

Technological developments in physical therapy and their impact on healthcare: A Literature Review

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Abstract: In recent years, advancements in technology have significantly altered the healthcare landscape, especially in the field of physical therapy. This transformation encompasses a wide range of innovations, from telemedicine to digital rehabilitation tools, all of which collectively improve patient engagement and the effectiveness of treatments. Numerous studies have highlighted that digital health technologies aim not only to enhance accessibility but also to address ethical concerns related to patient autonomy and beneficence. Furthermore, the integration of telemedicine has shown benefits for resource utilization and continuity of care, particularly during critical times such as the COVID-19 pandemic. However, challenges remain, including the need for adequate training for both healthcare providers and patients, as well as issues surrounding data security. This review will offer a critical evaluation of these technological advancements, focusing on their implications for improving physical therapy outcomes while also tackling the persistent ethical and systemic challenges.

Keywords: physiotherapy, healthcare, progress.

1. INTRODUCTION

Physical therapy is a branch of rehabilitative healthcare focused on enhancing mobility, functionality, and overall quality of life for individuals experiencing physical impairments or disabilities. This discipline includes a diverse array of treatment methods, such as manual therapy, exercise prescription, and patient education, all customized to address the specific needs of each patient. The advancement of technology within this field has greatly improved therapeutic practices, allowing for more personalized and effective care. For example, innovative digital platforms are being developed that facilitate remote monitoring and engagement with patients, ultimately resulting in more informed treatment strategies and improved health outcomes for those with chronic conditions. Moreover, the incorporation of robotics and virtual reality into rehabilitation acts as a driving force in enhancing physical therapy sessions, creating an interactive setting that increases patient motivation and compliance. As these technological innovations integrate machine learning, they hold the potential to transform rehabilitation approaches, further refining the concept of physical therapy in modern healthcare.. (1–3)

The realm of healthcare has undergone significant changes due to a variety of technological innovations that improve patient care and treatment results. A key focus is the incorporation of wearable devices and mobile applications tailored for home-

based rehabilitation, allowing patients to participate in recovery activities from their own residences. Recent studies demonstrate that these technologies not only encourage compliance with rehabilitation protocols but also enable remote monitoring, which may lead to a decrease in readmission rates. Additionally, developments in telemedicine and digital health platforms tackle mental health issues by offering improved access to therapeutic tools, as shown by the creation of mobile applications designed to enhance emotional regulation abilities. Although substantial advancements have been achieved, it is crucial to confront the existing obstacles to technology adoption among diverse populations to fully harness the transformative capabilities of these healthcare innovations. (1,4,5)

The incorporation of technology into physical therapy is demonstrating a transformative effect, improving patient care and optimizing therapeutic results. Recent developments, especially in artificial intelligence (AI) and remote monitoring technologies, have introduced novel methods that promote the ongoing involvement of patients in their treatment regimens. For example, a technological platform created for the remote monitoring of patients suffering from Chronic Obstructive Pulmonary Disease (COPD) illustrates a transition towards personalized healthcare by employing AI algorithms to collect and evaluate clinical data in real-time. Such initiatives not only enhance treatment effectiveness by offering healthcare providers a thorough overview of a patient's condition but also lower hospitalization rates through proactive management. Furthermore, the advancing landscape of AI in educational environments seeks to prepare future physical therapists with essential skills, thus improving productivity and potentially reducing errors in practice. As technological advancements continue to arise, their significance in facilitating effective rehabilitation is expected to increase, making it crucial for practitioners to stay updated on their applications and advantages. (3)

The objective of this narrative review is to clarify the notable technological advancements that have revolutionized the domain of physical therapy and, consequently, influenced the broader healthcare delivery system. By conducting a thorough examination of the current literature, this review seeks to emphasize both the novel tools and methodologies that have emerged and the subsequent effects on patient outcomes and the practices of healthcare practitioners.

2. INNOVATIONS IN PHYSICAL THERAPY TECHNOLOGY

The realm of physical therapy is undergoing a significant transformation due to extraordinary technological innovations, which are fundamentally improving patient care and the effectiveness of treatments. These advancements encompass a variety of elements, including the incorporation of artificial intelligence (AI) and advanced rehabilitation devices that support customized therapy plans. AI, for example, has become an essential resource that enhances access to medical data and improves diagnostic precision, thus enabling therapists to more effectively customize interventions to meet individual requirements, as emphasized in recent discussions regarding its role in physical therapy education. Furthermore, technologies like wearable sensors and telehealth platforms facilitate ongoing monitoring and immediate modifications to treatment strategies, thereby optimizing patient results. The merging of these innovations is not solely a matter of technology but also reflects socio-cultural changes, promoting a transition towards more proactive, patient-focused care methodologies, as observed in trends across various medical fields. Together, these advancements herald a hopeful future for healthcare, significantly improving the overall effectiveness of therapeutic practices. (6)

The emergence of telehealth and remote therapy options has significantly altered the healthcare delivery landscape, especially within the field of physical therapy. The COVID-19 pandemic hastened the implementation of these technologies, as healthcare professionals were forced to explore innovative strategies to sustain patient care during extensive restrictions. This transition not only improved access for patients in remote and underserved areas but also raised expectations for digital solutions among the populace. Telehealth's capacity to connect individuals across distances has revealed considerable advantages, such as enhanced patient outcomes and cost efficiency, particularly for chronic illnesses like diabetes. However, challenges remain, especially regarding technological obstacles and the necessity for equitable access to these digital health services. As a result, the incorporation of telehealth into conventional care frameworks presents a promising opportunity to improve accessibility in physical therapy while tackling existing inequalities in healthcare provision. (6-8)

The incorporation of wearable technology into the healthcare sector has introduced significant advantages, especially in the area of physical therapy. By utilizing devices that consistently track health indicators, such as heart rate and levels of physical activity, healthcare professionals can customize rehabilitation programs to address the specific needs of each patient, leading to improved therapeutic results. The integration of machine learning and the Internet of Things (IoT) within these wearables enables real-time feedback, which allows for prompt modifications to treatment strategies. Nevertheless,

the adoption of such technologies frequently encounters obstacles related to data privacy and the availability of sophisticated systems in rural areas. Additionally, while chatbots provide assistance for automated patient engagement, their use in primary healthcare is still insufficiently explored, indicating a necessity for targeted research. Ultimately, as new technologies progress, the ethical considerations regarding user consent and data protection must be meticulously managed to guarantee fair healthcare access for everyone, particularly for neurodivergent individuals. (9)

In recent years, robotics and automated rehabilitation devices have become essential elements in the progress of physical therapy, greatly improving patient care and rehabilitation results. These technologies, which utilize artificial intelligence, are crafted to offer consistent, guided rehabilitation exercises customized to individual requirements, thus enhancing patient engagement and adherence. Moreover, the incorporation of wearables and telehealth solutions has enabled remote monitoring, allowing healthcare providers to observe progress and implement necessary modifications in real time, as evidenced by the emergence of Tele-Neurorehabilitation (TNR) in the wake of the COVID-19 pandemic. The capacity to deliver personalized interventions through robotic devices not only improves therapeutic accuracy but also tackles issues related to accessibility and resource distribution within healthcare environments, particularly in underserved areas. As technological advancements continue to progress, the function of robotics in rehabilitation is set to transform traditional practices, ultimately resulting in better patient outcomes. Therefore, the future of physical therapy is expected to be increasingly connected with the capabilities provided by these groundbreaking devices. (10)

In recent years, the incorporation of virtual reality (VR) and augmented reality (AR) into therapeutic practices has emerged as a groundbreaking advancement in healthcare, significantly improving patient care. These immersive technologies enable the creation of realistic environments that support various therapeutic interventions, assisting patients in overcoming psychological barriers or physical limitations. For example, VR has demonstrated its ability to enhance rehabilitation outcomes for patients recovering from surgery or injury by offering engaging simulations that promote movement and interaction, thereby facilitating recovery through gamification. Moreover, AR technologies provide real-time overlays of information within a patient's environment, which can assist in education and motivation, enabling individuals to gain a better understanding of their treatment processes. Additionally, the integration of AI with VR and AR environments holds the potential to customize therapeutic experiences, tailoring them to the specific needs of individual patients and thereby enhancing therapeutic effectiveness. Consequently, the continuous advancement of these technologies is poised to transform the field of physical therapy, rendering healthcare services more accessible and efficient. (11)

3. IMPACT ON PATIENT OUTCOMES

The incorporation of technological innovations in physical therapy has significantly improved patient outcomes across multiple facets of healthcare. For example, remote monitoring systems designed for individuals with Chronic Obstructive Pulmonary Disease (COPD) utilize artificial intelligence to tailor treatment strategies, leading to enhanced disease management and a decrease in hospital admissions, which in turn elevates patients' quality of life. Moreover, the application of Polylactic Acid composites in bone regeneration reveals notable improvements in mechanical characteristics and biological activity, fostering enhanced osteoblast proliferation and, as a result, more efficient healing processes. In addition, the use of Virtual Reality (VR) in medical education and patient interaction provides immersive experiences that bolster comprehension and recovery while supporting informed decision-making. Together, these technological advancements represent a transition towards more patient-centered care, highlighting the potential for better clinical outcomes and increased patient satisfaction. (3,11)

The progress of technological innovations in physical therapy has greatly improved the availability of therapy services, a fact that was particularly evident during the challenges posed by the COVID-19 pandemic. Recovery colleges, for instance, showcased the effectiveness of hybrid models in delivering therapy services, which merge in-person interactions with online course offerings, thus extending their reach to individuals facing mental health issues. In a similar vein, healthcare professionals in Vietnam pointed out that digital rehabilitation technologies enhance patient care by addressing obstacles created by geographic constraints, although challenges such as insufficient training and privacy issues continue to be significant. The growing involvement of pharmacists in clinical settings further bolsters this trend, as their capacity to address medication-related issues can complement physical therapy and improve overall patient outcomes. Together, these advancements illustrate how technological progress is transforming service delivery, rendering therapy more accessible to a variety of populations, including those in rural and underserved regions. (12,13)

The incorporation of technology into physical therapy has significantly improved patient involvement and compliance, thus addressing essential elements of effective healthcare provision. Digital resources, such as telehealth services and mobile health applications, not only enable ongoing communication between patients and healthcare professionals but also empower individuals to actively participate in the management of their treatment plans. For example, research has demonstrated that remote assistance via these technologies enhances accessibility, especially in rural regions where healthcare services are limited. Additionally, educational programs offered through digital channels can dispel misconceptions and boost patient satisfaction, which are crucial factors influencing adherence to treatment protocols. Furthermore, the integration of arts and health initiatives within these technological frameworks promotes a comprehensive approach to patient care, enhancing both mental and physical health. Therefore, the combination of technology and patient-focused strategies in physical therapy plays a significant role in improving adherence and overall healthcare results. (14)

The emergence of data-driven personalized treatment plans signifies a crucial development in the realm of physical therapy, improving patient outcomes via customized interventions. By utilizing patient-specific data, such as genetic information, physical evaluations, and real-time monitoring, healthcare professionals can create more effective therapeutic approaches that cater to the distinct requirements of each individual. This methodology is in line with the increasing movement towards personalized medicine, as evidenced in oncology, where AI technologies greatly enhance treatment decision-making through precision and targeted therapies. Moreover, the incorporation of digital twins in healthcare facilitates dynamic simulations of patient responses, providing further insights to practitioners regarding optimal treatment pathways. Nevertheless, the adoption of these technologies requires strong ethical frameworks and regulatory measures to tackle issues related to data privacy and algorithmic bias. Therefore, while the transition towards data-driven personalized treatment plans is promising, it necessitates thorough consideration of the complex implications within the healthcare sector. (15–17)

The impact of technological innovations in physical therapy is demonstrated by their notable contributions to recovery rates in various healthcare settings. For example, digital rehabilitation technologies have proven effective in improving patient care, especially for individuals encountering challenges related to training and accessibility, as noted by Thapa et al. In the realm of perioperative care, advancements such as minimally invasive surgical methods and remote monitoring tools have been crucial in accelerating patient recovery and minimizing postoperative complications, thereby showcasing the relationship between technology and enhanced outcomes. Additionally, the incorporation of telemedicine into healthcare practices has been revolutionary, particularly during the COVID-19 pandemic, as it has validated its effectiveness in improving recovery processes through remote care alternatives. Ultimately, the amalgamation of these technological advancements highlights their significance in promoting more efficient recovery strategies for patients, thus transforming the healthcare landscape. (18,19)

4. CHALLENGES AND CONSIDERATIONS

As the integration of technology into therapeutic practices progresses, it unveils a multifaceted array of ethical considerations that warrant thorough examination. The swift incorporation of digital health innovations, including artificial intelligence and virtual reality, presents promising opportunities for improved patient care; however, it concurrently raises significant ethical dilemmas related to autonomy and beneficence. For example, the risk of undermining patient agency by permitting algorithms to determine treatment trajectories calls for a critical evaluation of the autonomy principle within medical ethics. Moreover, the convergence of social engagement and assistive technologies requires careful navigation to prevent any adverse effects on patient well-being, highlighting the necessity for comprehensive ethical frameworks to guide practice. As the European Union formulates policies to tackle these technological developments, the ramifications of AI in therapeutic contexts, especially regarding data protection and bias, emphasize the pressing need to establish ethical standards that guarantee fair treatment for all patients. (20)

In light of the technological progress in physical therapy, financial barriers and issues related to insurance coverage continue to pose significant challenges to achieving equitable access to healthcare. Numerous innovative therapeutic technologies, although potentially advantageous, often entail substantial costs that may discourage patients from pursuing essential treatment. This financial strain is intensified by insufficient insurance coverage, which frequently does not include the most recent technological interventions, thus restricting access for patients who could greatly benefit from them. A study indicated that international patients, even when insured, face ongoing obstacles in obtaining quality healthcare, suggesting that coverage issues transcend mere financial capacity. Furthermore, while advancements in telehealth improve service

availability, they may unintentionally worsen inequities due to differing patient abilities to utilize such technologies. Therefore, it is imperative to address these disparities in cost and coverage to fully harness the potential advantages of technological innovations in the realm of physical therapy. (7)

The changing dynamics of technology in physical therapy highlight the importance of thorough training and education for healthcare professionals. As innovations like telemedicine and digital rehabilitation technologies become essential components of patient care, there is a pressing requirement for practitioners to master these tools. Research shows that although digital platforms can significantly improve patient outcomes, there are still training deficiencies, especially concerning the usability and accessibility of these technologies across various environments, as noted in. Moreover, the use of virtual reality (VR) in therapeutic education promotes immersive learning experiences, allowing practitioners to rehearse intricate procedures without jeopardizing patient safety. The integration of artificial intelligence into educational systems can further enhance learning experiences by providing instant feedback and fostering critical thinking abilities. Ultimately, it is crucial to ensure that healthcare professionals possess the necessary technological skills to enhance healthcare delivery and improve patient experiences. (11,17)

As advancements in technology transform physical therapy practices, the issues of patient privacy and data security have become increasingly significant. Digital rehabilitation technologies have the capacity to greatly improve patient outcomes; however, they also introduce essential ethical dilemmas related to data management, informed consent, and privacy. For example, while utilizing platforms that track chronic conditions such as COPD can provide personalized health interventions, there is still the danger of insufficient safeguarding of sensitive information, particularly when incorporating AI systems that necessitate extensive user data. Moreover, the absence of standardization in digital health applications may result in discrepancies in data protection protocols, which could threaten patient autonomy and trust. Given the swift progression of technologies in healthcare, it is crucial for policymakers and technology developers to work together in tackling these issues to guarantee safe and effective patient engagement. (21)

5. CONCLUSION

In summary, the advancements in technology within the realm of physical therapy offer substantial opportunities to improve the healthcare environment, influencing both patient outcomes and the delivery of services. Recent studies indicate that telemedicine has become a vital component in enabling remote patient care, particularly emphasized during the COVID-19 pandemic, which has encouraged a transition towards more accessible healthcare options. Additionally, while digital health innovations such as artificial intelligence and virtual reality hold the potential to transform patient engagement and treatment methodologies, they also raise ethical dilemmas that require thorough examination. The experiences of healthcare practitioners in areas like Vietnam further illustrate the promise of digital rehabilitation technologies, highlighting both their advantages and the challenges related to training and accessibility that need to be addressed for successful implementation. Ultimately, the continuous development of these technologies marks a critical juncture in healthcare, where collaborative efforts among various stakeholders are crucial to surmount systemic obstacles and enhance patient care.(22)

The incorporation of technological innovations in physical therapy has produced considerable advantages for healthcare delivery and patient outcomes, as demonstrated by various recent studies. For example, digital health technologies, including mobile applications and telemedicine, have improved access to care by facilitating remote consultations and offering patients self-help resources, thus promoting greater independence in managing their health. Moreover, advancements in mobile health applications, illustrated by the creation of tools like "Safer," highlight the potential for targeted interventions that tackle intricate emotional and behavioral issues encountered by patients. In addition, a systematic review indicates that digital technologies, artificial intelligence, and the Internet of Things have transformed patient monitoring and data management, emphasizing both their revolutionary potential and the ethical dilemmas related to privacy and trust within healthcare systems. These insights emphasize the complex influence of technology on physical therapy and its wider implications for the healthcare sector. (5,23)

As technology advances, the future of physical therapy is set for significant transformations that can greatly improve patient engagement and therapeutic results. A promising avenue is the incorporation of artificial intelligence to develop dynamic platforms for remote patient monitoring, especially for chronic illnesses such as Chronic Obstructive Pulmonary Disease (COPD). This incorporation enables the creation of personalized treatment plans by allowing healthcare professionals to monitor patients' progress in real time. Moreover, new methodologies such as virtual reality and the metaverse provide

immersive rehabilitation experiences, which could greatly enhance patient motivation and adherence. However, the field encounters challenges, including insufficient specialized training for practitioners in innovative techniques like vestibular rehabilitation, which is vital for the management of neurological disorders. Consequently, it is crucial to address these deficiencies through educational programs and enhanced access to technology to fully realize the advantages of these advancements in physical therapy. (3,24,25)

The incorporation of technological innovations in physical therapy carries substantial implications for healthcare policy and practice, prompting a reassessment of current frameworks to integrate these advancements. The growing dependence on digital health technologies, including artificial intelligence and virtual reality, not only improves patient involvement but also introduces ethical dilemmas concerning autonomy and beneficence within care models. Policymakers are required to confront these issues by formulating regulations that foster equitable access to new therapies while protecting patient rights. Additionally, the rise of social media as a communication medium in healthcare presents opportunities for education and engagement, although institutions must address challenges related to expertise and risk. As the healthcare sector continues to progress technologically, there is an immediate necessity for policies that mirror these transformations, ensuring that innovations are directed towards enhancing patient outcomes in a responsible and inclusive way.

The advancement of technology in physical therapy represents a crucial development in the healthcare sector, reshaping the realm of patient rehabilitation and management. With the advent of innovative solutions like remote monitoring systems, patients are empowered to take an active role in their health journeys, highlighting the potential for more individualized care. Historical analyses further demonstrate the progression of therapeutic techniques from basic methods to evidence-based practices, integrating innovations such as music therapy, which has achieved professional recognition and emphasized the interconnectedness of various therapeutic fields. Additionally, the implementation of sophisticated imaging technologies, such as SPECT/CT, improves diagnostic accuracy and aids in the formulation of customized rehabilitation plans, particularly in the areas of cardiac and neurological care. Together, these developments not only enhance patient outcomes but also indicate a transition towards a more cohesive, patient-focused model in physical therapy, underscoring the vital relationship between technology and the effectiveness of healthcare. (3,26)

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