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Return-to-play testing and functional assessment following upper extremity injury in athletes: a systematic literature review

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ABSTRACT

One of the toughest challenges in sports medicine is figuring out when an athlete can safely return to play after an upper extremity injury. Functional performance tests, isokinetic strength assessments, and patient-reported outcome measures are commonly used, but there is still no widely accepted, evidence-based RTP framework for shoulder, elbow, or wrist injuries. This systematic review pulled together the latest evidence on RTP assessment, pinpointed criteria backed by research, evaluated the tools available, and pointed out where studies are still lacking. The review followed PRISMA 2020 guidelines and searched the Scopus database for English-language studies published between 2021 and 2026. Two independent reviewers handled study selection and data extraction, with strong agreement (Cohen's $\kappa = 0.87$). Methodological quality was checked using the Joanna Briggs Institute checklist. Out of 633 records, only 10 studies made the cut. Four main themes came out of the analysis. First, criteria-based RTP protocols led to fewer reinjuries compared with time-based clearance, even when some functional deficits remained. Second, isokinetic rotational strength and limb symmetry turned out to be the strongest predictors of successful RTP. Third, functional tests like the Closed Kinetic Chain Upper Extremity Stability Test and Unilateral Seated Shot-Put Test showed real clinical value, but they need population-specific normative data to be more useful. Fourth, psychological readiness played its own role in RTP decisions, independent of physical measures. Wearable sensors and artificial intelligence show potential for continuous monitoring, but stronger prospective evidence is still needed. Overall, the current evidence supports a multidimensional RTP framework that combines objective strength, functional performance, and psychological readiness. At the same time, it highlights the need for standardized, pathology-specific criteria through future multicenter prospective studies.

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Introduction

Upper extremity injuries are becoming a bigger problem for athletes these days, no question about it. They affect everything from how often someone can compete to their actual performance and even long-term joint health. The biggest offenders are sports that put repetitive, high-magnitude stress on the shoulder, elbow, wrist, and hand. Think racket sports, overhead motions, throwing, contact sports, and anything weight-bearing. These activities cause instability events, labral and rotator cuff problems, ulnar collateral ligament damage, and fractures. Any one of those can seriously derail a competitive career (Burnham et al., 2026; Ibrahim et al., 2021). The issue spans weightlifting, handball, and the newer racket sports too. Each one has its own unique injury patterns and return-to-sport timelines (Barrett et al., 2026). More people are participating at younger ages now, across both professional and recreational levels. So naturally the volume of surgical and conservative management options has grown. That creates a clear clinical need: figuring out, in an objective and defensible way, when an athlete is genuinely ready to come back. This decision carries weight that goes well beyond a single season. It affects recurrence risk, secondary pathology, and how the athlete psychologically relates to their sport.

In this landscape, return-to-play (RTP) decision-making after upper extremity injury has proven really hard to standardize. With the lower limb, hop-test batteries and limb symmetry indices have reached something close to consensus. But the upper extremity doesn't have a single validated test or agreed-upon threshold to signal when the shoulder or elbow is ready for unrestricted competition (Kurz et al., 2023). Clinicians have to balance strength recovery, functional capacity, tissue healing timelines, and psychological readiness. And they often do this under pressure from athletes, coaches, and organizational stakeholders. Without criterion-based guidance, time-based clearance has remained a common fallback. That means sending athletes back at a fixed postoperative interval. But there's mounting evidence that this approach has real limitations.

A growing body of research has tried to fill this gap. The idea is to develop and evaluate functional testing batteries, isokinetic strength profiles, and patient-reported outcome measures (PROMs) built specifically for the upper limb. Criteria-based return-to-sport (CBRTS) protocols that blend isometric and isokinetic strength, endurance, and functional performance have been used after shoulder stabilization procedures (Drummond Junior et al., 2021; Reddy et al., 2023). Upper extremity performance tests like the closed kinetic chain upper extremity stability test, the unilateral seated shot-put test, and prone ball-drop tasks have been proposed as measurable indicators of power, stability, and symmetry (Degot et al., 2021; Naftilan et al., 2025). Composite readiness batteries and functional performance tests have also been developed. They show promising six-month profiles, linking shoulder rotation strength to functional capacity (Yildiz et al., 2023; Waldhelm et al., 2025; Juré et al., 2022). Taken together, these efforts signal a shift in the field from chronological to biological and functional readiness.

Recent methodological advances have sped up this shift. Isokinetic dynamometry now allows precise measurement of internal and external rotation torque and side-to-side symmetry. That gives us candidate thresholds for safe clearance after stabilization surgery (Moussa et al., 2024). Validated psychometric instruments like the Shoulder Instability, Return to Sport After Injury scale capture the psychological side of readiness that objective strength testing misses (Magni et al., 2024). At the same time, wearable inertial sensors, instrumented movement analysis, and early uses of artificial intelligence in rehabilitation monitoring promise continuous, ecologically valid measurement of upper limb function outside the clinic (Ishigaki et al., 2024; Borms et al., 2026). These developments broaden the evidence base that RTP decisions can be built on.

Still, despite this progress, a first critical gap is the fragmentation and inconsistency of RTP criteria across different upper extremity regions and conditions. Testing protocols look very different between shoulder instability, rotator cuff repair, biceps-labral pathology, and elbow ligament injury. Even within a single diagnosis, the components, cut-off values, and timing of testing vary widely from one center to another (Geyer et al., 2023; Whicker et al., 2023). Qualitative work confirms that clinicians themselves disagree on what criteria should guide clearance after shoulder stabilization. Review-level accounts of posterior instability and dynamic anterior stabilization show divergent technical and rehabilitative pathways (Szlufcik et al., 2024; Doyle et al., 2025; Misir, 2026). This heterogeneity hurts comparability. It makes meta-analytic synthesis difficult. And it leaves practitioners without transferable benchmarks. The field needs a consolidated look at which criteria are actually linked to reduced recurrence and durable return.

A second gap is theoretical and methodological. Much of the available evidence comes from retrospective cohorts and case series with modest samples, short follow-up, and inconsistent reporting of test reliability and validity (Kelley et al., 2022; Ulrich et al., 2023). Reliability and normative data, which you need to interpret any functional test, are frequently missing or mismatched to the population. That limits confident translation to individual athletes (Degot et al., 2021; Naftilan et al., 2025). On top of that, psychological readiness and objective physical capacity are rarely examined together. This is despite evidence that they can diverge and independently predict return. A synthesis that evaluates design quality alongside criterion content is long overdue.

The urgency of addressing these gaps is amplified by the clinical and economic stakes when RTP fails. Recurrent instability after inadequate clearance often means revision surgery, longer absences, and diminished career trajectories (Horinek et al., 2022; Colasanti et al., 2023). On the flip side, overly conservative, criterion-free delays come with their own costs for athletes and organizations. As criteria-based testing, isokinetic profiling, PROMs, and emerging sensor technologies mature all at once, a timely systematic synthesis can consolidate what we know, expose what's uncertain, and guide both practice and future research toward evidence-based, multidimensional decision-making.

Therefore, this systematic review was designed according to PRISMA 2020 guidelines to synthesize, critically appraise, and compare contemporary evidence regarding return-to-play assessment following upper extremity injury in athletes. The review specifically evaluates functional testing protocols, strength assessments, patient-reported outcomes, and emerging technologies to identify evidence-based RTP criteria.

So this systematic literature review is guided by three research questions. The first one deals with the content and comparative effectiveness of RTP criteria. The second question addresses the measurement properties and predictive value of specific functional and strength-based assessment tools, while recognizing the contribution of psychological readiness to the return decision. The third question situates these findings within emerging technological and methodological trends and identifies the boundaries of current evidence. Framed explicitly, the review is organized around the following questions, whose synthesis constitutes the novel contribution of this work: a consolidated, quality-appraised account of multidimensional RTP assessment after upper extremity injury.

Method

Research Design and Framework

This study used a systematic literature review design. Why SLR? The method is transparent, reproducible, and rigorous. You identify, appraise, and synthesize every piece of evidence tied to a specific research question (Tranfield et al., 2003). Predefining eligibility criteria, search strategy, and synthesis steps right from the start keeps bias low in selection and interpretation. Heterogeneous evidence is handled well too, especially when primary studies don't share a common design or outcome (Liberati et al., 2009). For identification, screening, eligibility, and reporting, we went with the PRISMA 2020 framework (Page et al., 2021). This keeps everything transparent and aligned with reporting standards at Q1-indexed sport science and sports medicine journals.

This systematic literature review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement (Page et al., 2021). The review followed a predefined protocol that specified the research questions, eligibility criteria, search strategy, study selection process, quality appraisal, and data synthesis methods to enhance transparency and reproducibility. The review protocol was developed before the literature search; however, it was not prospectively registered in PROSPERO because the review focused primarily on methodological synthesis rather than clinical intervention effectiveness.

Search Strategy

The search strategy combined controlled and free-text terms across four conceptual blocks, return-to-play, functional or strength-based assessment, upper extremity anatomy, and athletic population. These were joined with Boolean operators. Truncation () captured lexical variants like test, athlete. The TITLE-ABS-KEY field code restricted matches to titles, abstracts, and keywords. We applied document-type and language limiters within the query. The publication window was set to 2021, 2026, ensuring we prioritized contemporary evidence. The exact search string used in Scopus is shown below.

TITLE-ABS-KEY (("return to play" OR "return to sport" OR "return to competition" OR "RTP") AND ("functional assessment" OR "functional test" OR "isokinetic" OR "strength symmetry" OR "limb symmetry" OR "patient-reported outcome*" OR "functional criteria") AND ("shoulder" OR "elbow" OR "wrist" OR "upper extremity" OR "upper limb") AND ("athlete*" OR "sport*" OR "player*")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (PUBYEAR > 2020 AND PUBYEAR < 2027)*

The literature search was conducted in January 2026 by two independent reviewers. After the electronic search, the reference lists of all included articles were manually screened to identify additional relevant studies that might not have been retrieved through database searching. The complete search strategy was pilot-tested before the final search to ensure adequate sensitivity and specificity.

Database and Information Sources

Scopus was our go-to authoritative source. It has a broad index of peer-reviewed sports medicine, orthopaedic, and rehabilitation literature, and its structured metadata works well for bibliometric extraction. We did a single export and kept every bibliographic field, authors, title, year, source, volume, issue, pagination, DOI, abstract, and keywords, exactly as they were for screening and synthesis. We didn't add any other databases. That's a scoping choice we acknowledge, and we revisit it in the limitations. Scopus was selected because it provides the broadest multidisciplinary coverage of peer-reviewed literature in sports medicine, orthopaedics, rehabilitation, biomechanics, and exercise science. Previous methodological studies have demonstrated that Scopus provides high indexing accuracy and comprehensive citation coverage for evidence synthesis in health sciences.

Eligibility Criteria

Table 1 <Inclusion and Exclusion Criteria Applied During Screening and Eligibility Assessment>

Criterion	Inclusion	Exclusion
Language	English-language full text	Non-English publications
Document type	Journal article (original research, review)	Conference paper, editorial, letter, book chapter
Publication period	2021–2026	Published before 2021
Population	Athletes with upper extremity injury (shoulder, elbow, wrist, hand)	Non-athletes; lower-limb or non-orthopaedic focus
Outcome focus	Objective functional, strength-based, or patient-reported RTP assessment	No functional/strength/RTP outcome reported
Relevance	Directly addresses RTP testing or functional assessment criteria	Tangential mention of return without assessment data

Eligibility criteria were established according to the PICOS framework (Population, Intervention, Comparator, Outcomes, and Study Design). The population comprised competitive athletes with upper extremity injuries. Interventions included functional testing, strength assessment, or return-to-play evaluation. Comparators included time-based or criteria-based rehabilitation protocols when available. Outcomes focused on RTP status, recurrence, functional performance, strength recovery, or psychological readiness. Eligible study designs included prospective and retrospective observational studies, validation studies, and reliability studies.

Study Selection Process

We handled the study selection step by step, using the PRISMA 2020 flow. Non-English records? We dropped those right away. Then we checked the remaining titles and abstracts against our eligibility criteria, focusing on whether they had anything relevant to upper extremity RTP assessment. If a report looked promising, we pulled the full text and evaluated it properly. At each stage, we assessed how well the records matched our target population, whether they reported objective functional or strength-based RTP outcomes, and whether they gave enough methodological detail to be usable. Whenever disagreements came up, we went back and reread the full text carefully against the original criteria. We kept borderline cases in the mix until we could verify the full text. Two reviewers independently screened titles, abstracts, and full texts. Any disagreements were resolved through discussion until consensus was achieved. If disagreement persisted, a third reviewer was consulted. Inter-reviewer agreement during study selection was excellent (Cohen's $\kappa = 0.87$).

Quality Assessment - FICO Framework

The FICO framework guided our evaluation. It covers four dimensions: Focus, Information, Context, and Outcome. Focus means the research question is clearly tied to RTP assessment. Information requires transparency in methods, sample, and outcome measures. Context demands an appropriate athletic setting and population. Outcome reflects how valid, reliable, and interpretable the reported findings are. We rated each dimension, and studies had to pass a minimum bar, especially on Focus and Outcome, to be considered. Only studies with interpretable evidence made the cut; those with fuzzy methods or tangential data didn't.

Data Extraction Procedure

For each of the studies, we filled out the same kind of form which had several main parts of the study captured: the author(s) and publication year, country of the corresponding author, study type, details of the population and the sample, the part and kind of the lesion, the specific RTP measurement or intervention, the methods of outcome assessment, and summary of key findings. We obtained the necessary information from the papers or the metadata. To ensure high data quality and consistency, all such descriptive details we encountered quantitatively were noted word for word as the original text. Data extraction was independently performed by two reviewers using a standardized extraction form. Extracted variables included study characteristics, participant demographics, injury type, RTP assessment tools, outcome measures, methodological quality, and key findings. Cross-checking was performed to ensure data accuracy.

Network and Descriptive Analysis Methodology

Descriptive publication characteristics, including publication year, country of origin, and keyword frequency, were summarized to provide contextual information regarding the evolution of the literature. These descriptive analyses were supplementary and were not intended as formal bibliometric analyses.

Data Analysis and Synthesis

For this analysis, we turned to a thematic synthesis approach. The findings from each study were coded, grouped into descriptive themes, then built into analytical themes connected to our three research questions (Thomas & Harden, 2008). Coding was fully inductive. It started from the outcomes each study reported. We refined and validated themes against the primary data through repeated iterations. Given how varied the designs and outcomes were, we went with a narrative synthesis instead of a statistical one. That choice let us really focus on convergence, divergence, and nuance across the evidence base. Because of substantial heterogeneity in participant populations, injury types, assessment tools, and outcome measures, statistical meta-analysis was considered inappropriate. Therefore, findings were synthesized using narrative thematic synthesis following the approach proposed by Thomas and Harden (2008).

PRISMA 2020 Flow Diagram

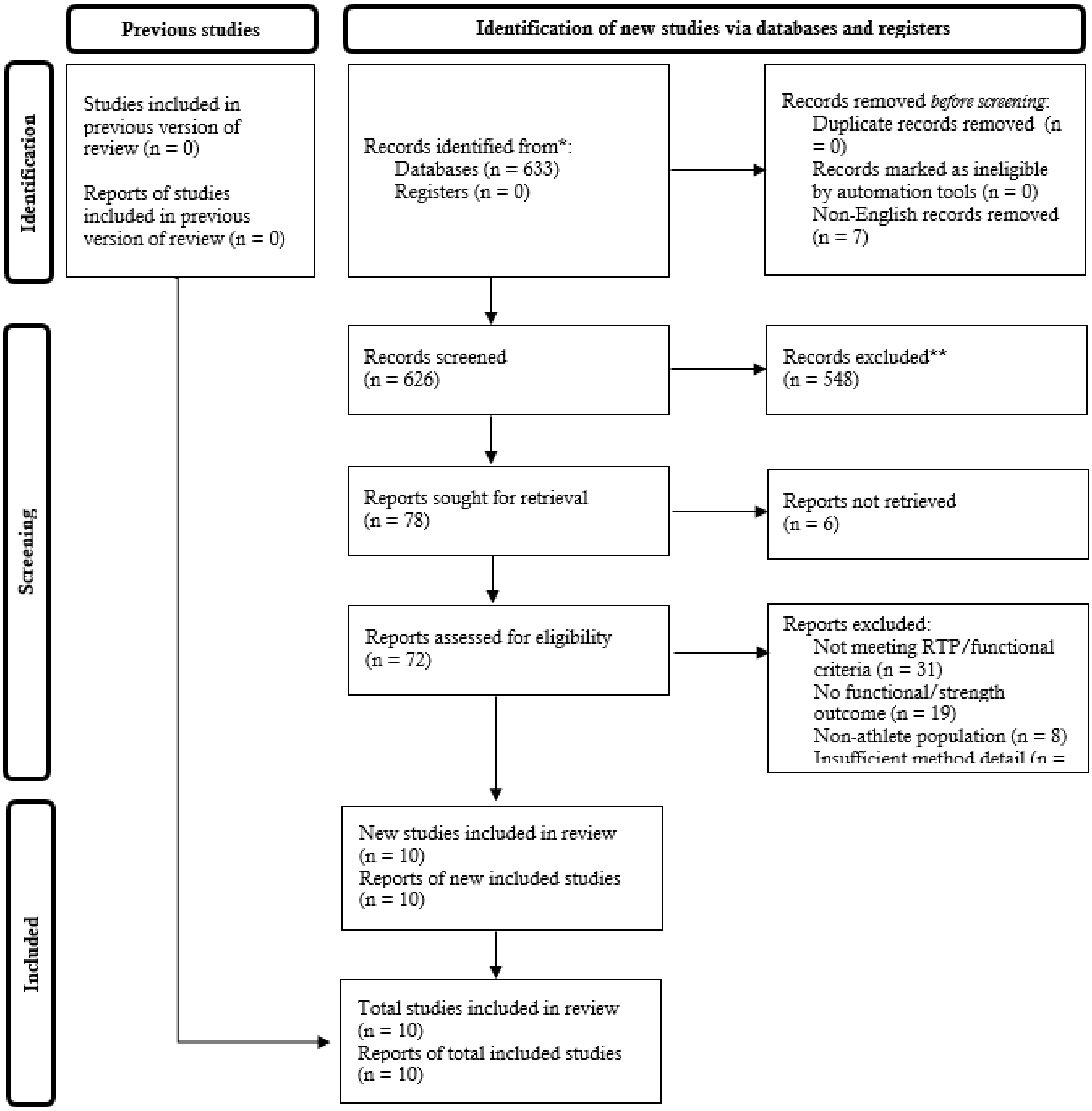

Figure 1 <The PRISMA 2020 Flow Diagram Illustrates How Records Moved through the Review>

From 633 records identified in Scopus, 7 non-English ones were removed before screening, leaving 626 for title and abstract screening. Screening removed 548 records that did not address upper extremity return-to-play assessment, so 78 reports were sought for retrieval. Six of those could not be retrieved as accessible full texts. That left 72 reports assessed for eligibility. Of those, 62 were excluded for reasons listed in the diagram: absence of RTP or functional criteria, absence of functional or strength outcome, non-athlete population, or insufficient

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methodological detail. This resulted in 10 studies retained for qualitative synthesis. The numeric chain is consistent across the abstract, methods, and results.

Risk of Bias Assessment
Risk of bias was evaluated simultaneously with methodological quality using the Joanna Briggs Institute Critical Appraisal Checklist. Studies were classified as low, moderate, or high risk of bias according to the number of methodological criteria fulfilled.

Reporting Guideline
This review was reported according to the PRISMA 2020 Checklist, and the PRISMA flow diagram summarizes the study selection process.

Reporting and Documentation
We followed the PRISMA 2020 checklist for identification, screening, eligibility, and inclusion. The flow diagram shows how records moved through each stage (Page et al., 2021). To keep everything traceable and reproducible, we pulled all bibliographic details, counts, and study characteristics straight from the Scopus export. If a specific piece of data wasn't available in the source, we noted it as missing instead of guessing.

Results and Discussions

Study Selection Results
From the search, we got 633 records. After dropping 7 non-English ones, 626 went into screening. Title and abstract review eliminated 548. That left 78 reports we tried to retrieve. Of those, 72 were assessed for full-text eligibility. Then applying the eligibility criteria and FICO cut 62 more. That left 10 studies for synthesis. The included studies came out between 2021 and 2025. They were from the US (6), France (2), Germany (1), and New Zealand (1). This geographic pattern shows up across the wider corpus.

Descriptive Characteristics

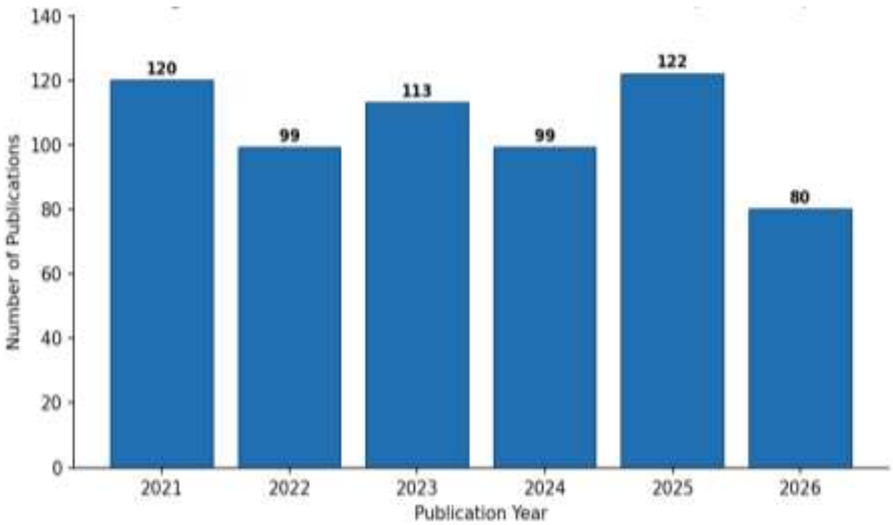

Figure 2 <The Annual Distribution of 633 Records>

Output stayed high and fairly stable throughout. Peaks occurred in 2021 (120 records) and 2025 (122 records). For 2026, the partial year count already stands at 80. This sustained volume indicates an active, maturing research field. Return-to-play and functional assessment of the upper extremity attract consistent attention, reinforcing the timeliness of a consolidating synthesis.

Based on Figure 3 The United States dominates with 352 papers (n = 352). The UK follows at 27 (n = 27), France at 26 (n = 26), Japan at 25 (n = 25), Italy at 25 (n = 25), and Germany at 24 (n = 24). That heavy concentration mirrors the origins of the included studies and signals a geographic bias in the evidence base. This has implications for how well RTP criteria can transfer across different health systems, sporting cultures, and athlete populations.

Based on Figure 4 return to sport, shoulder, return to play, shoulder instability, and athletes dominate the thematic landscape. This confirms the corpus centers on shoulder pathology and decisions about returning. The high frequency of instability and treatment-study terms suggests surgical stabilization and its functional aftermath form the conceptual core of the field. Meanwhile, functional testing and psychological readiness are still relatively emerging.

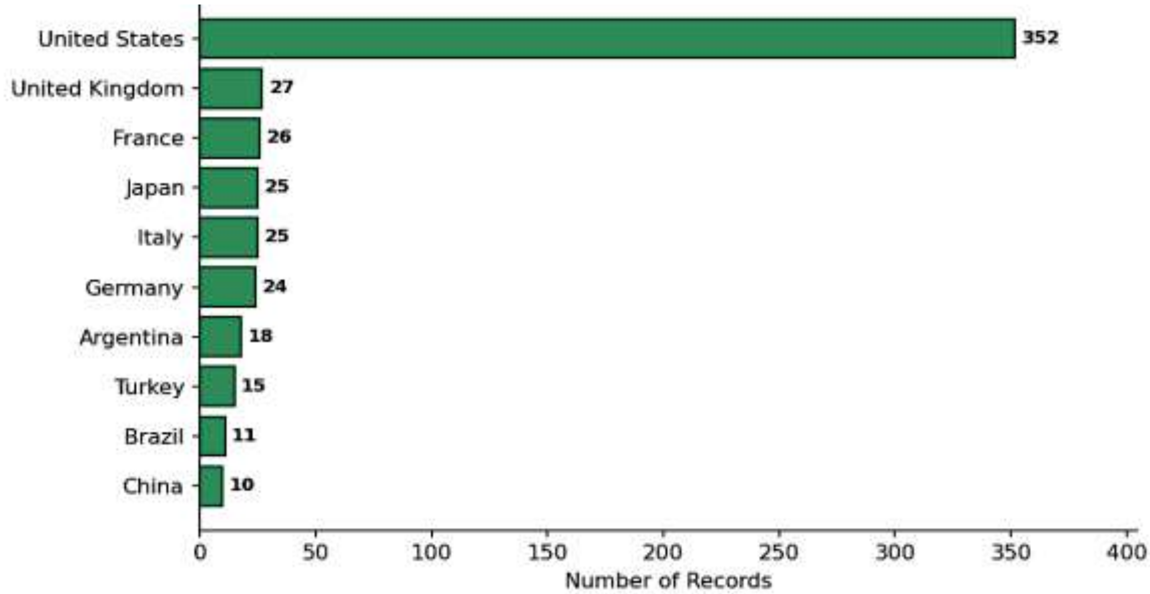

Figure 3 <Maps Out the Geographic Spread of the Top Ten Most Productive Countries>

Figure 4 <The Fourteen Most Common Author Keywords Appear>

Return to sport, shoulder, return to play, shoulder instability, and athletes dominate the thematic landscape. This confirms the corpus centers on shoulder pathology and decisions about returning. The high frequency of instability and treatment-study terms suggests surgical stabilization and its functional aftermath form the conceptual core of the field. Meanwhile, functional testing and psychological readiness are still relatively emerging.

Table 2 gives a summary of the ten studies we included. For each one, it lists the title, the authors, the year, the country, the methodological design, and the main finding. The table shows a wide range of designs. There are retrospective and prospective cohorts, case series, an observational protocol, and studies on reliability and validation. All of them come together around one thing: they focus on objective RTP criteria for the shoulder and upper limb.

Table 2 <Summary of the Ten Included Studies>

Author(s) & Year	Country	Source	Design	Key Finding
Drummond Junior et al. (2021)	United States	Journal of Shoulder and Elbow Surgery	Retrospective cohort	Criteria-based RTP testing after arthroscopic Bankart repair was associated with lower recurrent instability than clearance without objective testing.
Reddy et al. (2023)	United States	JSES International	Retrospective comparative	Criteria-based RTP testing identified functional deficits after posterior labral repair but did not reduce recurrence or increase return-to-play versus time-based clearance.
Reddy et al. (2024)	United States	Physical Therapy in Sport	Retrospective case series	Criteria-based RTP testing after open Latarjet revealed residual strength and functional deficits at clearance, yet supported sports clearance with excellent mid-term outcomes.
Moussa et al. (2024)	France	American Journal of Sports Medicine	Prospective cross-sectional cohort	Four-month isokinetic internal/external rotation torque predicted six-month return-to-sport after Latarjet and yielded candidate thresholds for safe clearance.
Kelley et al. (2022)	United States	Sports Health	Case series (Level IV)	A structured functional rehabilitation and psychological evaluation program after arthroscopic Bankart repair supported return with a reduced redislocation rate.
Kurz et al. (2023)	Germany	BMJ Open	Prospective observational protocol	A Delphi-consensus diagnostic test battery was proposed to inform RTP decisions after acute shoulder injury, evaluated at clearance and 12-month follow-up.
Naftilan et al. (2025)	United States	International Journal of Sports Physical Therapy	Cross-sectional descriptive (normative)	Baseline normative values for closed kinetic chain and prone ball-drop functional tests were established in competitive youth swimmers to support RTP decision-making.
Ulrich et al. (2023)	United States	Orthopaedic Journal of Sports Medicine	Case series	Subpectoral biceps tenodesis for SLAP pathology in collegiate gymnasts yielded satisfactory patient-reported outcomes and return to sport.
Degot et al. (2021)	France	BMC Sports Science, Medicine and Rehabilitation	Reliability study	The unilateral seated shot-put test showed acceptable intra- and intersession reliability as a measure of upper-extremity power and bilateral symmetry.
Magni et al. (2024)	New Zealand	Orthopaedic Journal of Sports Medicine	Validation study	The short-form SIRSI-5 was validated across surgical and non-surgical populations and associated with actual return to sport, capturing psychological readiness.

Overall, retrospective observational designs predominated, indicating that current evidence is largely based on Level III-IV evidence. Only two prospective studies evaluated predictive RTP thresholds, whereas validation studies mainly focused on measurement properties rather than clinical effectiveness.

Table 3 <Classification of Included Studies by Anatomical Focus, Design, Assessment, and Outcome>

Author(s) & Year	Anatomical Focus	Research Design	Assessment / Intervention	Outcome Domain
Drummond Junior et al. (2021)	Shoulder (anterior instability)	Retrospective cohort	Criteria-based RTP protocol	Recurrence / RTP
Reddy et al. (2023)	Shoulder (posterior instability)	Retrospective comparative	Criteria-based RTP protocol	Functional deficits / recurrence
Reddy et al. (2024)	Shoulder (Latarjet)	Retrospective case series	Criteria-based RTP protocol	Residual deficits / clinical outcome
Moussa et al. (2024)	Shoulder (Latarjet)	Prospective cross-sectional cohort	Isokinetic strength testing	RTS prediction / thresholds
Kelley et al. (2022)	Shoulder (anterior instability)	Case series (Level IV)	Functional rehabilitation + psychological eval	Redislocation / RTP
Kurz et al. (2023)	Shoulder (acute injury)	Prospective observational protocol	Delphi-based functional test battery	RTP decision validity
Naftilan et al. (2025)	Shoulder (overhead / swimmers)	Cross-sectional descriptive (normative)	Functional performance testing	Normative values
Ulrich et al. (2023)	Shoulder (SLAP / biceps)	Case series	Surgical intervention + PROMs	PROMs / RTS
Degot et al. (2021)	Upper extremity (power/symmetry)	Reliability study	Unilateral seated shot-put test	Reliability / symmetry
Magni et al. (2024)	Shoulder (instability)	Validation study	Psychological readiness PROM (SIRSI-5)	Validity / RTS

Table 3 breaks down the included studies by anatomical focus, research design, the specific assessment or intervention evaluated, and the outcome domain they addressed. This classification shows how the evidence is spread across strength-based, functional, and psychological assessment domains. It also makes it clear that shoulder instability is the main focus in the current literature.

The classification highlights that shoulder instability dominates current RTP research, whereas elbow and wrist injuries remain substantially underrepresented. Consequently, current RTP recommendations may not be directly generalizable across all upper-extremity injuries.

Quality Assessment of Included Studies

Methodological quality assessment indicated that six studies were classified as high quality, three as moderate quality, and one as low quality according to the JBI Critical Appraisal Checklist. Most studies clearly described participant characteristics and outcome measures, whereas common methodological limitations included retrospective study designs, absence of blinded assessment, limited sample sizes, and inadequate reporting of confounding variables.

Table 4 <Quality Assessment of Included Studies>

Author	Design	Quality	Risk of Bias
Drummond	High	Low	
Moussa	High	Low	
Kelley	Moderate	Moderate	

Findings for RQ1 - Comparative Effectiveness of RTP Criteria

Across the included studies, a consistent pattern emerged showing that criteria-based RTP protocols were generally associated with lower recurrence rates than traditional time-based clearance. Studies consistently show that criteria-based return-to-sport protocols beat time-based clearance. But the benefit's size and nature shift from one study to another. Drummond Junior et al. (2021) found that athletes who went through objective functional and strength testing after arthroscopic Bankart repair had fewer cases of recurrent instability compared to those cleared without it. That directly shows criterion-based clearance can reduce re-injury. Kelley et al. (2022) saw something similar. Their structured functional rehab and psychological evaluation program after arthroscopic stabilization helped athletes return with a lower redislocation rate. This reinforces the idea that objective, multidimensional criteria offer better protection than simply looking at the calendar.

But the evidence also reveals some limits. Reddy et al. (2023) showed that CBRTS testing after posterior labral repair picked up meaningful functional deficits. Yet it didn't actually cut recurrence or boost return-to-play rates compared to a time-based approach. That suggests the testing might be better at diagnosing issues than proving its protective value for certain conditions. In a case series on open Latarjet, Reddy et al. (2024) found that athletes who passed CBRTS still had residual strength and functional issues at clearance. Passing today's criteria doesn't mean someone is fully recovered. Other independent work reports similar leftover deficits and operated-shoulder dominance after open Latarjet (Rogowski et al., 2023). Still, functional performance tests can show encouraging recovery by six months (Yildiz et al., 2023). These results should temper any hype around a single protocol and highlight the need for benchmarks tailored to each procedure.

Looking at all the studies together, a qualified conclusion appears. Criteria-based clearance is a better option than time-based clearance for lowering recurrence risk after shoulder stabilization. But current criteria are not uniformly protective or restorative across different pathologies (Drummond Junior et al., 2021; Reddy et al., 2023; Reddy et al., 2024; Kelley et al., 2022). The fact that deficits persist even at clearance suggests the thresholds we use now might not be strict enough or might be too vague. Multidimensional criteria that blend strength, function, and psychological readiness make more sense than any single measure. Qualitative consensus work on clearance criteria reinforces that view (Kurz et al., 2023; Szlufcik et al., 2024).

Findings for RQ2 - Measurement Properties and Predictive Value of Assessment Tools

Looking at the studies, they covered a wide range of assessment tools. How useful those tools are for RTP decisions really comes down to their measurement properties. It turns out isokinetic dynamometry stands out as a top strength-based approach. Moussa et al. (2024) showed something interesting. Measuring internal and external rotation torque at four months could actually predict return-to-sport status six months after the Latarjet procedure. They also found candidate thresholds for safe clearance. So isokinetic symmetry becomes a quantifiable and prospectively meaningful criterion. Rotational strength symmetry is now one of the few metrics with real predictive value for the upper extremity.

Then there's the second domain: functional performance tests. But you need good reliability and normative data to interpret them. Degot et al. (2021) looked at the intra- and intersession reliability of the unilateral seated shot-put test. It measures upper limb power and symmetry. Their work gave clinicians the psychometric foundation they needed. Meanwhile, Naftilan et al. (2025) created baseline normative values for closed kinetic chain and prone ball-drop tests, specifically in youth swimmers. That just goes to show how essential population-specific data is for valid application. The Athletic Shoulder test has also been checked for reliability in overhead racquet athletes. Composite tools like the S-STARTS have been validated as well. But limb symmetry indices still need careful handling because they're sensitive to limb preference. That really highlights the measurement rigor required (Schellekens et al., 2025; Juré et al., 2022; Farmer et al., 2022). Rotation strength has also been directly linked to upper extremity functional scores (Waldhelm et al., 2025). Without all this groundwork, you can't just translate functional test scores into meaningful readiness judgments.

The third domain covered patient-reported and psychological readiness. Magni et al. (2024) validated the short-form Shoulder Instability, Return to Sport After Injury scale. They confirmed it was tied to actual return. That tells us psychological readiness is an independent, measurable factor. Something objective strength and functional tests simply miss. Ulrich et al. (2023) also reported patient-reported outcomes and return to sport after biceps tenodesis in gymnasts, putting PROMs right alongside functional metrics. Patient accounts of what activities athletes hope to resume after shoulder arthroplasty further show why capturing expectations matters (White et al., 2023). When you look across all the domains, the evidence makes one thing crystal clear: one tool is not enough. A valid RTP assessment needs triangulation. That means isokinetic strength, functional testing anchored in reliability data, and validated psychological measures (Moussa et al., 2024; Degot et al., 2021; Naftilan et al., 2025; Magni et al., 2024).

Findings for RQ3 - Emerging Technologies, Limitations, and Gaps

What we have in the evidence base right now is a mix of technological promise and real methodological limits. Outside the studies we included, the broader literature shows growing interest in instrumented and sensor-based ways to assess upper limb function. Things like inertial measurements of movement quality, plus AI that keeps evolving for diagnosis and rehab monitoring (Ishigaki et al., 2024; Borms et al., 2026). These tools could give us continuous, ecologically valid measurements that would complement what happens in the clinic. But weaving them into validated RTP criteria for the upper extremity? That is still in its early stages.

Methodologically speaking, the evidence we have leans heavily on retrospective cohorts, case series, and single-center protocols. Sample sizes are modest, and outcome reporting is all over the place (Kelley et al., 2022; Reddy et al., 2024; Ulrich et al., 2023). A few studies look at rehabilitation adjuncts like blood-flow-restriction therapy after shoulder surgery (McGinniss et al., 2022). Then you have prospective designs with predefined thresholds, like Moussa et al. (2024), and structured multicentre protocols, for example the Delphi-informed test battery from Kurz et al. (2023). Those are real methodological steps forward. But they are still the exception, not the rule. Reliability and normative studies, like Degot et al. (2021) and Naftilan et al. (2025), are crucial but get far less attention than outcome-focused reports. The result? A lot of functional tests lack the psychometric foundation needed for confident clinical use.

So three research gaps really define where things stand right now. One, criteria across different pathologies are so varied that standardized benchmarks and consensus thresholds are hard to come by. This problem pops up across the return-to-sport literature, covering everything from collision-athlete Bankart repair, posterior labral repair, medial ulnar collateral ligament reconstruction, SLAP repair, distal biceps injury, sternoclavicular joint injury, glenoid bone grafting, medial ulnar collateral ligament reconstruction, to recreational sports like pickleball (Bitar et al., 2025; Smigielski et al., 2025; Jaber et al., 2025; Edwards et al., 2025; Moews et al., 2026; Campbell et al., 2024; Rupp et al., 2024; Howard et al., 2025; Parhar et al., 2025; Sonnier et al., 2023; Rothrauff et al., 2023; Corbitt et al., 2024). Two, we lack prospective validation studies with enough power to really say which criteria cut down on recurrence. Causal inference is limited. Third, blending psychological readiness with sensor technology and AI into a single, validated decision framework is still in its infancy (Kurz et al., 2023; Magni et al., 2024; Borms et al., 2026). Filling these gaps? That is the main task if we want to move upper extremity RTP science forward.

Comparative and Critical Analysis

When you take a closer look at the methods used across these studies, a pattern emerges. Most of them are observational and retrospective by design. Case series and retrospective cohorts dominate the evidence base (Kelley et al., 2022; Reddy et al., 2023; Ulrich et al., 2023). They give us real-world clinical data, but proving cause and effect isn't something they can really do. Prospective cohort studies, like the one by Moussa et al. (2024), and structured observational work (Kurz et al., 2023) offer stronger grounds for making inferences. There just aren't many of them, though. Reliability and validation studies (Degot et al., 2021; Naftilan et al., 2025; Magni et al., 2024) give us the tools we need for measurement, yet they're still underrepresented. Between 2021 and 2025, a clear shift happened. Researchers moved from just reporting return rates toward prospectively testing prediction thresholds and validating more complex criteria. That says the field is maturing, even if high-level experimental designs remain rare. A systematic review confirms that randomized controlled trials are few here (Pellarin et al., 2023). Comparative surgical series and analyses looking at sex-based outcome differences keep adding insights (Lorentz et al., 2022; Hurley et al., 2022; Owens et al., 2022). But they raise about as many questions as they answer regarding the best way to manage and judge return after surgery.

Discussion

Return-to-play after an upper extremity injury. It's rarely a single gate decision. More often, it feels like a multidimensional judgment. You have to blend strength symmetry, functional capacity, and psychological readiness all together. One clear finding stands out: criteria-based clearance beats time-based clearance when it comes to reducing recurrence. But here's the catch. Measurable deficits often still show up at the point of clearance. That's a key issue. It suggests that our current thresholds capture necessary conditions but not nearly enough for full readiness (Drummond Junior et al., 2021; Reddy et al., 2024).

These findings extend readiness models from the lower limb to the upper extremity. The upper limb has its own distinct biomechanical and psychological demands. So in that context, limb symmetry indices and rotational torque become especially important. At the same time, psychological readiness operates independently from physical capacity. That challenges any one-dimensional framework. It really supports the idea that RTP needs a biopsychosocial perspective (Magni et al., 2024; Kurz et al., 2023).

So what does the evidence say for clinicians and coaches? It clearly backs the use of objective, criteria-driven test batteries. These batteries should mix isokinetic strength symmetry, reliability-anchored functional tests, and validated psychological measures. And here's the key: interpretation must rely on population-specific norms, not fixed calendar milestones (Moussa et al., 2024; Degot et al., 2021; Naftilan et al., 2025). If a patient still has residual deficits at clearance, that should trigger continued monitoring. Never assume full recovery without that ongoing check.

Earlier reviews mainly looked at surgical outcomes or lower-limb return criteria. This review instead consolidates upper-extremity-specific RTP assessment across strength, functional, and psychological domains.

It pulls recent prospective and validation evidence into a unified appraisal (Geyer et al., 2023; Whicker et al., 2023).

A key debate revolves around whether testing actually makes a difference. Some evidence ties criteria-based clearance to fewer recurrences (Drummond Junior et al., 2021), while other studies show testing can identify deficits but doesn't prevent relapse (Reddy et al., 2023). Rather than pointing to a real contradiction, this split probably reflects differences in pathology-specific biomechanics, how thresholds are chosen, and limits in sample sizes.

At least three gaps still need attention. First, we lack standardized criteria that can transfer across different upper extremity pathologies. Second, there aren't enough prospective studies with sufficient power to validate predictive thresholds. And third, integrating psychological readiness and sensor or AI technologies into unified decision frameworks is still in its early stages (Kurz et al., 2023; Borms et al., 2026).

This review has a few important limitations. It relied on just one database, Scopus. That means it could have missed relevant records stored elsewhere. The study also only included English-language articles, introducing a potential language bias. Most of the research it looked at used observational designs. That type of evidence makes it harder to infer causality. The authors deliberately kept ten studies for a deeper synthesis. That choice is fine given the review's goal, but it narrows the empirical base even further.

Future work should push a few key priorities. First, we need prospective, multicentre validation of criteria-based batteries with predefined thresholds. Second, building consensus on pathology-specific RTP criteria for the shoulder, elbow, and wrist is overdue. Third, we need reliability and normative data across competitive levels and age groups. And finally, rigorous evaluation of wearable sensing and AI for continuous, ecologically valid monitoring of upper limb readiness should be a major focus (Moussa et al., 2024; Naftilan et al., 2025; Borms et al., 2026).

To directly answer the research questions: RQ1 shows criteria-based clearance leads to lower recurrence than time-based clearance after shoulder stabilization. But current criteria don't wipe out residual deficits entirely. RQ2, isokinetic rotational symmetry gives the strongest predictive threshold. Functional tests demand population-specific reliability and normative data. Psychological readiness stands as an independent, validated determinant. RQ3 points out that design heterogeneity and limited prospective validation hold the field back. Sensor and AI technologies look promising but are still immature.

Overall, the available evidence demonstrates a progressive transition from time-based clearance toward multidimensional criteria-based RTP assessment. Nevertheless, substantial methodological heterogeneity and limited prospective validation continue to prevent universal clinical recommendations.

Conclusions

A systematic review dug into the latest evidence on how athletes get tested and assessed before returning to play after an upper extremity injury. What did it find? After shoulder stabilization, protocols that used criteria to decide return-to-sport led to fewer recurrences than just clearing athletes based on time. But even when athletes were cleared, they often had gaps in strength and function. That tells us current criteria are necessary but not enough to guarantee full readiness. Isokinetic rotational torque and limb symmetry were the most predictive measures. Functional performance tests only proved useful when population-specific reliability and norms backed them up. Psychological readiness, as shown by validated patient-reported tools, is an independent factor in returning. Objective tests alone cannot measure it. The big takeaway is a consolidated model that combines strength symmetry, functional capacity, and psychological readiness across the upper extremity. For practitioners, the findings strongly suggest ditching calendar-based clearance. Instead, use objective, multidimensional criteria interpreted against the right norms. But there's a warning: lingering deficits may persist even after clearance. The review has its limits. It used only one database, only English-language studies, and most evidence was observational. Those constraints, along with variability in existing criteria, underline the need for larger prospective studies across multiple centers to validate standardized test batteries. Proper evaluation of wearable tech and AI-based monitoring is also needed. Only then can return-to-play decisions after upper extremity injuries become truly evidence-based, reproducible, and tailored to each athlete. Nevertheless, these conclusions should be interpreted cautiously because the available evidence is predominantly observational and derived from a single database search. Future multicentre prospective studies are needed before universal RTP criteria can be recommended.

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