and diagnostic accuracy to determine the critical information of the research studies; (2) studies published from 2000 to September 2024; and (3) studies involving patients with MSK ailments, including a bone fracture, acute ankle sprain, and orthopedic injuries.

The exclusion criteria were as follows: (1) non-English articles; (2) commentaries, guidelines, editorials, book chapters, letter to the editor, reviews, and meta-analysis; (3) studies with MSKUS but no complete reports on diagnostic efficacy and accuracy; (4) in vitro and in vivo studies; (5) protocols; and (6) studies investigating intervention for involvements other than orthopedic and athletic injuries of the lower extremity. We also excluded studies that involved

simulated patients or fractures, non-blinded MSK-US operators, and non-blinded graphic interpretation, children as participants, and mixed pediatric and adult samples (where children and adult groups are not feasible to distinguish separately). We excluded studies in which children or mixed pediatric-adult samples took part, whose results cannot be differentiated from each other. Developmental factors frequently lead to considerably different pathophysiology, diagnostic ways, and treatment protocols concerning MSK conditions in children as compared to adults. For this reason, such a strict restriction to studies with participants exclusively classified as adults was necessary so that the findings have a straight relevance to adult orthopedic physical therapy. This focus is explicitly captured within both our inclusion and exclusion criteria, placing the relevance of MSK-US in adult clinical practice at the forefront.

2.3. Literature Search Strategy

This study only considered full-text articles published in English. The publications published between January 2000 and September 2024 were searched in the following six databases: PubMed, The Cochrane Library, Science Direct, Clinicaltrial.gov, Google Scholar, and PEDro databases. We used the following search terms and strings for the analysis: "musculoskeletal ultrasound" OR "ultrasonography" AND "physical therapy OR orthopedic physical therapy" OR "orthopedic conditions." We conducted a manual search of the reference lists and related reviews to identify additional pertinent studies. This process was repeated until no additional articles could be identified. There were no constraints on the country during the literature search.

2.4. Study Selection and Data Extraction

Titles were screened following duplication, and prospective relevant articles were identified by analyzing the associated abstracts. The abstracts and full-text papers of the identified studies were independently reviewed. The full contents of the articles included in the study were used to abstract the study information. Two independent reviewers extracted data from selected articles. Any discrepancies were resolved through discussion. If there were any unresolved discrepancies, a third reviewer was involved. The data was extracted using a standard Excel spreadsheet. Authors, publication year, sample size, age, study design, participants, intervention, primary outcomes, and significant findings of each included study were collected. Table 1 presents the overview and characteristics of the included studies. A meta-analysis was not performed due to the variability of the interventions, demographics, and outcome measures.

Table 1: Characteristics of the included studies

Study	Sample size	Mean Age (years)	Design of study	Diagnosis	Primary objective	Intervention	Key results	Outcome
Ang *et al.,* [22]	72	61.5	Before-and-after study	Distal radius fractures	Ultrasound guidance effectiveness of in the reduction of distal radius fractures	Ultrasound guidance	In the ultrasonography group, the rate of repeat manipulation and decrease was lower (1.6% vs 8.8%; P =.056). The ultrasound group exhibited better volar tilt, although the post-reduction radiography indices between the groups were identical (P =.048).	It is beneficial and advised to adopt ultrasound guidance often for treating distal radius fractures.
Faltus *et al.,* [23]	1	24	Case report	Quadriceps Femoris Muscle Tear	Musculoskeletal ultrasound effectiveness of in Quadriceps Femoris Muscle Tear	Musculoskeletal ultrasound	After undergoing six weeks of therapy sessions that included enhanced soft-tissue mobilisation, eccentric strengthening exercises, and stretching, the patient reported overall better function, strength, and discomfort levels.	Visual, quantifiable proof from MSKUS imaging supported the patient's subjectively stated results and better function.
Sabzghabaei *et al.,* [24]	130	36.5	Prospective case control study	Distal radius fractures	Effectiveness of ultrasound guidance in the reduction of distal radius fractures in adult patients	Musculoskeletal ultrasound	The ultrasound group experienced a lower rate of repeat reduction (9.2% vs 24.6%; P =.019). Volar tilt was better in the ultrasound group (mean, 7.6° vs 3.7°; P =.000).	The regular use of MSKUS guidance is effective and advised in the reduction of distal radius fractures
Ebadi *et al.,* [25]	50	NA	Randomized double-blind	Primary adhesive capsulitis	Analyse the potential contribution of ultrasound to the effects	Ultrasound	Pain, function, and range of motion did not show a significant time-group interaction effect (p>.05), indicating that both groups'	In individuals with primary adhesive capsulitis, using continuous

Study	Sample size	Mean Age (years)	Design of study	Diagnosis	Primary objective	Intervention	Key results	Outcome
			clinical trial		of manual therapy and exercise in the rehabilitation process.		improvements in all end measures were comparable.	ultrasound in addition to a schedule of semi supervised exercise and mobilisation had no extra benefit.
Zhang *et al.*, [26]	1	64	Case report	Hemiplegic shoulder pain (HSP)	Effectiveness of musculoskeletal ultrasound	Musculoskeletal ultrasound	Both the discomfort and shoulder function were greatly reduced. Tendon thickness and effusion extent were both decreased.	Physical treatment under musculoskeletal ultrasound guidance can efficiently lessen HSP symptoms and enhance inflammation, effusion, and lesioned tissue absorption.
Atilla *et al.*, [27]	246	37	Prospecti ve study	Acute foot and/or ankle sprain	Diagnostic accuracy of ultrasound for fractures	Ultrasound	The sensitivity and specificity of ultrasound scanning in detecting fractures were 87.3% and 96.4%, respectively.	Ultrasound had good sensitivity and specificity for diagnosing fifth metatarsal, lateral, and medial malleolus fractures in the patients with foot and/or ankle sprain. However, sensitivity and specificity of ultrasound for navicular fractures were low.
Dallau dière *et al.*, [28]	127	40.6	Single center observati onal cohort study	Bone fracture	Comparing the accuracy of on-the-spot ultrasonograp hy with X-ray in the screening for bone fractures	Ultrasonograph y and X-rays	The sensitivity, specificity, and accuracy of ultrasound was 98%, 98%, and 99%, respectively. Only one radial styloid process fracture was misdiagnosed with US.	Bedside musculoskeletal ultrasound performed is a useful method in determining and assessing bone fractures.
Frouza n *et al.*, [29]	100	31.43±12 .32 (upper limb fracture); 29.63±5. 89 (lower limb fracture)	Cross-sectional study	Trauma to the upper and lower extremities	Comparing the accuracy of ultrasound with plain radiog- raphy in diagnosis of upper and lower extremity long bone fractures	Ultrasonograph y and plain radiographs	The sensitivity and specificity of ultrasound were 98.6% and 83%, respectively, and the highest accuracy was observed in men, lower ages and femoral fractures.	Ultrasound has a high accuracy in the diagnosis of upper and lower extremity long bone fractures.
Ekinci *et al.*, [30]	131	37.2 ± 15.44	Prospecti ve study	Foot and ankle injuries.	Analyzing the accuracy of ultrasound scanning in foot and ankle injuries.	Ultrasound	Sensitivity, specificity, positive predictive value, and negative predictive value of ultrasound was 100%, 99.1%, 95.2%, and 100%. Respectively	Ultrasound imaging highly sensitive technique in the evaluation of foot and ankle fractures.

2.5. Literature Quality Evaluation

The Joanna Briggs Institute's (JBI) Critical Appraisal Checklists for Research were employed to evaluate the risk of bias in the selected studies during the quality assessment [31]. A study's chance of bias was considered high if the "yes" score was less than 49%. Studies with a score of 50 to 69% had a moderate risk of bias, while those with a score of 70%

or more had a low risk. The selected articles were independently reviewed and evaluated by two researchers using the criteria above. In the event of any discrepancies, a third researcher was consulted for their input.

3. RESULTS

3.1. Literature Selection

There were 772 citations, comprising 449 from PubMed, 142 from ScienceDirect, 114 from Google Scholar (as grey literature), 45 from The Cochrane Library, 18 from PEDro, and four from ClinicalTrials.gov. Among these, 261 duplicate studies were removed. After evaluating the titles and abstracts of 511 articles, 410 studies were eliminated. The remaining 101 articles fulfilled the full-text review criteria. After applying exclusion criteria, 92 full texts were excluded, and the other nine articles were included in the final qualitative analysis [22-30]. Figure 1 shows the study selection process.

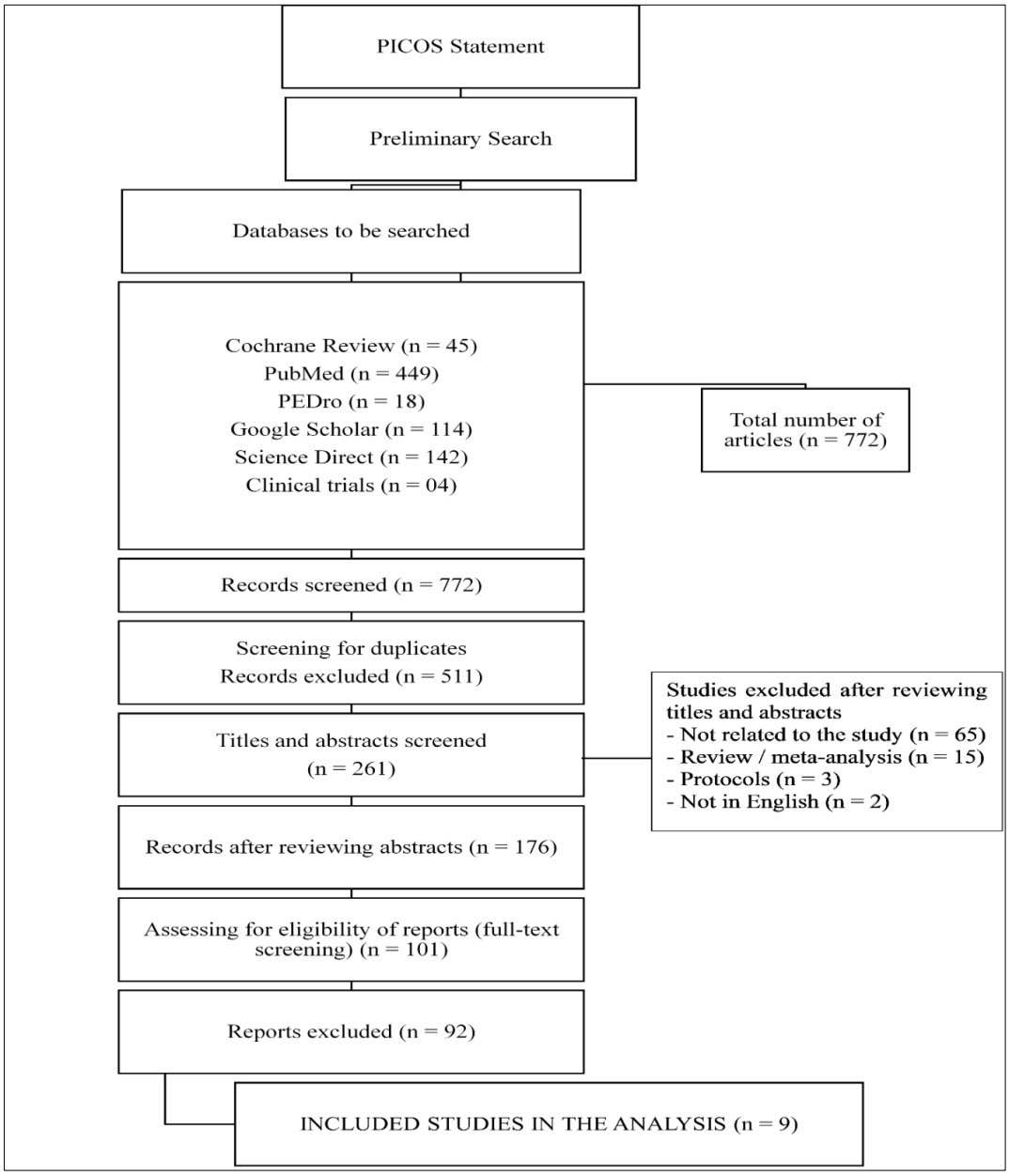

Figure 1: Flowchart showing the study process

3.2. Literature Quality

Two reviewers independently evaluated all the included studies. Most of the studies in this analysis had a low to moderate risk of bias. Two out of nine studies were of low quality, whereas one study was of moderate quality, and six studies were of high quality (Table 2).

Table 2: Quality of the included studies

Study	Limitations	Quality of Study	Risk of bias
Ang *et al.,* [22]	None noted	High	Low
Faltus *et al.,* [23]	Case report; lacks generalizability and statistical analysis	Low	High
Sabzghabaei *et al.,* [24]	Lack of blinding	High	Low
Ebadi *et al.,* [25]	Sample size - small	High	Low
Zhang *et al.,* [26]	Case report; lacks generalizability and statistical analysis	Low	High
Atilla *et al.,* [27]	Lack of blinding and possible confounders not accounted for in the analysis	High	Moderate
Dallaudière *et al.,* [28]	Observer bias; limits generalizability	High	Moderate
Frouzan *et al.,* [29]	Cross-sectional design limits the ability to establish causality, and potential biases due to non-randomized nature of the study	Moderate	Moderate
Ekinci *et al.,* [30]	Lack of blinding and possible confounders not accounted for in the analysis	High	Moderate

3.3. Characteristics of the Included Studies

Table 1 summarizes the study characteristics of all the included studies. The sample size ranged from 1 to 858 subjects, and the articles were published between 2010 and 2017. The mean age of participants across the nine studies varied significantly, reflecting the diverse population samples included in the research. The mean ages ranged from 24 to 64 years. Notably, one study had distinct age distributions based on the type of fractures, with a mean age of 31.43 ± 12.32 years for upper limb fractures and 29.63 ± 5.89 years for lower limb fractures. Another study reported a mean age of 37.2 ± 15.44 years, indicating a broad age range among its participants. Out of the nine included studies, three were conducted in Iran, two in Turkey, and one each in the United States, China, Singapore, and Nepal. Our analysis included one before-and-after study, two case reports, one prospective case-control study, one randomized, double-masked clinical trial, two prospective studies, one single-center observational cohort study, and one cross-sectional study.

3.4. Efficacy of the Diagnostic MSK-US

Ang *et al.,* [22], conducted a before-and-after study with 72 participants to evaluate the effectiveness of MSK-US guidance in reducing distal radius fractures. The study found that the rate of repeat manipulation was lower in the MSK-US group (1.6% vs. 8.8%; P = 0.056). Additionally, the MSK-US group exhibited better volar tilt post-reduction (P =.048). The study concluded that MSK-US guidance is beneficial and suggested for treating distal radius fractures. Faltus *et al.,* [23], reported a case study on the effectiveness of MSK-US in diagnosing and managing quadriceps femoris muscle tears. After six weeks of therapy, which included soft-tissue mobilization, eccentric strengthening exercises, and stretching, the patient showed significant improvement in function, strength, and discomfort levels. MSK-US imaging provided visual confirmation of the patient's subjective improvements.

Sabzghabaei *et al.,* [24], conducted a prospective case-control study with 130 patients to assess the effectiveness of MSK-US guidance in reducing distal radius fractures in adults. The MSK-US group had a lower rate of repeat reduction (9.2% vs. 24.6%; P = 0.019) and better volar tilt (mean, 7.6° vs. 3.7°; P = 0.000). The study concluded that MSK-US is effective and recommended for reducing the incidence of distal radius fractures. Ebadi *et al.,* [25], conducted a randomized double-masked clinical trial with 50 participants to evaluate the role of MSK-US in the rehabilitation of primary adhesive capsulitis in conjunction with manual therapy and exercise. The results indicated that MSK-US did not provide any additional benefit in the rehabilitation process, as there was no significant difference in pain, function, or range of motion improvements between the groups (p >.05).

Zhang *et al.,* [26], conducted a case report examining the efficacy of MSK-US in evaluating hemiplegic shoulder pain (HSP). The patient experienced a substantial decrease in pain, an improvement in shoulder function, and a reduction in tendon thickness and effusion. The research emphasized that MSK-US guided physical therapy effectively reduces HSP symptoms and enhances the absorption of lesioned tissue, effusion, and inflammation. A prospective study was conducted by Atilla *et al.,* [27], to evaluate the diagnostic accuracy of the MSK-US for acute foot and ankle injuries, involving 246 participants. The research determined that MSK-US had a sensitivity of 87.3% and a specificity of 96.4% for diagnosing fractures, with a particular emphasis on the fifth metatarsal, lateral malleolus, and medial malleolus. Nevertheless, the sensitivity and specificity of the test for navicular fractures were subpar.

Dallaudière *et al.,* [28], conducted a single-center observational cohort study with 127 participants to compare the accuracy of MSK-US and radiographs in screening for bone fractures. High sensitivity (98%), specificity (98%), and accuracy (99%) were demonstrated by MSK-US, with only one radial styloid process fracture misdiagnosed. The study concluded that bedside MSK-US is a valuable method for evaluating bone fractures. A cross-sectional study was conducted by Frouzan *et al.,* [29], to compare the accuracy of MSK-US and plain radiography in long bone fracture diagnosis in the

upper and lower extremities. The study included 100 participants. The study concluded that MSK-US had a sensitivity and a specificity of 98.6% and 83%, respectively. Men, individuals of lesser age, and femoral fractures exhibited the highest degree of accuracy. In the diagnosis of long-bone fractures, the study highlighted the high accuracy of MSK-US.

The precision of MSK-US in diagnosing foot and ankle injuries was evaluated in a prospective study conducted by Ekinci *et al.,* [30], with 131 participants. The study reported a sensitivity of 100%, a specificity of 99.1%, a positive predictive value of 95.2%, and a negative predictive value of 100%. The results indicated that MSK-US is a highly sensitive technique for assessing foot and ankle fractures.

4. DISCUSSION

MSK-US is used increasingly in the diagnosis and treatment of MSK conditions, as it provides various advantages like affordability, non-ionizing radiation exposure, portability, and precise performance of interventional procedures [32]. MSK-US is an ideal clinical companion that can be used in the assessment and treatment of MSK conditions, owing to its dynamic assessment, sonopalpation of potentially painful tissues, and real-time visualization for interventional therapy [33]. MSK-US assisted neurolysis has been identified to be clinically beneficial and safe. However, most data supporting physical therapists' imaging-related decisions comes from case studies that emphasize the connection between imaging and physical therapy.

MSK-US is a suitable choice for physical therapist applications, as the operator interacts directly with the patient, conducting a thorough physical examination and palpating the patient's musculoskeletal system. The ability and experience of the operator play a significant role in the diagnostic value of MSK-US images, which explains the discrepancy in claimed sensitivity for MSK disorders [32]. Physical therapists have an opportunity to incorporate MSK-US and embrace technology. Recent research has consistently supported its application in physical therapy for a diverse range of patients, including diagnosis, treatment, and research [8].

A review by Ang *et al.,* [22], demonstrated that MSK-US contributes to the improved first-attempt fracture reduction, with a significant decrease of repeat manipulation and reduction from 8.8% to 1.6%. Similarly, open reduction and internal fixation was significantly reduced in the MSK-US group, from 4.9% to 16.7% in the control group, indicating that guided reductions result in more accurate reductions, thereby minimizing the need for surgical procedures. In the MSK-US group, there was a clinically significant improvement in volar tilt. An appropriate volar tilt is essential in preventing radial shortening, a complication well known to occur after distal radius fractures. This means that MSK-US provides better diagnostic accuracy for the realignment of fragments, particularly regarding volar tilt, which may be an essential factor in reducing the need for further interventions [22].

A case report by Zeppieri *et al.,* [34], studied the efficacy of the administration of MSK-US guided platelet-rich plasma injections to athletes and reported that MSK-US guided platelet-rich plasma injections have been associated with positive outcomes and that platelet-rich plasma injections could be an effective supplement to physical therapy for athletes who need to return to their sport as quickly as possible. The role of MSK-US in sports medicine has seen a substantial increase, with studies focusing on platelet-rich plasma [35].

Considering the included studies, we have observed that the studies provide insight into the wide range of applications and various degrees of effectiveness of MSK-US in diagnosing, treating, or managing MSK conditions. Studies by both Ang *et al.,* [22], and Sabzghabaei *et al.,* [24], suggest that MSK-US can be used to reduce the number of fractures that occur in the distal radius by facilitating early diagnosis and identification. The effectiveness of MSK-US in fracture care is highlighted by the fact that it results in significant reductions in the number of repeated manipulations and an improvement in volar tilt. The studies included in our analysis support these findings of effective early diagnosis with MSK-US guidance.

In contrast, Ebadi *et al.,* [25], discovered that MSK-US did not provide any extra benefits when paired with physical therapy and exercise in the treatment of primary adhesive capsulitis. This finding suggests that the effectiveness of MSK-US may be condition-specific. By giving visual confirmation of soft tissue changes and symptom reduction, case studies conducted by Faltus *et al.,* [23], and Zhang *et al.,* [26], highlighted the effectiveness of MSK-US in guiding therapy and enhancing outcomes in muscle tears and hemiplegic shoulder pain, respectively. There was a remarkable functional improvement, with a gain in shoulder motion and a decrease in pain. This further demonstrates the functional improvement of the shoulders due to MSK-US-guided therapy, as it reduces the thickness and effusion of the tendon, thereby aligning with the functional benefit literature. Another case report by Chorba *et al.,* [36], highlighted the use of MSK-US in the diagnosis and management of a high-grade triceps tendon avulsion in a 35-year-old male patient. A high-grade partial triceps brachii tendon rupture was found from the MSK-US of the patient, which was performed after the patient presented to a physical therapist with acute-on-chronic pain in the right elbow. The study has concluded that MSK-US has the

potential to play a significant role in the diagnosis of complex tendon injuries and the timely referral of patients, thereby improving patient outcomes.

Subsequently, Atilla *et al.*, [27], Dallaudière *et al.*, [28], Frouzan *et al.*, [29], and Ekinci *et al.*, [30], reported the high diagnostic accuracy of MSK-US in identifying fractures, particularly in the foot, ankle, and long bones. However, the sensitivity of MSK-US can vary depending on the site of the fracture. The findings of these studies collectively imply that although MSK-US is highly beneficial in fracture diagnosis and specific therapeutic approaches, its advantages may be less evident in other areas. This observation underscores the importance of tailoring MSK-US to the condition being treated.

Several studies have demonstrated the effectiveness of MSK-US in identifying various types of fractures, with studies showing improved volar tilt and lower operation rates. In orthopedic physical therapy, MSK-US has been proven to be a popular supplementary technique. However, it takes years of practice and experience to gain the abilities necessary to use MSK-US, which is highly user-dependent. Physical therapists are more cost-effective than orthopedic surgeons in managing nonsurgical MSK issues, with no significant differences in patient outcomes other than patients treated by physical therapists reporting higher levels of satisfaction with their care.

The current study has a few limitations. First, we have included limited studies due to a lack of similar published studies. Second, we have used studies of various sample sizes and interventions; therefore, a meta-analysis has not been performed. This limits the generalizability of our findings. Thus, future studies should focus on more randomized controlled trials and clinical trials to validate these findings.

5. CONCLUSION

This systematic review underlines the considerable utility of MSK-US in orthopedic physical therapy, demonstrating its sufficiency for the diagnosis and management of MSK injuries. MSK-US was identified as a beneficial, highly effective modality for rapid and accurate assessment, thereby facilitating early diagnosis with high accuracy in fracture detection, soft tissue injury diagnosis, and guiding therapeutic procedures. While the value of MSK-US as a diagnostic tool is undeniably essential, especially in specific conditions such as soft tissue injury, the overall generalizability and its therapeutic application in a wide range of contexts remain to be determined. Studies are needed to establish its role in various clinical settings. Further, MSK-US has not been fully integrated into routine clinical practice, and optimal training for physical therapists using MSK-US remains an area of development.

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