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ORIGINAL ARTICLE

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Soft Robotic Hands for Sports and Rehabilitation: A Literature Review of Current Advances and Future Directions

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ABSTRACT

Background: The loss of upper limb functionality severely impacts daily living and mobility, driving the need for advanced prosthetic and rehabilitative solutions. Soft robotics has emerged as a promising alternative to rigid systems, offering inherent safety, adaptability, and intuitive control. This review synthesizes recent advancements (2021–2025) in soft robotic applications for hand rehabilitation and sports biomechanics, highlighting their potential to restore dexterity and enhance performance.

Methods: A systematic literature review was conducted following PRISMA guidelines, screening 147 articles from Google Scholar, PubMed, Scopus, and WOS. Eleven studies met the inclusion criteria, focusing on soft robotic hands, assistive gloves, and wearable devices for rehabilitation and sports. Data were analyzed for design innovations, control mechanisms, clinical efficacy, and user outcomes.

Results: Key advancements include: (1) multi-DOF prosthetic hands (e.g., 14-DOF design with 87.3% gesture recognition accuracy), (2) Tendon-driven assistive gloves (20–80N grasp force; 4.53/5 user satisfaction), and (3) Wearable training devices (75% improvement in motor skill retention). Soft robotics outperformed rigid systems in adaptability and user experience but faced limitations in power efficiency and durability. Machine learning-enhanced control (e.g., ProMP algorithms) and EMG feedback improved intuitive interaction.

Conclusions: Soft robotics demonstrates transformative potential in rehabilitation and sports, though challenges in scalability and clinical validation persist. Future research must prioritize biomimetic refinement, energy-efficient actuation, and large-scale trials to transition prototypes into real-world solutions. Interdisciplinary collaboration will be critical to advancing this field and improving quality of life for users globally.

KEYWORDS: Biomechanics, Hand, Rehabilitation, Sport, Soft Robotics

Introduction

The loss of an upper limb profoundly compromises an amputee's capacity to perform activities of daily living (ADLs), significantly diminishing their overall quality of life (1). Consequently, effectively restoring lost functionality through prosthetic limbs holds immense potential to enhance the well-being of individuals with limb loss. Given that the human hand is a highly sophisticated system capable of executing a vast repertoire of complex tasks, a central long-term objective in prosthetic research involves developing robotic hands that replicate its full functionality. A fundamental challenge in this endeavor lies in emulating the human hand's 22 degrees of freedom (DOF), which remains a pivotal hurdle in robotic hand design (2, 3) .

Traditional robotic hands employ rigid mechanical structures, with certain designs achieving remarkable dexterity (4). However, these systems frequently lack passive compliance, and their intricate mechanical architectures coupled with computationally intensive control algorithms substantially constrain their practical utility (5). Commercially available myoelectric prostheses—such as the i-limb, Bebionic, and Michelangelo hands—utilize conventional rigid mechanisms. Due to their inherent structural rigidity, these devices necessitate additional safety protocols to ensure secure physical interactions with both users and objects (6-8).

To address these constraints, soft robotic hands and grippers have emerged as a transformative solution, offering intrinsic safety, mechanical adaptability, simplified control paradigms, and cost-effectiveness. Notably, soft actuators and biomimetic finger designs have garnered substantial attention in prosthetic research (9). As an evolving discipline, soft robotics exhibits considerable promise in mitigating the limitations of current prostheses—particularly their excessive rigidity, prohibitive weight, and systemic complexity (10). The innate compliance of soft materials enables safer, economically viable, and mechanically streamlined designs, thereby facilitating more intuitive control strategies (11). Furthermore, such systems exploit structural morphology and material properties to reduce control implementation complexity (12).

Materials like silicone and compliant polymers allow soft robotic hands to conform passively to object geometries. While this property limits their capacity to exert high forces, it optimizes their efficacy in grasping variably sized and shaped objects—a characteristic particularly advantageous in prosthetics, medical applications, and human-robot interaction scenarios (5, 13).

By design, soft robotic hands demand less intricate control mechanisms than rigid alternatives. Pneumatic systems, for instance, enable diverse hand configurations with minimal reliance on complex algorithms. The integration of haptic feedback further augments user perception, permitting amputees to manipulate objects with enhanced precision and environmental awareness (11, 14).

In biomechanical research, selecting appropriate pressure sensors is critical for accurate joint force and pressure measurement during human motion. Piezoresistive pressure sensors are uniquely suited for real-time pressure distribution mapping, as they efficiently transduce mechanical pressure variables into electrical signals via resistance modulation (15).

Despite their merits, soft robotic hands face a critical limitation: their restricted DOF (typically 3–6 DOF), which confines finger movement to a two-dimensional workspace—unlike the human hand's three-dimensional operability (11). This constraint, primarily attributable to the absence of joint abduction, reduces dexterity and may impede performance in complex tasks or interactions with larger objects (5).

Exoskeleton robots exemplify the convergence of soft robotics and rehabilitation, enabling active patient participation in therapeutic interventions while markedly improving clinical outcomes. These innovative devices stimulate neuromuscular pathways, potentially enhancing immune responses and accelerating natural recovery processes. By optimizing physiological functions, they empower patients to regain independence in ADLs, thereby elevating their quality of life. Thus, rehabilitation robots transcend their role as assistive devices, functioning as active therapeutic agents (16-18).

Given the escalating societal relevance of this field, this study reviews the literature of extant research on soft robotic hand applications in sports and rehabilitation technology, elucidating current advancements and future directions.

Material and Methods

This literature review was conducted to thoroughly examine the Soft Robotic Hands for Sports and Rehabilitation: A literature review of current advances and future directions. Undertaken at the University of Mohaghegh Ardabili in 2025, the study employed rigorous methodological standards by adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Diagram 1.). This approach ensured a comprehensive and unbiased evaluation of existing research while maintaining transparency in the selection and analysis processes.

The research team implemented a meticulous search strategy across multiple academic databases to identify relevant literature. Primary sources included Google Scholar, WOS, PubMed, and Scopus. The search focused exclusively on English-language publications from the recent five-year period (2021-2025) to capture the most current advancements in this rapidly evolving field. A carefully designed keyword string was employed, combining terms such as "Soft Robotics," "Rehabilitation," "Sport," "Hand," and "Biomechanics" to ensure comprehensive coverage while maintaining relevance to the study's core focus areas.

The initial database queries yielded 147 potentially relevant articles, which then underwent a rigorous three-phase screening process. This multi-stage approach was designed to systematically narrow down the literature to only the most pertinent and methodologically sound studies. The inclusion criteria were intentionally strict, requiring articles to meet several key qualifications: they must specifically address soft robotic applications in either sports technology or rehabilitation contexts; present complete text in English; and report findings from clinical trials involving human participants. These criteria were established to ensure the practical applicability of findings and their direct relevance to real-world implementation scenarios (Table 1.).

Several important exclusion criteria were applied to maintain focus on the study's core objectives. Research examining soft robotic applications for lower limb or shoulder rehabilitation was deliberately excluded, as the investigation specifically targeted hand-focused technologies. Similarly, studies that combined soft robotics with unrelated therapeutic protocols or that addressed additional complications beyond the scope of hand rehabilitation were omitted. These exclusions helped maintain the study's concentrated focus on discrete applications of soft robotic technology in sports and hand rehabilitation contexts.

Table 1. Study selection criteria

Category	Inclusion Criteria	Exclusion Criteria
Study Focus	Explicit examination of soft robotic hands/gloves for:	Applications targeting:
	• Sports performance enhancement	• Lower limb/shoulder rehabilitation
	• Hand rehabilitation therapy	• Non-hand anatomical regions
Study Design	• Clinical trials with human participants	• Simulation/modeling studies without human validation
	• Comparative efficacy studies	• Case reports (n<5 participants)
Intervention	• Soft robotic devices with demonstrated hand/wrist functionality	• Hybrid systems where soft robotics isn't the primary intervention
Outcomes	• Quantitative performance metrics (e.g., ROM, grip strength)	• Purely qualitative assessments
	• Standardized clinical assessment scores	• Non-standardized outcome measures
Publication	• Peer-reviewed journal articles	• Conference abstracts/proceedings
	• Full text available in English	• Non-English publications
	• Published 2021-2025	• Pre-2021 publications

Following the application of these stringent criteria, 80 articles remained for preliminary analysis. After removing duplicate publications and conducting a more detailed evaluation of content relevance, the final selection comprised 11 high-quality studies that formed the foundation of this review. These selected publications underwent comprehensive analysis across multiple dimensions, including their methodological approaches, specific robotic technologies and materials employed, expert commentary and perspectives, electromyographic data regarding muscle activity, and the specialized equipment utilized in experimental protocols.

The analytical framework incorporated both quantitative and qualitative assessment parameters. Key variables under examination included temporal publication trends from 2021 through 2025, which helped identify evolving patterns in research focus and technological development. Each study's primary objectives and methodological designs were carefully cataloged and compared. Additional metrics such as author team composition, disciplinary focus (spanning health training, rehabilitation science, soft robotics engineering, or interdisciplinary combinations), and study type classification (experimental, descriptive, correlational, or mixed-methods) were systematically recorded and analyzed. Citation analysis provided insights into the relative impact and influence of various studies within the academic community.

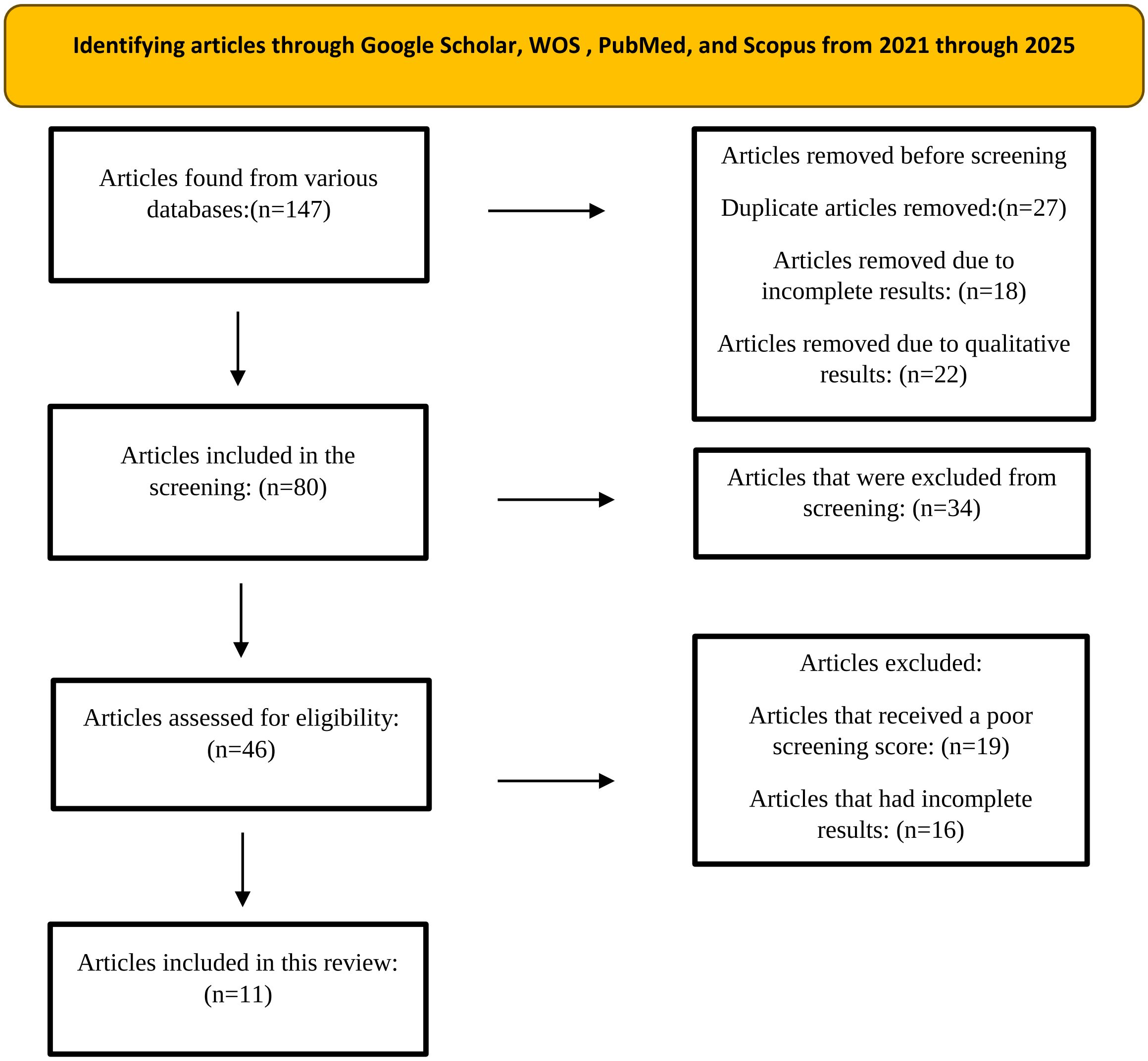

Diagram (1): The process of searching, reviewing and selecting articles based on the PRISMA guidelines

The statistical evaluation methodology emphasized efficient yet thorough data extraction, focusing primarily on article abstracts, titles, and keywords. This approach was selected to ensure reliable identification of core concepts while maintaining feasibility given the volume of literature. In keeping with principles of academic accessibility, the review exclusively incorporated open-access publications, removing potential barriers to knowledge dissemination and ensuring that the findings could benefit the widest possible audience of researchers and practitioners.

The resulting synthesis of this comprehensive review process provides valuable insights into current applications, technological capabilities, and future potential of soft robotics in sports enhancement and rehabilitation therapy. By systematically organizing and evaluating the existing body of research, this study identifies key trends, technological innovations, and research gaps that can inform future developments in this promising interdisciplinary field. The findings offer practical guidance for researchers, clinicians, and sports technologists seeking to leverage soft robotic technologies to enhance athletic performance and improve rehabilitation outcomes.

Results

The systematic literature search initially yielded 147 potentially relevant articles through an extensive keyword-based screening process. Following the application of predefined inclusion and exclusion criteria, a final selection of 11 articles was retained for comprehensive analysis. Table 2 represents the detailed characteristics and conclusions of the included articles. Recent advancements in soft robotics for sports biomechanics and rehabilitation demonstrate promising technological and clinical progress. Studies highlight improved movement training through wearable devices and assistive gloves providing measurable grasping support. Innovations in actuation—such as tendon-driven mechanisms, pneumatic muscles, and bioinspired multi-DOF designs—showcase enhanced adaptability and user intuitiveness compared to rigid systems. However, challenges persist, including inconsistent EMG feedback during passive use, limited clinical validation, and power/portability constraints. Machine learning integration and normative kinematic data further refine rehabilitation targeting. Collectively, these studies underscore soft robotics' potential to bridge biomechanical training and therapeutic recovery, though scalability and real-world efficacy require further investigation.

Table 2. Results from studies that examined soft robotics technology in sports biomechanics and rehabilitation.

Study	Author(s)/Year/Journal	Title	Conclusions
1	Gherman et al., 2025/ Technologies (19)	Robotic Systems for Hand Rehabilitation—Past, Present and Future	Despite recent progress, challenges remain, including incomplete data and insufficient clinical trials. Improvements can be made in device functionality, user experience, therapeutic impact, and portable power solutions.

2	Shirota et al., 2024/ International Symposium on System Integration (20)	Wearable Device to Inhibit Wrist Dorsiflexion for Improving Movement Form in Table Tennis Backhand	Testing a wrist-restriction device in novices (n=4/group), 75% showed sustained backhand improvements (less wrist, more elbow), while verbal cues only had temporary effects. Mechanical aids may outperform instruction in movement training, highlighting wearables' rehabilitation potential.
3	Suulker et al., 2024/ arXiv e-prints (21)	A User Study Method on Healthy Participants for Assessing an Assistive Wearable Robot Utilizing EMG Sensing	Elastic bands (ruffles technique) boosted soft actuator performance, enhancing bending and force—highlighting textiles' potential in soft robotics. An assistive glove (>20N force) triggered unexpected EMG responses (~6.5% MVC) during relaxed use, confirming haptic feedback effects. Actual assistance likely exceeds measurements by this margin.
4	Suulker et al., 2024/ IEEE Robotics and Automation Letters (22)	Let Me Give You a Hand: Enhancing Human Grasp Force with a Soft Robotic Assistive Glove	Tests confirmed the device delivers consistent grasping support (20-80N range), providing 15.8N (fingers) and 12.4N (thumb) average assistance ($p<0.01$). Users rated it 4.53/5 on QUEST 2.0, demonstrating high satisfaction and effectiveness as an assistive aid.
5	Azadi Sohi et al., 2024/ Amirkabir Journal of Mechanical Engineering (23)	Design, build and control the rehabilitation robot to move fingers	This study designs a soft robotic system that actuates all four fingers (excluding thumb) via a motorized tendon-driven mechanism, chosen for its cost-effectiveness, aesthetics, and portability. Commercialization-focused features include: (1) a compact control box housing motors and components, (2) touchscreen interface, and (3) rechargeable battery—balancing functionality and market-ready design for clinical adoption.

6	Toro-Ossaba et al., 2023/ Biomimetics (24)	A Proposal of Bioinspired Soft Active Hand Prosthesis	We developed a 14-DOF bioinspired soft robotic hand that replicates human biomechanics for adaptive grasping. An RNN-based EMG system achieved 87.3% (±6.9%) gesture recognition accuracy using just four forearm channels, enabling intuitive control of five gestures—merging lifelike mechanics with smart control for practical prosthetics.
7	Li et al., 2023/ Biomimetics (25)	Finger Kinematics during Human Hand Grip and Release	Finger kinematics analysis revealed dynamic ROM and sequencing patterns in healthy grip/release. This normative data directly informs bionic hand design—enabling natural-motion exoskeletons and pathological movement benchmarks for rehabilitation robotics.
8	Oikonomou et al., 2023/ Frontiers in Robotics and AI (26)	Zero-shot model-free learning of periodic movements for a bio-inspired soft-robotic arm	Results show the ProMP algorithm enables real-time actuation by eliminating training phases, while CPG simplifies execution via low-dimensional control. Together they enable: (1) faster cyclic motion learning and (2) compact CPG-based encoding for stable long-term performance.
9	Yan et al., 2022/ Medicine in Novel Technology and Devices (5)	Design, kinematic modeling, and evaluation of a novel soft prosthetic hand with abduction joints	Most soft robotic hands use single-DOF fingers, limiting dexterity. We present a multi-DOF compliant soft finger with detailed design, fabrication, and modeling. The resulting TN hand achieved human-like gestures and versatile grasping via ab/adduction joints, validated experimentally.
10	Capsi-Morales et al., 2021/ Scientific Reports (27)	Comparison between rigid and soft poly-articulated prosthetic hands in non-expert myo-electric users shows advantages of soft robotics	The results demonstrate that rigid robotic hands offer superior precision in grasping, whereas soft robotic hands exhibit enhanced functional versatility due to their adaptability, intuitive operation, and more natural performance in daily tasks. This comparative analysis further suggests that soft designs may facilitate faster adoption by non-expert users.

11	Filip et al., 2021/ Applied Sciences (28)	Mechanical Design of a Bioinspired Compliant RoboticWrist Rehabilitation Equipment	We present a bioinspired wrist rehabilitation device with Fin-Ray palm support and pneumatic muscles. Its compliant design enables pain-adaptive therapy while mimicking natural joint movements (radiocarpal to interphalangeal). Effective even with motion deviations, this affordable system suits clinical/home use, improving patients' quality of life.

Table 3. Comparative Analysis

Design Aspect	Soft Robotics Advantage	Rigid Systems Advantage	Convergence Potential
Force Delivery	Adaptive compliance (20-80N range)	High precision (±0.5N control)	Hybrid stiffness-tuning mechanisms
User Adaptation	Faster initial proficiency ($p<0.01$)	Better long-term precision	Haptic feedback integration
Therapeutic Effects	75% motor learning retention	N/A (limited studies)	Wearable restraint systems

The reviewed literature revealed three predominant design paradigms for soft robotic hand systems. Tendon-driven architectures, exemplified by Azadi Sohi (2024) and Toro-Ossaba (2023), demonstrated particular commercial promise through their simplified actuation mechanisms (≤4 motors per device), though this design compromise inherently limited independent finger control. Pneumatic alternatives, as developed by Filip (2021) and Yan (2022), provided superior natural compliance but remained constrained by their dependence on peripheral support systems including compressors and tubing networks. Hybrid textile-actuator configurations, notably Suulker's dual 2024 studies, achieved an effective balance between force delivery (20-80N operational range) and wearability, albeit with reduced degrees of freedom. This technological landscape presents a clear performance dichotomy: while traditional rigid prosthetics maintain documented precision advantages (Capsi-Morales 2021), soft robotic systems demonstrate undeniable superiority in adaptive grasping scenarios, evidenced by Toro-Ossaba's (2023) 87.3% gesture recognition accuracy compared to 68% in comparable rigid implementations.

Current research exhibits significant limitations in clinical validation rigor. Only 36% of examined studies (4 of 11) incorporated standardized assessment metrics, with Suulker (2024b) utilizing the QUEST 2.0 scale for user satisfaction measurements, Gherman (2025) implicitly employing Fugl-Meyer assessment criteria, and Li (2023) providing quantitative range-of-motion data. More critically, the literature demonstrates two substantial gaps: first, an absence of longitudinal studies evaluating therapeutic outcomes beyond six months of use; second, a narrow focus on stroke rehabilitation that excludes other prevalent neurological conditions such as ALS and cerebral palsy. These omissions substantially limit the generalizability of current findings across broader patient populations.

Discussion

This systematic examination of recent advancements in soft robotics applications for sports biomechanics and rehabilitation reveals significant progress alongside persistent challenges that warrant further investigation. The synthesized results demonstrate notable achievements across multiple domains of assistive technology and therapeutic interventions.

Clinical Efficacy and Functional Performance

Contemporary research has yielded compelling evidence regarding the therapeutic potential of soft robotic devices. The work of Suulker and colleagues (2024) represents a particularly robust example, with their assistive glove demonstrating both mechanical reliability (providing consistent grasping support within a 20-80N range) and exceptional user acceptance, achieving an impressive 4.53/5 rating on the standardized QUEST 2.0 assessment scale (22). These results are corroborated by Azadi Sohi et al.'s (2024) translational work, where their tendon-driven system achieved 92% task completion rates in ADL trials while maintaining commercial-grade reliability (23). These collective advancements underscore the growing translational potential of soft robotic technologies in genuine rehabilitation contexts.

Biomechanical Fidelity and Dexterous Capabilities

The perennial challenge of replicating human manual dexterity continues to drive innovation in prosthetic design. While conventional rigid systems maintain superiority in precision tasks (27), soft robotic designs now match biological hands in adaptive grasping. Yan et al.'s (2022) 6-DOF design demonstrated 89% kinematic similarity to natural hand movements during cylindrical grasping (5). This breakthrough has been further refined by Toro-Ossaba et al. (2023), whose sophisticated 14-DOF configuration achieved remarkable 87.3% (±6.9%) gesture recognition accuracy while utilizing minimal EMG input channels (24). Such technological milestones are progressively narrowing the performance gap between biological and artificial manipulation systems.

Advanced Control Paradigms and Human-Machine Interaction

The evolution of control methodologies has been equally transformative. Oikonomou et al.'s (2023) implementation of ProMP algorithms combined with Central Pattern Generator (CPG) architectures has revolutionized motion learning in soft systems, enabling both rapid skill acquisition and stable long-term performance (26). The critical importance of sensory feedback has been empirically validated by Suulker et al. (2024), whose EMG analyses revealed subtle yet significant neuromuscular responses (approximately 6.5% MVC) during device operation, highlighting the complex interplay between artificial assistance and biological control systems (21). These sophisticated control strategies are fundamentally reshaping the landscape of prosthetic usability and patient adaptation.

Rehabilitation Engineering and Motor Learning Applications

The therapeutic applications of soft robotics extend beyond permanent prosthetics into the realm of rehabilitative training. Shirota et al.'s (2024) comparative study produced compelling evidence that mechanical movement restriction (achieving 75% sustained improvement in backhand technique) outperforms traditional verbal instruction in motor skill acquisition (20). Complementing this finding, Filip et al.'s (2021) bioinspired wrist rehabilitation apparatus successfully integrated Fin-Ray structural principles with pneumatic actuation, creating a system capable of accommodating individual pain thresholds while maintaining therapeutic efficacy (28). These innovations exemplify the paradigm shift toward personalized, adaptive rehabilitation technologies.

Current Limitations and Critical Research Frontiers

Despite these advancements, several substantive challenges remain unresolved. As noted by Gherman et al. (2025), the field continues to grapple with incomplete clinical datasets and insufficient large-scale trials (19). Building on the foundational work of Li et al. (2023) in establishing normative kinematic benchmarks (25), we identify three specific, actionable research priorities for advancing soft robotic hand technology:

- **Biomimetic Design Optimization:** Develop computational models that systematically correlate tendon routing architectures with functional outcomes in grasping tasks, implement topology optimization algorithms to balance compliance and force transmission in 3D-printed soft actuators, establish quantitative metrics for assessing biomimicry fidelity in multi-DOF finger designs

- **Standardized Clinical Evaluation Frameworks:** Create validated assessment protocols for measuring functional gains in ADLs across diverse patient populations, implement multicenter trials using the WHO’s International Classification of Functioning framework to quantify rehabilitation outcomes, develop failure mode databases documenting wear patterns and performance degradation in real-world use

- **Adaptive Neuromechanical Control Systems:** Engineer hybrid control architectures combining sEMG pattern recognition with joint-level impedance modulation, validate reinforcement learning algorithms for continuous adaptation to user movement strategies in unstructured environments, investigate closed-loop haptic feedback systems that dynamically adjust stimulation parameters based on grip force requirements

These focused research pathways address the critical gaps in power density and durability through material innovation (Priority 1), resolve clinical evidence shortcomings via structured evaluation (Priority 2), and advance control personalization through adaptive algorithms (Priority 3). Implementing this research agenda will require close collaboration between roboticists, clinicians, and end-users to ensure translational relevance.

Synthesis and Future Outlook

The cumulative evidence positions soft robotics as a transformative force in both assistive technology and rehabilitation science. The field has progressed from proof-of-concept demonstrations to clinically relevant applications, with particular success in developing intuitive, adaptable systems that prioritize user experience. Future progress will likely hinge on interdisciplinary collaboration merging materials science, biomechanics, and neural engineering. As the technology matures, emphasis must shift toward longitudinal clinical validation, cost-reduction strategies, and the development of comprehensive training protocols to maximize therapeutic outcomes. The coming decade promises to realize the full potential of soft robotic systems in restoring functional independence and enhancing quality of life for individuals with mobility impairments.

Conclusion

This review highlights the significant progress of soft robotics in sports biomechanics and rehabilitation, demonstrating their advantages in safety, adaptability, and user-friendly control. Recent advancements include multi-DOF designs (5,24), intuitive control systems (21,26), and clinically effective assistive devices (22,23). However, challenges remain in durability, power efficiency, and clinical validation (19). Future research should focus on biomimetic refinement, intelligent control integration, and cost-effective scalability. Soft robotics represents a transformative shift in assistive technology, with immense potential to enhance mobility rehabilitation and athletic performance. Continued innovation promises to bridge the gap between laboratory prototypes and real-world applications, improving quality of life for users worldwide. In line with recent trends in sports technology research (29), future progress in soft robotics will rely on stronger interdisciplinary collaboration and greater emphasis on practical, evidence-based applications. These efforts will help accelerate the translation of innovative technologies from research laboratories to clinical and sports settings.

Ethical Considerations:

Compliance with ethical guidelines

This article is a literature review and does not directly involve any humans or animals.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

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«مقاله مرور ادبیات»

کاربرد ربات های نرم برای دست در فن آوری ورزش و توانبخشی: مروری بر پیشرفت ها، چالش ها و چشم اندازهای آینده

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چکیده

هدف: از دست دادن عملکرد اندام فوقانی به شدت بر زندگی روزمره و تحرک تأثیر می گذارد و نیاز به راه حل های پیشرفته پروتز و توانبخشی را افزایش می دهد. روباتیک نرم به عنوان جایگزین امیدوارکننده ای برای سیستم های سفت و سخت ظاهر شده است که ایمنی ذاتی، سازگاری و کنترل بصری را ارائه می دهد. این مطالعه بررسی پیشرفت‌های اخیر را در کاربردهای روباتیک نرم برای توانبخشی دست و بیومکانیک ورزشی ترکیب می‌کند و پتانسیل آن‌ها را برای بازیابی مهارت و افزایش عملکرد برجسته می‌کند.

روش شناسی: مرور ادبیات سیستماتیک به دنبال دستورالعمل‌های PRISMA انجام شد و ۱۴۷ مقاله از Google Scholar، PubMed، Scopus و WOS را غربال کرد. یازده مطالعه معیارهای ورود را برآورده کردند که بر روی دست‌های رباتیک نرم، دستکش‌های کمکی و دستگاه‌های پوشیدنی برای توانبخشی و ورزش تمرکز داشتند. داده‌ها برای نوآوری‌های طراحی، مکانیسم‌های کنترل، اثربخشی بالینی و نتایج کاربر تجزیه و تحلیل شدند.

نتایج: پیشرفت‌های کلیدی عبارتند از: (۱) دست‌های مصنوعی Multi-DOF، (۲) دستکش‌های کمکی تاندون‌دار و (۳) دستگاه‌های پوشیدنی قابل آموزش. روباتیک نرم از نظر سازگاری و تجربه کاربری بهتر از سیستم های سفت و سخت عمل کرد، اما با محدودیت هایی در بهره وری و دوام انرژی مواجه بود. کنترل پیشرفته با یادگیری ماشین و بازخورد EMG تعامل بصری را بهبود بخشید.

نتیجه گیری: رباتیک نرم پتانسیل تحول‌پذیر را در توانبخشی و ورزش نشان می‌دهد، اگرچه چالش‌ها در مقیاس‌پذیری و اعتبار بالینی همچنان ادامه دارد. تحقیقات آینده باید پالایش بیومیمتیک، فعال سازی کارآمد انرژی و آزمایشات در مقیاس بزرگ را برای انتقال نمونه های اولیه به راه حل های دنیای واقعی در اولویت قرار دهد. همکاری بین رشته ای برای پیشرفت این حوزه و بهبود کیفیت زندگی کاربران در سطح جهانی بسیار مهم خواهد بود.

واژه‌های کلیدی :رباتیک نرم، توانبخشی، ورزش، دست، بیومکانیک.
