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DIGITAL MONITORING OF RETURN-TO-PERFORMANCE AFTER ACHILLES TENDON RUPTURE IN BASKETBALL: A NARRATIVE REVIEW

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ABSTRACT

Achilles tendon rupture (ATR) is among the most consequential injuries in basketball because it interrupts participation, alters explosive lower-limb function, and often prevents full recovery of preinjury competitive output. Recent studies in the National Basketball Association, Women's National Basketball Association, and National Collegiate Athletic Association show that many athletes do return to competition after ATR, yet substantial losses in playing time, efficiency, durability, and career longevity remain common. At the same time, contemporary Achilles rehabilitation literature shows considerable variation in how readiness for return is judged, with many pathways still relying more on elapsed time than on multidimensional recovery data. This narrative review synthesizes recent PubMed-indexed evidence on basketball-specific ATR outcomes, ATR rehabilitation, and digital monitoring technologies relevant to return-to-performance. The review focuses on wearable sensors, portable strength devices, force-plate testing, ultrasound and magnetic resonance imaging, electronic patient-reported outcomes, markerless video, and artificial intelligence-assisted analytics. A staged basketball-specific framework is proposed in which digital tools are aligned with early protection, progressive loading, court reintroduction, and return-to-performance phases. The synthesis suggests that digital monitoring is most useful when it quantifies tendon status, plantar-flexor recovery, gait and jump asymmetry, external workload, repeated court exposure, and psychological readiness over time. Current evidence does not support fully automated clearance decisions, but it does support replacing calendar-based progression with a criteria-based, sport-specific, and digitally informed rehabilitation model.

KEYWORDS

Achilles Tendon Rupture, Basketball, Return-to-Performance, Wearable Sensors, Digital Health, Sports Rehabilitation

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1. Introduction

Achilles tendon rupture (ATR) has become a defining injury in high-demand court sports because it combines structural disruption with a long period of physical deconditioning and a substantial threat to future performance. Basketball is especially affected because the sport concentrates the very actions that challenge the Achilles tendon most intensely: forceful propulsion, abrupt deceleration, repeated jumps, single-leg landing, and rapid transitions between eccentric braking and concentric push-off. For players whose competitive value depends on repeated explosive actions, the outcome of ATR cannot be judged only by whether they return to a game roster. The more meaningful question is whether they regain sufficient tendon capacity, neuromuscular function, and movement quality to reproduce their prior level of on-court performance.

This distinction between return to play and return to performance is now well supported by the basketball literature. The most comprehensive basketball-focused review published to date concluded that Achilles rupture is consistently associated with meaningful performance decline after return, even when athletes resume competition (Alegre et al., 2021). Broader sport reviews of professional athletes similarly show that career outlook after ATR is uneven and that elite basketball is among the sports in which performance recovery is especially challenging (Johns et al., 2021; LaPrade et al., 2022). In the NBA, postinjury studies report that return is possible for a majority of players but is often followed by reductions in value metrics, efficiency, or long-term roster survival (Chauhan et al., 2021; Meadows et al., 2024). Similar concerns have been reported in the WNBA and NCAA Division I basketball, where return does not reliably translate into sustained preinjury production (Hodgens et al., 2021; Sanchez et al., 2021; Momtaz et al., 2024).

Recent basketball studies also show that ATR recovery is heterogeneous. Sex and league context appear to matter, because comparisons between NBA and WNBA cohorts suggest different timelines and performance trajectories after rupture (Momtaz et al., 2024). Laterality may matter as well, as dominant- versus non-dominant-side rupture has been associated with different postreturn patterns in elite basketball players

(Weinberg et al., 2024). Mechanism studies add further nuance: video analyses in professional basketball indicate that many ruptures occur during noncontact, closed-chain offensive actions, including acceleration and take-off tasks that closely resemble the most demanding movements in match play (Petway et al., 2022; Yüce et al., 2024). These findings imply that rehabilitation and monitoring should target sport-specific movement exposures rather than rely only on generic clinical milestones.

The need for better monitoring is reinforced by the broader ATR rehabilitation literature. Although rehabilitation philosophy has shifted toward earlier functional recovery and progressive loading, there is still no universally accepted return-to-sport decision model after Achilles rupture (Liu et al., 2021; Massen et al., 2022; Marrone et al., 2024). A recent scoping review found that many published pathways continue to rely heavily on time after surgery, basic range-of-motion findings, calf circumference, or heel-rise testing, with little agreement on what actually constitutes readiness for sport-specific return (Busà et al., 2026). Such measures remain clinically useful, but they do not fully capture tendon morphology, plantar-flexor force production, jump-landing asymmetry, cumulative workload, or the athlete's psychological willingness to tolerate high-speed competition.

Digital monitoring has attracted growing interest because it can convert these less visible dimensions of recovery into longitudinal, interpretable signals. Wearable devices can quantify mobility, acceleration profiles, and exposure to progressive loading. Portable force systems and force plates can detect deficits in plantar-flexor output, jump impulse, and landing symmetry. Ultrasound and magnetic resonance imaging can contribute information on tendon continuity, elongation, and remodeling. Electronic patient-reported outcome measures can track symptoms, confidence, and fear of reinjury, while recent artificial intelligence (AI) and markerless-video approaches offer new possibilities for combining disparate signals into a more coherent picture of readiness (Seshadri et al., 2023; Rebelo et al., 2023; Olsen et al., 2025; Souaifi et al., 2025; Yuan et al., 2026).

The relevance of this topic extends beyond orthopaedic sports medicine. Basketball ATR provides a useful model for digital health in applied rehabilitation because the gap between tissue recovery and performance recovery is unusually visible. A player can satisfy basic medical expectations—wound healing, acceptable range of motion, or generalized functional testing—yet still fail to reproduce the repeated high-power movements required in games. Digital monitoring is attractive in this setting because it creates a shared language across clinicians, performance staff, and the athlete. Instead of loosely describing the athlete as “looking better,” the rehabilitation team can observe whether jump symmetry is stabilizing, whether running exposure is increasing without symptom flare, whether tendon morphology is acceptable, and whether the athlete is psychologically prepared to tolerate the sport's most demanding actions.

This review therefore treats digital monitoring not as an isolated technology question, but as a systems question. The issue is how data from different sources can be organized so that the return-to-performance decision becomes more transparent, more individualized, and less dependent on habit. The basketball ATR problem illustrates how emerging technologies can be integrated into a complex real-world decision process rather than being evaluated only as stand-alone gadgets.

Against this background, the purpose of the present review is threefold. First, it synthesizes the recent literature describing the performance burden of ATR in basketball. Second, it integrates that literature with contemporary evidence on ATR rehabilitation and digital monitoring. Third, it proposes a basketball-specific, criteria-based framework for using digital tools to support return-to-performance decisions. The review is intended for clinicians, sports scientists, athletic trainers, strength-and-conditioning professionals, and journal readers interested in how digital health approaches can be applied to athlete care.

2. Methodology

PubMed and the Cochrane Library were searched through March 2026 using combinations of the terms Achilles tendon rupture, basketball, return to play, return to performance, rehabilitation, wearable, sensor, force plate, ultrasound, MRI, machine learning, and artificial intelligence. The search strategy deliberately combined sport-specific and technology-related terms because direct studies on digital monitoring after ATR in basketball remain limited.

Articles were considered eligible when they contributed to at least one of three evidence streams: (a) basketball-specific studies examining outcomes after Achilles tendon rupture; (b) recent studies or reviews focused on Achilles rupture rehabilitation, healing assessment, or return-to-sport decision making; and (c) recent sports medicine, orthopaedic, or biomechanics studies addressing digital monitoring technologies that could plausibly inform ATR recovery. Priority was given to publications from 2021 onward in order to satisfy

the request for contemporary evidence and to reflect the rapid evolution of digital monitoring tools. Older sources were avoided unless they were necessary to explain context, and none were retained in the final reference list.

Because the purpose of the review was synthesis rather than pooled effect estimation, formal meta-analytic procedures were not undertaken. Instead, the selected literature was organized around clinically relevant domains: basketball-specific burden after ATR, the current state of rehabilitation and clearance criteria, digital tools capable of quantifying recovery, and the practical assembly of these tools into a staged return-to-performance framework. This approach was chosen because the available literature is methodologically heterogeneous and includes retrospective league studies, systematic reviews, prospective cohort studies, validation papers, and technology-focused scoping reviews. A narrative design therefore offered the most useful way to translate the evidence into an applied basketball rehabilitation model.

3. Results

3.1. Basketball-specific burden after Achilles tendon rupture

The recent basketball literature provides a consistent message: ATR is not only a medical event but also a performance event. The 2021 basketball systematic review by Alegre et al. brought together early evidence showing that rupture often leads to significant reductions in postinjury productivity, and subsequent studies have generally reinforced rather than softened that conclusion (Alegre et al., 2021). A parallel systematic review of professional athletes by Johns et al. and a scoping review of elite male athletes by LaPrade et al. both showed that Achilles rupture can materially alter career trajectory and postreturn output in sports dependent on explosive lower-limb performance (Johns et al., 2021; LaPrade et al., 2022).

In the NBA, Chauhan et al. reported that most players in their cohort did return to competition, but return was slow and incomplete when judged against performance rather than simple participation. In that study, mean time to return was approximately 10 months, and declines remained visible in advanced offensive performance indicators after return (Chauhan et al., 2021). Meadows et al. extended this picture by emphasizing the economic and roster-level consequences of ATR in the NBA. Their analysis suggested that the financial burden of recovery is substantial and that many players who do return still face reduced longevity in the league, indicating that successful medical rehabilitation does not necessarily restore prior competitive value (Meadows et al., 2024).

Women's basketball and collegiate basketball show similar concerns, although the trajectory may differ by level and population. Hodgens et al. reported that WNBA players experienced important postrepair performance consequences, while Sanchez et al. documented measurable changes in NCAA Division I basketball outcomes after return from Achilles repair (Hodgens et al., 2021; Sanchez et al., 2021). More recently, Momtaz et al. compared NBA and WNBA players and found meaningful differences in both time to return and postinjury career patterns, suggesting that sex, league context, style of play, and perhaps exposure history may shape recovery expectations (Momtaz et al., 2024). Weinberg et al. added another layer by showing that performance patterns differed depending on whether the ruptured tendon was on the dominant or non-dominant side, which is highly relevant when evaluating unilateral power tasks in basketball (Weinberg et al., 2024).

Mechanism studies strengthen the case for basketball-specific monitoring. Petway et al. analyzed rupture mechanisms in NBA players and found that many injuries occurred during offensive, noncontact situations characterized by forceful push-off or transition-type movements rather than by overt collisions (Petway et al., 2022). Yüce et al. reported comparable findings across professional athletes, showing recognizable movement configurations around the moment of rupture (Yüce et al., 2024). When these mechanism data are considered alongside epidemiologic reviews showing the ongoing burden of tendon rupture in sport, as well as broader analyses of injury patterns in the NBA and WNBA, it becomes clear that post-ATR monitoring in basketball must ultimately target the same high-load, repeated actions that define the sport itself (Lian et al., 2022; Lyons et al., 2024; Xergia et al., 2023).

Taken together, these studies show that the most useful outcome after ATR in basketball is not a binary cleared/not-cleared endpoint. What matters is whether the athlete can rebuild court-specific power, tolerate repeated game demands, and retain enough durability to convert physical recovery into meaningful minutes and production. Any monitoring system intended for basketball must therefore move beyond calendar-based clearance and instead ask whether the athlete is regaining the specific qualities that underpin basketball performance.

Table 1. Selected recent basketball-specific Achilles tendon rupture studies and implications for digital monitoring

Study	Cohort	Headline finding	Monitoring implication
Alegre et al. (2021)	Systematic review of basketball studies	The early basketball literature already suggested that ATR is followed by reduced postinjury performance rather than uncomplicated restoration of prior level.	Supports using return-to-performance, not simple return-to-play, as the main endpoint.
Chauhan et al. (2021)	NBA cohort	Return was usually possible but delayed; advanced performance indicators declined after return.	Late-stage monitoring should include performance-oriented rather than purely medical metrics.
Hodgens et al. (2021)	WNBA cohort	Postrepair performance consequences remained evident after return.	Sex- and league-specific baselines should be considered.
Sanchez et al. (2021)	NCAA Division I basketball	Postreturn output changed after Achilles repair in collegiate athletes.	Younger athletes also require structured performance monitoring.
Petway et al. (2022)	NBA video/mechanism study	Many ruptures occurred during noncontact offensive actions involving aggressive push-off or transition.	Monitoring should target propulsion, braking, and take-off tasks.
Meadows et al. (2024)	NBA economic/performance analysis	ATR carried major roster and economic costs, and many returners still had shortened league survival.	Durable availability and workload tolerance are part of successful recovery.
Momtaz et al. (2024)	NBA vs. WNBA comparison	Time to return and performance trajectories differed between leagues.	One-size-fits-all thresholds are unlikely to be appropriate.
Weinberg et al. (2024)	NBA/WNBA laterality analysis	Dominant- versus non-dominant-side rupture was associated with different postreturn patterns.	Unilateral testing should be interpreted in the context of side dominance.
Yüce et al. (2024)	Professional athletes, video analysis	Rupture followed recognizable body-position patterns during sport tasks.	Markerless video may help assess movement-specific risk and readiness.

3.2. Contemporary ATR rehabilitation and the case for objective monitoring

The rehabilitation literature has shifted noticeably toward earlier mobilization, earlier loading, and more functional progression, yet it also reveals how incomplete current clearance models remain. Meta-analytic work by Liu et al. showed that early functional rehabilitation after acute rupture can offer advantages over prolonged traditional immobilization, particularly when the goal is restoration of function rather than simple protection of the repair (Liu et al., 2021). Massen et al. similarly concluded that rehabilitation after operative treatment should be progressive and function oriented, although the authors also highlighted heterogeneity across postoperative protocols (Massen et al., 2022). Reviews focused on conservative or nonoperative care reached comparable conclusions: earlier weightbearing or accelerated rehabilitation can be appropriate in selected patients, provided progression is carefully controlled (Ghaddaf et al., 2022; Coopmans et al., 2022).

At the same time, the literature cautions against simplistic enthusiasm for every early-loading strategy. Wang et al. reported in a systematic review and meta-analysis that immediate mobilization after repair may increase rerupture risk in some settings, illustrating that timing and loading dose still matter (Wang et al., 2024). Fan et al. found that surgery reduces rerupture risk but carries its own complication profile relative to nonoperative care, while Bak et al. showed that return-to-play and functional outcomes remain influenced by

both treatment choice and rehabilitation design (Fan et al., 2024; Bak et al., 2024). These studies do not undermine functional rehabilitation; rather, they show why recovery should be measured repeatedly instead of inferred from elapsed weeks alone.

Recent clinically oriented rehabilitation reviews echo this point. Marrone et al. emphasized staged restoration of tendon capacity, calf strength, plyometric function, and sport-specific loading as the basis for return to sport after Achilles repair (Marrone et al., 2024). Mitrogiannis et al. described an early functional unsupervised protocol that still yielded safe functional return in a selected cohort, suggesting that technology-assisted monitoring could eventually support less clinic-dependent progression where appropriate (Mitrogiannis et al., 2024). Yet Busà et al. demonstrated that the literature still lacks a unified return-to-sport framework and that many published studies continue to treat time from surgery as a *de facto* criterion, even though it says little about the athlete's actual readiness for basketball-specific demands (Busà et al., 2026).

Importantly, none of the recent rehabilitation studies support the idea that a single clinical test can stand in for the full recovery process. Heel-rise performance remains informative but cannot capture movement strategy under basketball-specific loading. Range of motion can normalize while explosive function still lags. Similarly, a patient may report acceptable symptoms yet continue to demonstrate substantial plantar-flexor weakness or avoidance of rapid push-off. The value of digital monitoring lies in making these hidden dissociations visible. When recovery is tracked across several domains simultaneously, clinicians are better positioned to distinguish between apparent progress and genuinely transferable sport readiness.

A related lesson from the rehabilitation literature is that recovery is not strictly linear. Fluctuation is expected as loading progresses, particularly when athletes move from controlled gym-based tasks to higher-velocity court demands. For this reason, serial measurement is more informative than isolated testing. A single excellent force-plate session may not indicate robust recovery if performance deteriorates sharply with repeated exposures or after heavier practice days. Likewise, a stable ATRS score may conceal worsening fear during sport-specific tasks. The literature therefore supports monitoring trajectories and response patterns over time rather than interpreting one-off test results in isolation.

Another important development is the emergence of more precise tissue and patient-level predictors. Saarensilta et al. showed that early tendon morphology after surgical repair was associated with longer-term outcome, implying that healing characteristics visible early in recovery may anticipate later function (Saarensilta et al., 2023). Sukanen et al. found that early asymmetry in Achilles tendon resting angle predicted one-year plantar-flexor strength recovery after nonoperative management, again supporting the idea that simple structural or positional measures can foreshadow later performance deficits (Sukanen et al., 2024). Imaging work by Joannas et al. further demonstrated that both ultrasound and MRI can meaningfully contribute to assessment of tendon healing after percutaneous repair (Joannas et al., 2024).

Patient-reported and subgroup findings also broaden the picture of what needs to be monitored. Larsson, Brandt Knutsson, et al. established a patient acceptable symptom state for the ATRS, giving clinicians a more interpretable benchmark for symptom-based recovery (Larsson, Brandt Knutsson, et al., 2024). Larsson, LeGreves, et al. showed that fear of reinjury is linked to poorer recovery and lower physical activity after rupture, making psychological readiness a clinically relevant variable rather than an optional add-on (Larsson, LeGreves, et al., 2024). Larsson, Nilsson, et al. found sex-related differences in early heel-rise deficits, while Aufwerber et al. reported that deep venous thrombosis after repair can affect long-term outcome (Larsson, Nilsson, et al., 2024; Aufwerber et al., 2024). These findings collectively support a multimodal model of recovery in which tendon status, calf function, symptoms, confidence, and complications are monitored in parallel.

3.3. Digital monitoring modalities relevant to basketball ATR

Wearable technologies form the most scalable layer of digital monitoring because they can capture movement exposure repeatedly in daily life, rehabilitation sessions, and progressive sport reintroduction. A feasibility study by Oskouei et al. in patients with Achilles tendinopathy showed that wearable devices can successfully track activity volume and biomechanical variables such as stride rate, shank angular velocity, and acceleration during physiotherapy care (Oskouei et al., 2023). Although tendinopathy is not equivalent to rupture, the study demonstrates the practical feasibility of capturing Achilles-relevant loading signals outside laboratory settings. More general reviews in sports medicine have similarly concluded that wearable systems can assist with monitoring external load, physiological strain, recovery patterns, and return-to-play progression (Seshadri et al., 2023; Rebelo et al., 2023; Olsen et al., 2025).

For basketball-specific ATR rehabilitation, wearable monitoring is especially valuable during the transition from protected ambulation to repeated court exposure. Step counts, walking speed, asymmetry during gait, acceleration and deceleration events, and progressive jump counts can all function as indirect markers of how the athlete is tolerating increasing loading. Braun et al. highlighted the growing value of step count as a digital mobility outcome in orthopaedics, while Iwasyk et al. described how wearable technologies are expanding within orthopaedic practice more broadly (Braun et al., 2026; Iwasyk et al., 2025). In practical terms, wearables make it easier to detect abrupt spikes in exposure, underloading due to persistent apprehension, or asymmetrical movement patterns that would be invisible if clinicians relied only on scheduled clinic visits.

Force-based monitoring represents a second essential layer because plantar-flexor weakness and asymmetrical power production are common after ATR and are highly relevant to basketball performance. Saab et al. reported on a portable device for measuring isometric plantar-flexion force after open Achilles repair, showing that clinically usable strength quantification is increasingly feasible outside specialized laboratories (Saab et al., 2024). At the same time, the force-plate literature has matured quickly. Collings et al. demonstrated favorable validity and reliability for several force-based assessments using a commercially available platform, and Badby et al. showed in a 2025 scoping review that force plates are widely used to monitor acute changes in lower-body neuromuscular function (Collings et al., 2024; Badby et al., 2025).

This matters for basketball because jump and landing tasks are not incidental to Achilles recovery; they are central to the performance problem. Koshino et al. showed that hip and knee kinematics, center-of-pressure position, and ground-reaction-force features are associated with Achilles tendon force during jump landing (Koshino et al., 2024). Accordingly, force-plate monitoring can provide more than a general strength score. It can help clinicians examine jump impulse, braking strategy, interlimb asymmetry, loading rate, and repeated-task fatigue, all of which have direct relevance to the actions that precipitate many basketball ruptures and to the movements players must relearn before returning to competition.

Imaging provides a third layer of digital information by addressing tissue healing rather than only external performance. Ultrasound and MRI remain the principal options in current clinical practice, and recent studies suggest that each adds different strengths to post-ATR monitoring. Joannas et al. concluded that both modalities can support evaluation of tendon healing after percutaneous repair, while Saarensilta et al. and Sukanen et al. showed that early structural or positional variables may predict later functional recovery (Joannas et al., 2024; Saarensilta et al., 2023; Sukanen et al., 2024). Beyond conventional imaging, Horvat and Kozinc reviewed the growing role of shear-wave ultrasound elastography in musculoskeletal monitoring, and Lei et al. described the design and application of wearable ultrasound devices, indicating that tendon imaging may become more portable and more repeatable over time (Horvat & Kozinc, 2024; Lei et al., 2025).

AI and markerless video analysis represent a fourth layer, one that is best understood as integrative rather than autonomous. Souaifi et al. reviewed the rapid expansion of AI in sports biomechanics, noting applications in wearable-data analysis, motion analysis, and injury prevention (Souaifi et al., 2025). Yuan et al. documented the emerging literature on machine-learning models that predict return to sport after injury, while Xia et al. demonstrated that Achilles tendon force during common motor tasks can be estimated from markerless video (Yuan et al., 2026; Xia et al., 2024). These developments are promising because they allow multiple inputs—wearable load, force testing, imaging, and symptom reporting—to be synthesized into a more coherent recovery profile. Even so, the current evidence does not justify delegating clearance decisions to algorithms. Rather, AI should be viewed as a tool for pattern recognition, dashboard construction, and clinical decision support.

Finally, digital monitoring should include athlete-reported recovery rather than focusing only on mechanical outputs. Electronic administration of the ATRS, pain ratings, training tolerance reports, and fear-of-reinjury questionnaires can help identify discordance between objective recovery and the athlete's willingness to load the limb. In basketball, where hesitancy during take-off, landing, or deceleration can materially affect performance, such discordance is clinically important. The strongest monitoring strategy is therefore multimodal: tendon status, mechanical capacity, workload exposure, and psychological readiness should be tracked together, not as isolated domains.

Electronic patient-reported outcome collection deserves separate emphasis because it is one of the simplest forms of digital monitoring and one of the easiest to integrate across settings. The ATRS, pain scales, perceived exertion after sessions, confidence ratings, and fear-of-reinjury responses can all be delivered through secure digital platforms and reviewed alongside mechanical data. This combination is particularly important after ATR because the athlete's willingness to trust the injured side often changes at a different pace

from objective strength recovery. In practical terms, digital patient-reported outcomes can alert the team to rising apprehension, underreporting of post-session symptoms, or reduced readiness for aggressive loading before those issues appear in formal performance tests.

Another developing area is the use of integrated dashboards rather than isolated metrics. In a dashboard model, clinicians can review workload trends, plantar-flexor force scores, jump asymmetry, imaging notes, and symptom reports on the same timeline. This improves interpretability because it reveals how domains interact. For example, a sudden rise in court workload accompanied by a drop in jump impulse and higher pain scores may indicate that the current progression is too aggressive. Conversely, stable imaging, improving plantar-flexor force, and rising external-load tolerance together may strengthen confidence that the athlete is ready for the next phase. Although robust basketball-specific validation studies are still limited, the logic of integrated monitoring is strongly supported by the broader sports-digital-health literature.

Markerless video may be especially valuable for bridging the final gap between laboratory testing and live basketball. Because video can be collected in ecologically valid environments, it allows clinicians to examine whether a player changes take-off strategy, avoids loading the repaired side in open space, or lands with altered trunk and lower-limb positions during real court tasks. The recent ability to estimate Achilles tendon force from markerless video is especially notable because it suggests that the field may eventually move toward more accessible estimation of internal loading without the expense of full motion-capture systems (Xia et al., 2024). Even before that stage is reached, video-based qualitative and quantitative review can substantially enrich late-stage rehabilitation decision making.

The reviewed studies also suggest that digital monitoring should not be interpreted only in terms of sophistication. Simpler tools may still have high value if they answer clinically meaningful questions. A reliable step-count trend, a repeated plantar-flexion force measurement, a weekly ATRS score, and a periodic ultrasound check may together provide more actionable insight than a larger but poorly integrated set of complex variables. In this sense, the quality of a digital monitoring system depends less on novelty than on whether the chosen measures correspond to the functional bottlenecks that typically follow Achilles rupture.

3.4. Proposed staged framework for basketball return-to-performance

On the basis of the reviewed literature, a staged digital monitoring model for basketball after ATR can be proposed. In the early protection phase, the primary purpose of technology is not to maximize activity but to regulate exposure and document the initial response to rehabilitation. Step count, protected walking time, pain and swelling logs, calf-girth trends, and when clinically indicated, ultrasound or MRI findings can provide a first layer of longitudinal information. If early morphology or tendon position appears concerning, those findings can inform more cautious progression even when symptoms seem manageable (Saarensilta et al., 2023; Sukanen et al., 2024; Joannas et al., 2024).

During the progressive loading phase, the monitoring focus should shift toward gait normalization and restoration of plantar-flexor function. At this stage, repeated measurement of isometric plantar-flexion force, heel-rise performance, wearable-derived asymmetry during walking and light running, and patient-reported tolerance becomes valuable. The objective is not merely to increase activity volume, but to determine whether increasing load is accompanied by improving force output and declining asymmetry. If wearable activity rises while plantar-flexor force remains stagnant or symptoms worsen, progression may need to be slowed despite apparently favorable calendar timing (Saab et al., 2024; Oskouei et al., 2023; Larsson, Brandt Knutsson, et al., 2024).

In the late gym-to-court transition, more basketball-specific variables should be introduced. Force-plate testing of bilateral and unilateral jumps, landing mechanics, repeated hop tasks, and rate-of-force-development measures can clarify whether the athlete has moved beyond general strength recovery to functional power recovery. Wearables can then quantify controlled court exposure, including acceleration and deceleration counts, running distance by zone, and the gradual reintroduction of repeated jumps. Electronic outcome measures remain important in this phase because athletes who are physically improving may still report apprehension or reduced confidence during higher-speed tasks (Koshino et al., 2024; Badby et al., 2025; Larsson, LeGreves, et al., 2024).

The final return-to-performance phase should center on whether the athlete can tolerate basketball density rather than simply complete isolated tests. Here, digital monitoring should capture repeated practice exposure, variability in workload across days, the ability to recover between sessions, and the stability of jump or force outputs over time. Markerless video and AI-assisted analytics may be particularly useful in this phase because they can help interpret changes in movement strategy during offensive take-offs, cutting, or single-leg

landings without requiring the athlete to remain in a laboratory setting (Petway et al., 2022; Xia et al., 2024; Souaifi et al., 2025). Importantly, the athlete should be judged relative not only to the uninjured side but also to preinjury role demands, sex- and league-specific context, and positional workload expectations (Momtaz et al., 2024; Weinberg et al., 2024).

This staged framework does not imply that any single variable should dominate the decision. The literature instead supports the opposite conclusion: the most reliable return-to-performance judgments will probably be those that integrate structural, functional, exposure-based, and psychological information. Digital monitoring is valuable precisely because it makes such integration more practical. It allows recovery to be represented as a trajectory rather than as a series of disconnected checkpoints.

From an implementation perspective, a minimum viable monitoring battery can be conceptualized for settings without access to advanced laboratories. Such a battery could include an activity wearable for mobility and training load, a standardized heel-rise or plantar-flexion force assessment, an electronic ATRS plus fear/readiness items, and periodic video analysis of sport-specific tasks. Where ultrasound is available, structural monitoring can be added at key decision points. This simplified package would not capture every aspect of recovery, but it would still address the core domains identified in the literature: exposure, force, symptoms, confidence, and movement quality.

In contrast, high-performance programs may adopt a more comprehensive model that layers daily player-tracking data, portable or laboratory force testing, repeated imaging, and AI-supported pattern recognition. The key challenge in such settings is not acquiring more variables but deciding which variables should trigger a change in progression. The reviewed literature suggests that the most defensible triggers are those based on converging evidence across domains—for example, persistent jump asymmetry together with plateaued plantar-flexor force and worsening athlete confidence. This is preferable to any decision model that relies on a single impressive value while ignoring discordant indicators elsewhere.

Table 2. Proposed basketball-specific digital monitoring framework across rehabilitation phases

Phase	Clinical aim	Suggested digital tools	Core signals for progression
Phase 1: Early protection and controlled mobility	Protect repair or healing tendon, regulate exposure, monitor symptoms and early tissue response.	Step count/activity wearable; pain and swelling log; calf girth; selective ultrasound or MRI.	Daily activity tolerance, trend in pain/swelling, early tendon morphology, gross asymmetry.
Phase 2: Progressive loading and gait normalization	Restore plantar-flexor activation, normalize gait, improve tolerance to increasing load.	Wearable gait metrics; portable plantar-flexion force device; heel-rise testing; ATRS/ePROs.	Walking/running symmetry, isometric force trend, heel-rise initiation, symptom acceptability, confidence.
Phase 3: Gym-to-court transition	Rebuild explosive function, energy storage, landing control, and repeated submaximal basketball loading.	Force plates; wearable acceleration/deceleration tracking; repeated hop/jump testing; ePROs.	Jump impulse, landing asymmetry, repeated-hop tolerance, session workload, fear of reinjury.
Phase 4: Return to team practice and performance	Tolerate dense basketball exposure and reproduce sport-specific movement quality over time.	Player-tracking wearables; force-plate rechecks; markerless video; integrated analytics dashboard.	Repeated court exposure, session-to-session recovery, stable jump outputs, take-off/landing strategy, readiness relative to role demands.

4. Discussion

The studies reviewed here support a clear conceptual shift from time-based return after Achilles rupture toward criteria-based return-to-performance, especially in basketball. The modern rehabilitation literature has already shown that progressive loading and functional restoration are preferable to overly conservative immobilization-centered models in many cases, but it has also shown that clinicians still lack a standardized, sport-specific way of deciding when an athlete is truly ready for return (Liu et al., 2021; Massen et al., 2022; Busà et al., 2026). Digital monitoring does not solve this problem automatically, yet it provides the measurement infrastructure needed to approach it more rigorously.

A major strength of digitally informed rehabilitation is that it allows recovery to be evaluated across multiple levels at once. Tendon healing can be followed with imaging, calf and plantar-flexor recovery with portable strength devices and heel-rise measures, movement quality with wearables and force plates, and practical readiness with workload data and athlete-reported outcomes. When these signals are interpreted together, clinicians are less dependent on surrogate markers such as elapsed postoperative weeks. This is particularly important after ATR because an athlete may show acceptable symptoms while still demonstrating persistent asymmetry or inadequate tendon-related power, or conversely may display encouraging objective measures while remaining psychologically hesitant during explosive tasks.

Basketball magnifies the value of this multimodal approach because the sport imposes repeated unilateral propulsion and braking tasks that are not well represented by generic clinical tests. Mechanism studies indicate that rupture often occurs during offensive, high-velocity actions rather than in static or linear situations (Petway et al., 2022; Yüce et al., 2024). From that perspective, the relevance of wearable acceleration data, force-plate jump testing, and markerless video analysis becomes obvious: they provide information about the same classes of movement that create both injury risk and performance value. Digital monitoring is therefore not simply a technological embellishment; it is a means of aligning rehabilitation metrics with the sport's real movement ecology.

Another advantage is personalization. Basketball players do not return to a single universal demand profile. The expected loading pattern of a high-usage NBA guard is different from that of a WNBA forward or an NCAA role player. Sex-related differences, league structure, laterality, and preinjury style of play all appear capable of influencing recovery pattern after ATR (Hodgens et al., 2021; Sanchez et al., 2021; Momtaz et al., 2024; Weinberg et al., 2024). Digital monitoring makes individualized progression more feasible because it allows clinicians to compare an athlete not only with population benchmarks or the contralateral limb, but also with their own evolving response to load and, where available, their preinjury performance history.

The technologies discussed here sit along a spectrum of complexity and cost. High-resource settings may combine advanced imaging, laboratory force testing, player tracking, and machine-learning dashboards. Lower-resource clinics may rely on fewer tools, such as an activity wearable, an ATRS administered electronically, a portable force or heel-rise assessment, and selective ultrasound follow-up. The core principle is not technological maximalism; it is consistent, decision-relevant measurement. That principle is compatible with both elite and community contexts.

An additional implication concerns communication. One reason return-to-performance decisions after ATR are difficult is that different stakeholders often prioritize different outcomes. Surgeons may focus on tendon continuity and complication avoidance, physical therapists on movement quality, strength staff on force production, coaches on availability, and athletes on confidence or perceived explosiveness. Digital monitoring cannot eliminate these differing priorities, but it can make them visible and discussable within a shared framework. When data are presented longitudinally, disagreements can shift from intuition-based debate to evidence-informed planning.

The reviewed evidence also supports a more cautious interpretation of limb symmetry. After Achilles rupture, the contralateral limb is a useful comparator, but it should not be treated as the sole standard. In elite athletes, the uninjured limb may itself adapt during the rehabilitation period, and preinjury asymmetries may already have existed. This is especially relevant in basketball, where dominant-side preferences, positional demands, and individual movement styles can influence unilateral tasks. Digital systems that preserve repeated within-athlete data over time therefore offer an advantage over single-session symmetry checks because they allow trends to be interpreted in personal context.

From a research-design standpoint, future studies would benefit from linking digital markers to outcomes that matter directly in basketball. These outcomes should extend beyond calendar days to first game and include repeated-game availability, per-minute production, jump-load tolerance, player efficiency trends, and career retention. Economic outcomes are also relevant. Meadows et al. showed that ATR in the NBA

carries a substantial financial burden; consequently, there is a plausible case that better monitoring could have value not only for athlete health but also for organizational decision-making. That hypothesis now needs prospective testing rather than speculation.

Finally, the social and ethical dimension of digital rehabilitation deserves attention. Increased monitoring can support precision, but it also increases data capture, storage, and interpretation demands. Athletes may worry about how readiness scores or workload data will be used in contract or roster decisions. Programs adopting digital monitoring should therefore establish clear governance regarding consent, data access, intended use, and the role of clinical judgment. These concerns fit squarely within the social-science orientation of IJITSS because the success of digital rehabilitation depends not only on sensor accuracy but also on trust, workflow design, and responsible implementation.

Important limitations remain. First, direct basketball-specific trials of digital monitoring after ATR are scarce. Much of the reasoning in this review is therefore based on triangulation: basketball-specific outcome studies are integrated with broader ATR rehabilitation research and with sports-technology literature that is often not restricted to Achilles rupture. Second, most basketball outcome studies are retrospective and involve relatively small cohorts, which limits causal inference. Third, no consensus thresholds currently exist for many of the variables that clinicians may wish to monitor, such as acceptable jump asymmetry, acceleration exposure, or imaging-defined healing benchmarks for basketball-specific progression. Accordingly, the staged framework proposed here should be understood as evidence-informed and practice-oriented rather than as a validated algorithm.

Digital implementation itself also brings challenges. Wearable data can be noisy or context dependent, device ecosystems may not communicate seamlessly, and staff must be trained to interpret rather than merely collect data. Over-monitoring is another risk: if too many metrics are gathered without a clear decision pathway, clinicians may confuse data abundance with clinical insight. Privacy, data governance, and the athlete's comfort with surveillance technologies also deserve more attention, especially as AI-based models expand (Olsen et al., 2025; Iwaszk et al., 2025; Souaifi et al., 2025). For these reasons, technology should remain embedded within multidisciplinary clinical reasoning rather than replacing it.

Future research should move in several directions. First, prospective basketball-specific studies are needed to test whether digitally guided rehabilitation improves return-to-performance, not just time to return. Second, more work is needed to define which combinations of variables are most predictive at different stages of recovery: imaging may be more useful early, whereas force and workload profiles may matter more during court reintegration. Third, sex-specific and league-specific analyses should be expanded, given the signals already seen in the WNBA and NBA literature. Finally, AI models should be evaluated not only for predictive accuracy but also for transparency, fairness, and usability in real clinical settings.

Despite these limitations, the current evidence already justifies a meaningful change in practice. ATR recovery in basketball should no longer be framed as a countdown to a date. It should be approached as a monitored progression in which tendon integrity, calf recovery, movement quality, training exposure, and athlete confidence are repeatedly assessed and interpreted together. Digital monitoring is valuable precisely because it turns that philosophy into something operational.

5. Conclusions

Achilles tendon rupture in basketball is a performance-threatening injury whose consequences extend beyond the point of medical clearance. Recent evidence from professional and collegiate basketball shows that many athletes return to competition, yet durable recovery of preinjury performance remains uncertain. Contemporary rehabilitation literature likewise shows that return-to-sport decision making after ATR is still too variable and too dependent on time-based reasoning.

A digitally informed rehabilitation model offers a practical way forward. Wearables, portable force testing, force plates, ultrasound and MRI, electronic patient-reported measures, and AI-assisted analytics can be combined to track tissue healing, plantar-flexor recovery, asymmetry, workload tolerance, and psychological readiness throughout rehabilitation. In basketball, these tools are especially valuable when they are linked to the demands that define the sport: unilateral propulsion, repeated jumping, landing control, high-speed transitions, and exposure to dense practice and game schedules.

The strongest conclusion from the current literature is not that one device should determine readiness, but that return-to-performance decisions are likely to improve when multiple digital signals are interpreted together within a sport-specific framework. Future prospective studies should test whether such monitoring can improve not only return rates, but also durability, efficiency, and career longevity after Achilles tendon rupture.

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