
# The Rise of Telerehabilitation in Sports Medicine: A Postpandemic Paradigm Shift

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## ABSTRACT

The COVID-19 pandemic fundamentally transformed health care delivery, elevating telerehabilitation from a peripheral modality to a cornerstone of sports medicine practice. This review paper synthesizes evidence demonstrating comparable efficacy between telerehabilitation and traditional in-person care for musculoskeletal injuries and postsurgical recovery, particularly when enhanced by wearable technology and artificial intelligence (AI) analytics. While telerehabilitation improves access and adherence, especially for athletes in remote regions, significant challenges persist regarding digital equity, clinician training, and data privacy. The postpandemic era presents an opportunity to develop hybrid care models that combine technological innovation with personalized supervision, establishing telerehabilitation as a sustainable component of athletic care rather than merely a crisis-response measure. Furthermore, reports indicate positive changes in access, patient adherence, and care persistence, particularly among athletes in remote or underserved locations. Nevertheless, the swift trend toward the use of telerehabilitation also reveals vulnerabilities in the system, including digital access disparities, a lack of clinician training, regulatory ambiguity, and data privacy issues. Additionally, the lack of uniformity in study designs and results makes it challenging to generalize results across diverse athletic populations. Notwithstanding these factors, the postpandemic era presents a unique opportunity to establish postpandemic rehabilitation paradigms that incorporate hybrid models combining digital technology and person-directed care. This review paper also presents certain technological, clinical, ethical, and policy considerations that cannot be overlooked to achieve sustained, equitable, and evidence-based telerehabilitation practices. One final consideration regarding telerehabilitation or rethinking its role in sports medicine is the potential for it to become a core part of sports medicine rather than a short-term solution to emergency crises.

**Keywords:** Tele-rehabilitation, Sports medicine, Wearable technology, Virtual reality, AI-based analytics

## Introduction

Telerehabilitation is a subspecialty of telemedicine that involves providing rehabilitation services through digital communication processes to enable the administration of rehabilitation to patients at distant sites, including evaluation, review, and direction. Although it initially contributed little to the practice and was often viewed as an accessory to traditionally in-person care, telerehabilitation has experienced a significant leap in practicality and use following the COVID-19 pandemic in the field of sports medicine.[1] Lockdowns and social distancing were a rude awakening to athletes and clinicians, but digital technology became important in ensuring that the functions of rehabilitation and performance recovery programs remained operational. In the field of sports medicine (where early action, individualized plans, and constant follow-up play a monumental role in functional outcomes), telerehabilitation has become more than a backup plan.

It has offered an alternative route as a means of compensation for delayed treatment and prevention of the negative consequences of deconditioning.[2] The application of remote biometric sensors, wearable biosensors, health apps, and real-time video assessment in remote physiotherapy has enabled athletes to receive customized attention without necessarily visiting clinical rooms, and in many cases, with results that are not significantly different from those of in-person programs. As suggested by recent research articles, the remote form of rehabilitation intervention can be equivalent to, and even better than, usual care in terms of compliance, satisfaction, and recovery in specific athletic populations. Nonetheless, the accelerated growth of telerehabilitation is also an object of critical consideration.[3] Novel as it may be, the shift has not been equally equitable. Access to technologies, digital competency among clinicians, regulatory compliance, and data protection are all issues that have not yet been adequately addressed. Secondly, the current evidence base remains in the maturity stage, and most studies lack longitudinal outcomes or extensive comparisons. This review paper will critically investigate the technology-driven changes in telerehabilitation for sports medicine, addressing technological innovation, clinical context, challenges, systemic issues, and policy aspects to outline the emerging paradigm.[4] Through the synthesis of existing research on telerehabilitation, this review paper aims to enhance the understanding of advances made in injury recovery, performance maintenance, and long-term care of athletes through telerehabilitation. Its eventual goal is to educate stakeholders, including clinicians, researchers, policymakers, and technology developers, on how to institutionalize and maximize the use of telerehabilitation as a viable and efficient aspect of contemporary sports medicine.

There was a systematic search that revealed 1,203 records in the MEDLINE, EMBASE, and IEEE Xplore (2000–2025) databases. Following the elimination of the duplicates and abstract screening, 42 studies were included (English, sports-related injuries, human populations, telerehabilitation interventions). Studies other than the controlled groups ($n$ = 38) or technological descriptions ($n$ = 29) were excluded (Figure 1).

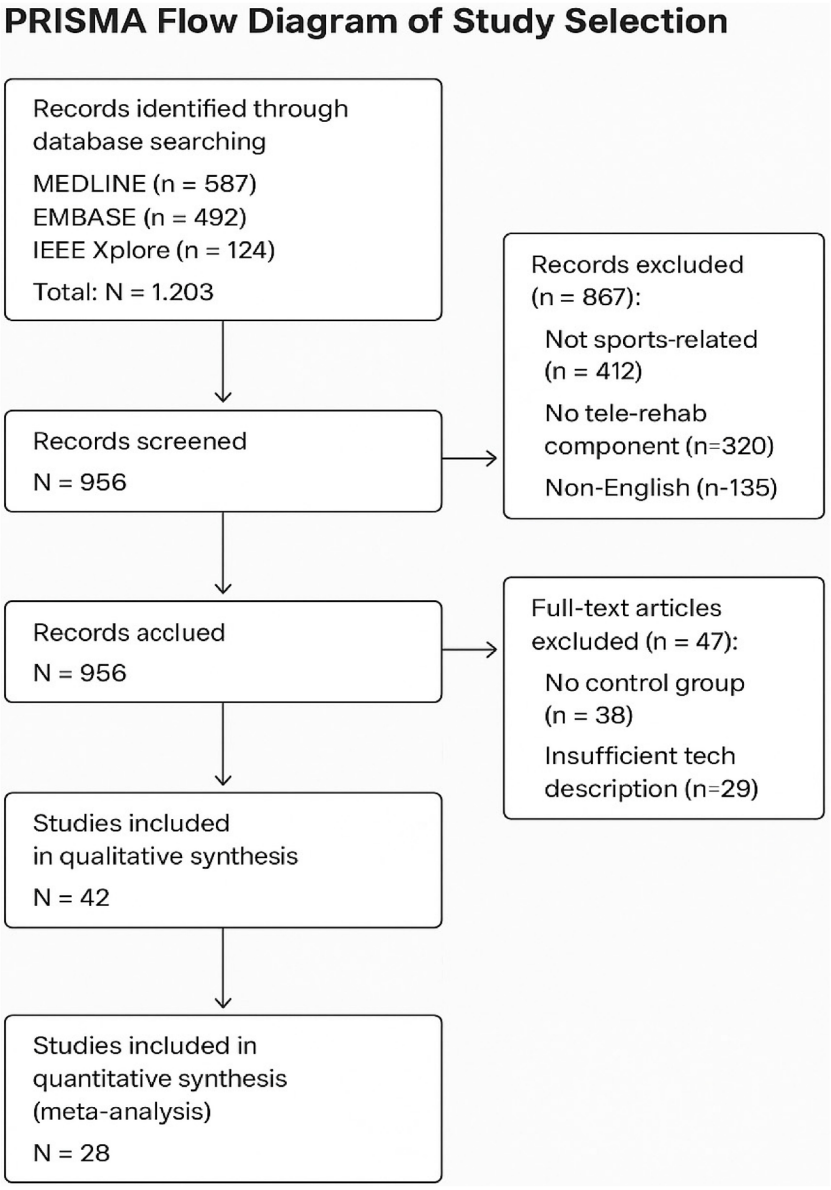


**Fig 1 | PRISMA flow diagram of study selection**

### Evolution of Telerehabilitation Pre- and Post-COVID-19

Telerehabilitation was seen up to the COVID-19 pandemic as a marginal, experimental supplement to traditional rehabilitation services. Its usage in sports medicine was ad hoc, and it applied to special situations, such as when a patient needed a far-away consultation or when there was an opportunity to check up on a patient with low acuity in the aftercare setting. The skepticism regarding efficacy, the unavailability of reimbursement models, improper training of clinicians, and concerns about data security hindered the extensive integration.[5] Moreover, regulatory environments in different countries were non-uniform and even limiting, so the telerehabilitation programs could not become scalable.

Within this pre-pandemic environment, the use of telerehabilitation technologies among people with athletic backgrounds was minimal. Hands-on evaluation and physical presence during therapy sessions were standard practice, as most sports medicine practitioners considered close contact necessary for precise diagnosis, biomechanical investigations, and manual treatment. Despite emerging isolated studies indicating the possibility of virtual rehabilitation platforms in injury prevention and postsurgical recovery, such innovations attracted minimal attention from mainstream clinical service providers.[6] The COVID-19 crisis acted as an unprecedented accelerator, spurring a worldwide reevaluation of the role of telerehabilitation in clinical practice.

The rampant lockdowns and indefinite postponement of elective outpatient services left sports medicine practitioners with no choice but to implement virtual care modalities. The formerly gradual technological evolution turned into a race of changes based on necessity. State agencies and medical examiners did not waste any time: mutually agreed-upon temporary waivers of licensure, emergency reimbursement guidelines, and rapid approval of digital health ecosystems eliminated a significant number of traditional institutional obstacles.

The structural shift in the sports rehabilitation environment occurred after the pandemic.[7] Telerehabilitation is no longer regarded as an emergency alternative but rather as a part of the athlete's care services, which can be scaled up or down as needed. Such developments in clinical workflows incorporate hybrid practices, which require a combination of remote monitoring and virtual sessions merging with occasional face-to-face assessments. Traditional research on the postpandemic population makes a high number of claims of patient satisfaction, adherence, and functional outcomes among various sportspeople, especially concerning health issues such as anterior cruciate ligament (ACL) reconstruction, rotator cuff injury, and stress fractures.

More importantly, the mode of funding has also undergone a change. Public and private payers are also beginning to pay more attention to telerehabilitation as a reimbursable service, particularly in cases where objective tracking of results is feasible using digital measurements.[8] Telehealth infrastructures, including high-resolution video-based platforms, artificial intelligence (AI)-controlled movement analysis, and sensor-based remote monitoring, have experienced significant growth. Since 2020, venture capital investment in digital rehabilitation technology has increased more than twofold, indicating that the model has long-term market credibility.

However, the speedy scale-up has created some novel problems. The issues of standardizing care and care delivery, as well as the digital divide (lack of access to technology) and clinician expertise on virtual platforms, are still being addressed. Due to the temporary nature of numerous policy relaxations, particularly those related to licensure and cross-border care, the future of long-term regulation of telerehabilitation remains uncertain.[9] To conclude, the pandemic not only accelerated the use of telerehabilitation but also


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significantly changed its perception of validity, practicability, and direction in the world of sports medicine.

This shift from marginal adoption to mainstream integration is a transformative paradigm. Still, it now requires refinement with an evidence-based focus, strategic policies, and considerations, such as sports ethics, to make it more beneficial and fairer to athletes in the postpandemic world. Figure 2 provides a visual summary of how the widest possible range of patients abruptly embraced telerehabilitation in the early weeks and months of the pandemic by comparing their marginalization before COVID-19 to their place in the clinical workflow after. This change was motivated by short-term policy exemption (e.g., licensure cross-state reimbursement) and maintained by patient satisfaction measures.[7]

### Technological Innovations Driving Telerehabilitation

Advanced technology has been instrumental in transforming telerehabilitation from the old system of video consultation to systems rich in interactivity and personalized for sports medicine. Wearable, AI-based rehabilitation tools, virtual reality (VR), mobile applications in health care, and motion sensing-based technologies are among the most significant innovations that play a role in improving remote athletic recovery paths.[10] Now, it is possible to monitor biomechanical parameters in real time, including joint angle, muscle activation, balance, and gait, thanks to the employment of wearable technology, such as inertial measurement units, bright garments, and GPS-enabled fitness trackers. Such solutions provide objective feedback to patients and clinicians, ensuring the benefits of remote rehabilitation sessions that are biomechanically accurate.

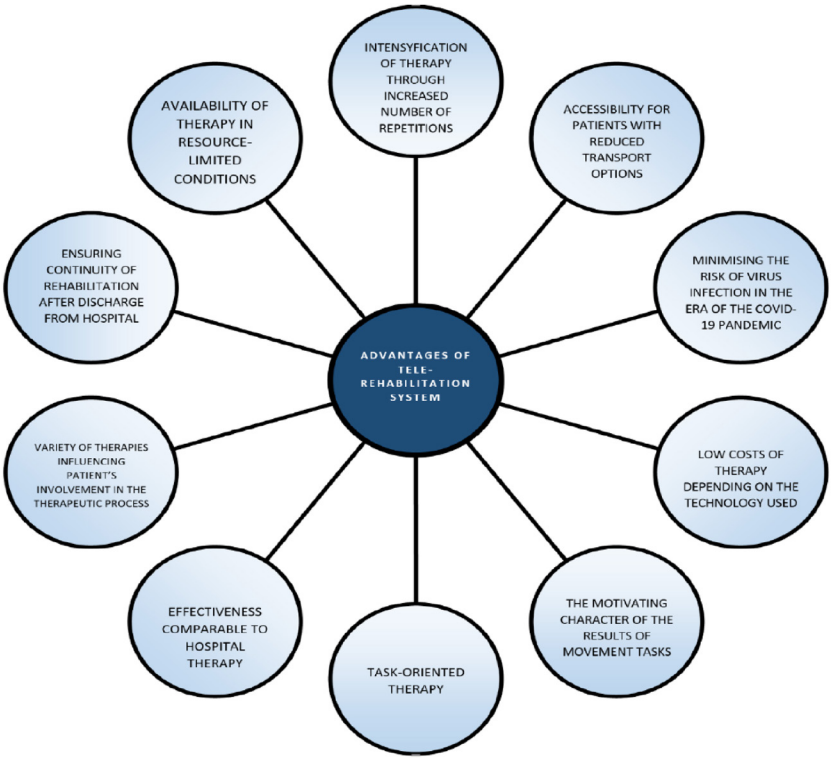


**Fig 2 | Telerehabilitation of poststroke patients**[16]

More importantly, wearables have become more proactive than just passive tracking, ensuring they can drive prescriptive analytics to warn clinicians when they are off target in achieving test performance and risk of injury profiles. This ecosystem is also complemented by AI, which interprets massive datasets produced during the rehabilitation process.[11] The embedded Machine learning algorithms in telerehabilitation platforms can evaluate the quality of muscle rehabilitation exercise performance, determine recovery schedules, and customize exercise schedules depending on the user. These AI models have considerable potential, but in athletics, they remain undervalidated, raising concerns over bias, data integrity, and clinical transparency.

In addition, their performance is constrained not only by the quality and variety of the training data, which tend to lack representation of elite or diverse athletes but also by the lack of representation of these athletes in the panel. Neuromuscular re-education is a new field of application being explored through VR and augmented reality as immersive technologies, which are particularly useful in managing concussions and training proprioception and balance recovery.[12] Rehabilitation programs using VR allow for a simulated recreation of the real game environment, increasing the level of cognitive-motor involvement and motivation in an athlete's work. High hardware prices and the requirement for users to adapt to them, however, make them unsuitable for use across all levels of athletic care.

Mobile health (mHealth) apps are low-cost, readily available platforms that guide people in executing exercise routines, track adherence, and facilitate communication with medical professionals. The specific characteristics of gamification, biofeedback, and video demonstrations are incorporated into many apps to enhance engagement.[13] However, the quality of apps is highly diverse, and the majority of them do not undergo any regulatory control or clinical verification, raising questions about their safety, effectiveness, and data security. Lastly, motion capture technologies, including accelerometers that come with smartphones or 3D motion sensors, have helped the ordinary individual gain access to what was previously only accessible in a laboratory to assess movement.

Although these tools maximize the accuracy of remote diagnostics, concerns remain regarding inter-device variability and clinician training in data interpretation. In brief, technological innovation has significantly enhanced the potential of telerehabilitation in sports medicine.[14] Nonetheless, scrutiny of usability, fairness, medical validation, and ethical application is necessary so that such devices can be relevant to the various athletic groups and generate similar effects (Figure 3).

### Clinical Applications in Sports Medicine

Telerehabilitation has become a groundbreaking approach in the field of sports medicine, particularly in key medical specializations such as orthopedic recovery, concussion management, strength conditioning,

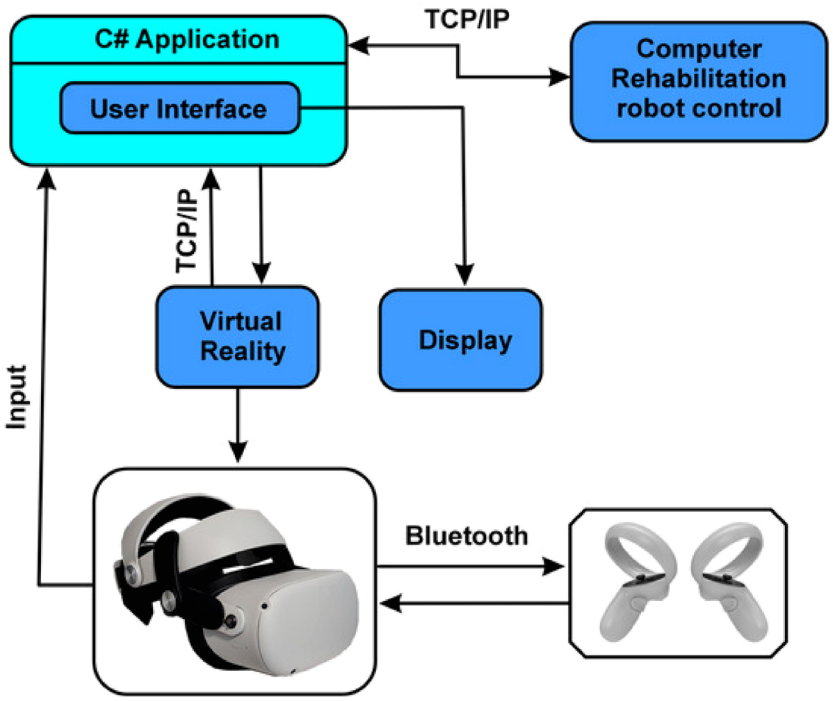


Fig 3 | Development of a VR-based environment for telerehabilitation[22]

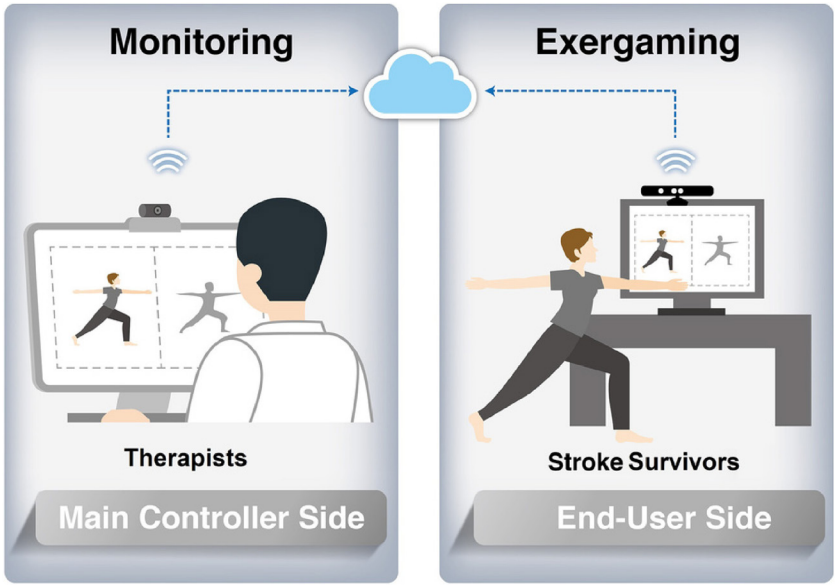


Fig 4 | Feasibility and effect of interactive telerehabilitation[9]

**Table 1 | Clinical applications**

| Clinical Application | Telerehabilitation Approach | Key Findings | Limitations |
|---|---|---|---|
| Orthopedic Recovery (ACL) | Wearable sensors + video guidance | Comparable ROM and strength gains to in-person care[7] | Early-stage manual therapy still requires in-person visits |
| Concussion Management | VR-based cognitive training | Improved vestibular function ($p < 0.05$)[16] | Challenges in symptom monitoring |
| Strength Conditioning | AI-powered motion tracking | 89% adherence in amateur athletes | Safety concerns for high-intensity exercises |
| Injury Prevention | mHealth apps with reminders | 40% reduction in recurrent injuries | Limited load monitoring capabilities |

and injury prevention. While it is clear that its increasing utility is well-recognized, there are some questions over its effectiveness and applicability, which are context-specific and are ineffectively examined in settings of high-performance athletics. The field of orthopedic recovery is the least explored area of telerehabilitation.[15] The tendency to switch to remote monitoring and guided therapy after procedures such as ACL reconstruction, rotator cuff repair, and meniscal surgery has been demonstrated in postoperative care.

Research indicates similar results in terms of range of motion (ROM), muscle strength, and functional scores between telerehabilitation and in-person traditional physiotherapy; however, these findings can be further substantiated when both are combined with wearable sensors and video-guided exercise protocols.[16] However, most of these findings are based on general or recreational populations of athletes; indeed, there is no evidence that they operate similarly in the elite sporting arena. Moreover, postoperative care in the early stages, which includes manual treatment, edema management, and fine clinical decision-making, can be considered essential and may continue to necessitate follow-up visits. Telerehabilitation has proposed new devices to facilitate cognitive and neuromotor rehabilitation in a VR environment and on a gamified rehabilitation platform, particularly in the context of concussion care.

These enable home-based vestibular training, reaction time exercises, and balance training in an engaging and interactive format.[17] At the same time, diagnosis and surveillance of the symptoms associated with concussion, in particular mild cognitive impairment or psychopathology, may be challenging to measure remotely, which potentially means that under-reporting or misclassification issues arise in unsupervised situations. Neuromuscular training and strength conditioning sessions are also starting to incorporate elements of telerehabilitation, especially during off-season periods or when recovering from an injury. Online training programs with motion tracking sensors and in-progress feedback can be used to supervise athletes through their specific plan, with an emphasis on progressive loading and form mastery.

However, face-to-face supervision is often lacking and, therefore, may not always be safe when it comes to high-intensity or intricate patterns of movement.[18] In addition, differences in equipment availability within home settings can be restrictive to program compliance and effectiveness, especially among younger or amateur athletes. Scalable models for implementing evidence-based injury prevention programs through telerehabilitation, e.g., neuromuscular warm-ups, proprioceptive drills, and flexibility routines, have been added to injury prevention. Apps and cloud-based interventions offer compliance through daily reminders, educational videos, and self-reporting tools.

Nevertheless, injury prevention is multidimensional, and it requires proper screening and training loads as well as behavioral compliance, all of which are limited to some extent, even in remote situations. In

combination, although telerehabilitation has excellent potential for various clinical purposes, its existing role can be interpreted as supportive rather than a replacement for traditional care.[19] Prospects should be based on stratified practices — specifically, identifying the type of athlete, injury, and stage of recovery that can be safely and remotely treated on an individual basis to achieve the best outcomes (Figure 4 and Table 1).

### Benefits and Limitations of Telerehabilitation for Athletes

The insertion of telerehabilitation in sports medicine has been a twofold story of increased potential and unanswered complexity. On the one hand, its advantages, particularly in terms of accessibility, affordability, and patient involvement, are well-established. Consequently, on the one hand, there are still issues surrounding affordable access to technologies, clinical supervision, and regulatory integrity that limit its cross-scale effectiveness and widespread implementation.[20] The most direct benefit of telerehabilitation may be that of accessibility.

Athletes in underdeveloped or otherwise geographically remote regions who could not obtain special therapy due to issues of logistics now have the option of undertaking structured rehabilitation processes with the guidance of specialists. This is especially applicable in amateur and collegiate games where elite-level rehabilitation is not usually available. However, the belief that everybody can access digital is confusing.

Numerous differences exist in broadband access and the acquisition of digital devices, as well as digital literacy, particularly among low-income or rural populations, which may hinder equitable care delivery.[21] A common strength of telerehabilitation is its cost-effectiveness. The cost for both providers and patients can be significantly reduced through decreased expenses in travel, facility setup, and administrative overheads. However, these savings do not happen evenly.

The implementation of secure platforms and the integration of wearables or motion-based sensor technologies can be costly for start-up organizations. Additionally, the varying reimbursement policies of different health care systems create financial confusion between patients and providers. Patient satisfaction and compliance are also expected to be higher in rehabilitation than in conventional models, particularly those interventions that use modification, visualization, and guidance, as well as those provided with regular feedback.

The autonomy, convenience, and flexibility offered by remote programs are highly desirable to athletes, especially when combined with performance targets and goals. But these viewed advantages may be weak.[22] Unless it is overseen and supervised in real time or partially socially enforced by other individuals, the motivation may decline, and specific users report feeling disconnected from clinicians, which may subsequently hinder long-term adherence. Data privacy is one of the issues where little progress has been made.

The flow of sensitive health data via consumer-level devices and third-party applications raises the ethically important question of consent, privacy, storage, and cybersecurity. Many regulatory frameworks, such as the Health Insurance Portability and Accountability Act (HIPAA) and the General Data Protection Regulation (GDPR), provide some protection; however, these laws are not enforced equally, even across borders. Conclusively, the advantages of utilizing telerehabilitation in sports medicine are optimistic; nevertheless, they cannot be fully realized and are not allocated comparably.[23] It is through addressing the structural constraints, including technical, regulatory, and human limitations, that the model of telerehabilitation will be sustainable, as it supports inclusion and innovation rather than unintentional omission and disparity.

### Policy, Ethical, and Legal Considerations

Telerehabilitation in sports medicine has gone ahead too rapidly to encompass complete policy, ethical, and legal protection. Since the establishment of virtual care is on the rise, factors like data security, professional licensing, insurance reimbursements, and regulatory oversight are to be made a priority in the sustainable and responsible exemplary introduction. One of the most urgent issues is data security.[24] Telerehabilitation platforms may entail exchanging sensitive health and performance information through the use of cloud-based platforms, mobile applications, and wearables.

Even with such regulatory structures as HIPAA and GDPR, there are irregularities and difficulties in the application of regulatory bodies in most jurisdictions. Multiple third-party applications do not have end-to-end encryption or reveal their use of data, leaving athletes, especially professional ones, vulnerable to data leaks or unauthorized commercial use of any personal data. Another legal gray area is the licensing and cross-jurisdictional practice.

Licensure of clinicians requires them to practice in the state or the country where the athlete is located, hampering the ability to obtain specialty care across borders.[25] As much as the various licensure relaxations allowed more people to have access to the end of reporting temporary licensure relaxations during the pandemic, most legislation was interim in character, and neither the long-term nor permanent legal situation was clear. Insurance reimbursement is also disintegrated. Active policy changes, such as the introduction of the International Federation of Association Football (FIFA) 2024 Tele-Rehabilitation Framework and the National Athletic Trainers' Association (NATA) Position Statement on remote physiotherapy, have started to fill the crucial governance gaps.

The specification of end-to-end encryption of biometric data of the athlete (Article 3.2) sets crucial security standards that, in turn, conflict with the possibilities provided by the state laws of the United States, which allow sharing third-party data. Likewise, though the NATA supports the use of hybrid teams in contact sports, demographic distinctions become less clearly defined when the organization avoids recommending telerehabilitation services in the case of pediatric sports performers. These policy asymmetries explain

why harmonized international standards should be established, particularly in relation to elite athletes competing internationally.[26] In the absence of a strong legal framework, chances of malpractice, unfairness, and data abuse are likely to neutralize the gains of telerehabilitation in sports medicine.

### Future Directions and Research Gaps

The existing evidence pool has been marred by heterogeneous study designs and variability in outcome measures. To understand this, we can take the example of the meta-analysis that showed the telerehabilitation intervention shortened the recovery time of ACL by 0.3 days compared to traditional care;[5] however, the heterogeneity across studies was high (I 2 = 72%), which indicates a great variation in implementation procedures. In future, the discipline will need: (1) agreed definitions of successful outcomes (e.g., validated digital biomarkers of recovery), (2) technology specifications (sensor accuracy, sampling rates) to be reported in a standardized way, and (3) stratification of analyses by athlete level (elite vs. recreational). Lack of clinical practice guidelines on the assessment and management of repetitive strain injuries and acute musculoskeletal injuries in sports physicians, sports technologists, and rehabilitation specialists would be filled by the development of clinical practice guidelines through the Delphi method.[27] The introduction of standardized clinical pathways and tried and tested diagnostic digital assessment tools will be needed to benchmark efficacy with regard to population groups and injury types.

The other urgent vacuity includes the lack of high-quality prospective comparative research. The majority of the research carried out is concentrated on short-term functional outcomes, with minimal studies taking place in the long term. There are fewer randomized controlled trials of hybrid and telerehabilitation models using cohorts of elite athletes, in particular.

In the absence of the data, clinical decision-making is still as convenient as it is evidence-based. The problem of underrepresentation of certain groups of people is another restrictive factor of current research since it should include para-athletes, youth athletes, and female athletes.[28] More knowledge about how telerehabilitation may influence various groups, physically and psychologically, is necessary in order to design appropriate intervention methods. Technologically speaking, interoperability and integration with electronic health records are not sufficiently developed.

A smooth transfer of data among devices, platforms, and care providers is crucial in order to provide continuity, limit redundancy, and enhance athlete safety. Finally, the understanding of clinician training, user engagement tactics, and adherence variables remains elusive. Digital literacy, communication, and trust are human factors that should not be pushed aside along with the sophistication of digital equipment.[29] It is this research that helps better understand the realities of telerehabilitation as a clinical standard, as well as to be able to provide it in an equitable, athlete-centered course that will traverse a path based on robust scientific inquiry.

### Conclusion

Telerehabilitation in sports medicine is one of the most critical areas of postpandemic paradigm shifts that have defined the recovery, training, and prevention of injuries among athletes on various levels of competition. What was earlier termed as the contingency measure in a state of lockdown due to COVID-19 has become a realizable, expandable alternative to the old school rehabilitation systems. These advantages are huge (improved accessibility, cost reduction, individualized care, and enhanced compliance), especially with the help of numerous fast-developing technologies: wearables, motion sensors, AI platforms, mobile applications, and related technologies.

The transformation is, however, limited. Variability in clinical efficacy, digital equity gaps, regulatory uncertainty, and data privacy concerns are major threats to sustainable integration. The lack of long-duration, high-quality evidence—especially in elite athlete populations—highlights the need for robust research and improved clinical guidelines.

In addition, the human component of the care process cannot be replaced by a virtual setting (such as clinician-athlete rapport and practical evaluation by a clinician). Therefore, in that aspect, hybrid models should be the most practical way to proceed. Legal and ethical systems need to develop immediately to safeguard the data of athletes, guarantee equal access to them, and outline obvious principles of remote practice. The gaps identified in policies, medicine, technology, and research should be bridged by the involvement of policymakers, clinicians, technologists, and researchers in facilitating the future orientation of telerehabilitation in an inclusive, evidence-based, and ethically responsible manner.

As a consequence of telerehabilitation, the field of sports medicine will never be the same again, and it is no longer a measure of crisis response, but a true form of care. The evidence is especially useful in cases of: (1) the maintenance phase of rehabilitation during which biomechanical tracking is better than hands-on intervention, (2) the cases of athletes in geographically remote settings, who do not have access to specialists, and (3) recovery regimes that require high adherence, as digital reminders are useful. Nevertheless, the application must pay close attention to personalized aspects of athletes, such as the type of injury (acute vs. chronic), technological literacy, and support systems.

The success of the future will depend on handling the policy asymmetries, certifying technologies on different populations, and sustaining clinician-athlete therapeutic connection via balanced hybrid models.

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