



Kent Academic Repository

Olawade, David B, Adeleye, Khadijat K, Egbon, Eghosasere, Nwabuoku, Udoka Shalom, Clement David-Olawade, Aanuoluwapo, Boussios, Stergios and Vanderbloemen, Laura (2025) *Enhancing home rehabilitation through AI-driven virtual assistants: a narrative review*. *Annals of Translational Medicine*, 13 (5). p. 61. ISSN 2305-5839.

Downloaded from

<https://kar.kent.ac.uk/112109/> The University of Kent's Academic Repository KAR

The version of record is available from

<https://doi.org/10.21037/atm-25-61>

This document version

Publisher pdf

DOI for this version

Licence for this version

CC BY-NC-ND (Attribution-NonCommercial-NoDerivatives)

Additional information

Versions of research works

Versions of Record

If this version is the version of record, it is the same as the published version available on the publisher's web site. Cite as the published version.

Author Accepted Manuscripts

If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding. Cite as Surname, Initial. (Year) 'Title of article'. To be published in **Title of Journal**, Volume and issue numbers [peer-reviewed accepted version]. Available at: DOI or URL (Accessed: date).

Enquiries

If you have questions about this document contact ResearchSupport@kent.ac.uk. Please include the URL of the record in KAR. If you believe that your, or a third party's rights have been compromised through this document please see our [Take Down policy](https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies) (available from <https://www.kent.ac.uk/guides/kar-the-kent-academic-repository#policies>).



Enhancing home rehabilitation through AI-driven virtual assistants: a narrative review

David B. Olawade^{1,2,3}, Khadijat K. Adeleye⁴, Eghosasere Egbon⁵, Udoka Shalom Nwabuoku⁶, Aanuoluwapo Clement David-Olawade⁷, Stergios Boussios^{2,8,9,10,11,12,13}, Laura Vanderbloemen^{14,15}

¹Department of Allied and Public Health, School of Health, Sport and Bioscience, University of East London, London, UK; ²Department of Research and Innovation, Medway NHS Foundation Trust, Gillingham, UK; ³Department of Public Health, York St John University, London, UK; ⁴Elaine Marieb College of Nursing, University of Massachusetts, Amherst, MA, USA; ⁵Department of Tissue Engineering and Regenerative Medicine, Faculty of Life Science Engineering, FH Technikum, Vienna, Austria; ⁶Department of Human Physiology, Faculty of Basic Medical Sciences, College of Health Sciences, Delta State University, Abraka, Nigeria; ⁷Endoscopy Unit, Glenfield Hospital, University Hospitals of Leicester, NHS Trust, Leicester, UK; ⁸Faculty of Medicine, School of Health Sciences, University of Ioannina, Ioannina, Greece; ⁹Department of Medical Oncology, Ioannina University Hospital, Ioannina, Greece; ¹⁰Faculty of Medicine, Health and Social Care, Canterbury Christ Church University, Canterbury, UK; ¹¹Faculty of Life Sciences & Medicine, School of Cancer & Pharmaceutical Sciences, King's College London, London, UK; ¹²Kent Medway Medical School, University of Kent, Canterbury, Kent, UK; ¹³AELIA Organization, 9th Km Thessaloniki – Thermi, Thessaloniki, Greece; ¹⁴Department of Primary Care and Public Health, Imperial College London, London, UK; ¹⁵School of Health, Sport and Bioscience, University of East London, London, UK

Contributions: (I) Conception and design: DB Olawade, KK Adeleye, L Vanderbloemen; (II) Administrative support: All authors; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: DB Olawade, US Nwabuoku, A Clement David-Olawade; (V) Data analysis and interpretation: KK Adeleye, E Egbon, S Boussios; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

Correspondence to: David B. Olawade, MPH. Department of Allied and Public Health, School of Health, Sport and Bioscience, University of East London, University Way, Newham, London E16 2RD, UK; Department of Research and Innovation, Medway NHS Foundation Trust, Gillingham, UK; Department of Public Health, York St John University, London, UK. Email: d.olawade@uel.ac.uk.

Background and Objective: Artificial intelligence (AI)-driven virtual physiotherapy assistants (VPAs) are increasingly adopted in home-based rehabilitation, offering real-time feedback and personalised guidance through wearable sensors. These systems enhance treatment adherence, minimise clinic visits, and improve rehabilitation outcomes. However, challenges such as sensor accuracy, patient engagement, and affordability hinder widespread implementation. This review explores current applications, benefits, and limitations of AI-driven VPAs.

Methods: A comprehensive narrative review was conducted across PubMed, IEEE Xplore, Scopus, Google Scholar, and Web of Science databases. Search terms such as: “artificial intelligence”, “virtual physiotherapy assistants”, “home rehabilitation”, and “wearable sensors”. From 847 initially identified articles, 31 peer-reviewed publications (2018–2024) met inclusion criteria. Exclusion criteria eliminated non-English publications, conference abstracts, and studies without AI components. The review synthesised literature on sensor accuracy, AI-based monitoring algorithms, and patient engagement strategies.

Key Content and Findings: Analysis of 31 studies revealed that AI-driven VPAs enhance adherence and reduce in-person visits. Integrating wearable sensors and AI facilitates real-time feedback and personalised support, improving exercise accuracy. Critical limitations include inertial measurement unit drift, electromyography sensor placement variability, and optical system environmental dependencies. Challenges remain in sensor precision, user motivation, cost barriers, and technology accessibility. Novel findings highlight potential for predictive analytics, gamification strategies, and telehealth integration.

Conclusions: AI-driven VPAs offer a promising accessible, personalised home-based rehabilitation solution. Evidence demonstrates therapeutic potential, though systematic addressing of sensor accuracy, engagement strategies, and accessibility barriers is essential for implementation. Technological improvements and increased affordability are crucial for broader adoption and long-term impact on rehabilitation delivery.

Keywords: Artificial intelligence (AI); home-based rehabilitation; wearable sensors; virtual physiotherapy; telehealth integration

Submitted Apr 23, 2025. Accepted for publication Jul 22, 2025. Published online Oct 28, 2025.

doi: 10.21037/atm-25-61

View this article at: <https://dx.doi.org/10.21037/atm-25-61>

Introduction

The global demand for rehabilitation services is rising, driven by ageing populations, an increase in chronic health conditions, and a greater awareness of the benefits of physical rehabilitation (1,2). Physiotherapy is a crucial aspect of rehabilitation, particularly for individuals recovering from injuries or surgeries or managing chronic conditions (3,4). Traditionally, physiotherapy often requires regular in-person visits to clinics, which can be challenging for patients with mobility issues, living in remote areas, or facing other logistical barriers (5). In recent years, the integration of artificial intelligence (AI) into healthcare, particularly in rehabilitation (6,7), has gained significant attention. Virtual physiotherapy assistants (VPAs) represent a novel approach that leverages AI technologies to enhance home-based patient rehabilitation (8-10). However, despite these potential benefits, little is known about VPAs and their effectiveness in home-based rehabilitation.

Advancements in machine learning, motion analysis, and computer vision have driven the evolution of virtual rehabilitation technologies (11,12). These technologies enable machines to analyze movement patterns, provide real-time feedback (13), and personalize rehabilitation protocols based on individual patient data (10,14,15). VPAs aim to bridge the gap between traditional physiotherapy, which often requires direct interaction with a healthcare professional, and remote treatment strategies that capitalize on digital tools (16,17). By offering accessible, flexible, and personalized care, VPAs have the potential to enhance patient outcomes and expand rehabilitation access, particularly for those who face challenges attending in-person sessions.

Despite these advantages, the application of VPAs presents several challenges (18,19). One of the primary concerns is the accuracy of the wearable sensors used to track patient movements, maintain patient engagement, and ensure compliance with their home-based physiotherapy routine. In addition to engagement, there are concerns about the cost and accessibility of VPAs (20). Furthermore,

reliable internet access and mobile devices are necessary to benefit fully from virtual physiotherapy systems, and not all patients can access these resources (18,21). Data security is another critical consideration in the widespread adoption of VPAs (22). While virtual assistants offer flexibility and convenience, some patients may find it challenging to stay motivated without the direct supervision of a therapist. This is particularly true for patients who are not accustomed to using technology in their healthcare or struggle with self-discipline when sticking to a treatment plan. Ensuring that virtual physiotherapy platforms are user-friendly and easy to navigate is crucial, as is finding ways to keep patients motivated in the long term.

Despite these challenges, the future potential of VPAs in home-based care is immense. As AI technology evolves, these systems will likely become more accurate, personalized, and widely accessible. Future advancements could include even greater integration with telehealth platforms, enabling patients to consult with their therapists in real-time while receiving feedback from their virtual assistants. The continued development of machine learning algorithms could enable virtual assistants to predict patient outcomes based on past data, providing even more tailored treatment plans (23). Additionally, as technology becomes more affordable and accessible, VPAs could become a standard part of rehabilitation, particularly in regions with limited access to in-person care.

The rationale for this review stems from the growing demand for accessible and flexible physiotherapy solutions, particularly in home-based care, which has become increasingly relevant due to the challenges posed by the coronavirus disease 2019 (COVID-19) pandemic and the need for remote healthcare options. VPAs, driven by AI and wearable sensors, present a promising solution to address these needs by offering patients real-time feedback and guidance during home-based rehabilitation exercises. However, despite the potential benefits, significant gaps remain in understanding the effectiveness, challenges, and limitations of these tools, particularly in areas such as sensor accuracy, patient engagement, cost, and data security. This

review aims to provide a comprehensive analysis of the application of VPAs, explore their benefits and limitations, and propose future directions for research and development to optimize their use in home-based care. We present this article in accordance with the Narrative Review reporting checklist (available at <https://atm.amegroups.com/article/view/10.21037/atm-25-61/rc>).

Methods

This narrative review employed a systematic search strategy across multiple academic databases to identify relevant literature on AI-driven VPAs in home-based rehabilitation settings. The methodology was designed to provide a comprehensive overview of current knowledge whilst identifying gaps and future research directions.

Search strategy and information sources

A comprehensive literature search was conducted using the following databases: PubMed/MEDLINE, IEEE Xplore Digital Library, Scopus, Web of Science, and Google Scholar [to supplement with grey literature (non-peer-reviewed sources) including reports, theses, and conference proceedings].

The search strategy incorporated the following key terms and their combinations:

- ❖ “Artificial intelligence” OR “AI” OR “machine learning”;
- ❖ “Virtual physiotherapy” OR “virtual assistant” OR “digital rehabilitation”;
- ❖ “Home-based rehabilitation” OR “remote physiotherapy” OR “telerehabilitation”;
- ❖ “Wearable sensors” OR “motion tracking” OR “sensor technology”;
- ❖ “Patient engagement” OR “adherence” OR “compliance”;
- ❖ “Digital health” OR “mHealth” OR “eHealth”.

Inclusion and exclusion criteria

Inclusion criteria

- (I) Peer-reviewed articles published between January 2018 and November 2024.
- (II) Studies focusing on AI-driven rehabilitation systems or virtual physiotherapy platforms.
- (III) Research examining home-based or remote rehabilitation applications.

- (IV) Articles addressing wearable sensor technology in rehabilitation contexts.
- (V) Studies investigating patient engagement and adherence in digital health interventions.
- (VI) English language publications.
- (VII) Full-text articles available.

Exclusion criteria

- (I) Conference abstracts without full-text availability.
- (II) Non-peer-reviewed publications.
- (III) Studies focusing exclusively on in-clinic applications without home-based components.
- (IV) Articles not specifically addressing AI or virtual assistant technologies in rehabilitation.
- (V) Duplicate publications.
- (VI) Studies published before 2018.
- (VII) Non-English language publications.

Study selection and data extraction

The literature search was conducted by two independent reviewers who initially screened titles and abstracts against the inclusion and exclusion criteria. Full-text articles were then retrieved for detailed assessment. Any disagreements regarding study inclusion were resolved through discussion and consensus. A total of 847 articles were initially identified, with 283 articles remaining after removal of duplicates. Following title and abstract screening, 156 articles underwent full-text review, resulting in 31 articles being included in the final narrative synthesis.

Table 1 provides a comprehensive summary of the search strategy and methodological approach employed in this narrative review.

Figure 1 illustrates the systematic literature selection process following PRISMA guidelines, demonstrating the progression from 847 initially identified records through duplicate removal, screening, and eligibility assessment to the final inclusion of 31 studies in the narrative synthesis, with detailed exclusion criteria and reasons provided at each stage.

Data synthesis

Given the heterogeneous nature of the included studies and the objective to provide a comprehensive overview of the field, a narrative synthesis approach was employed. Key themes were identified and organised into categories covering:

Table 1 Search strategy summary

Items	Specification
Date of search	November 2024
Databases and other sources searched	PubMed/MEDLINE, IEEE Xplore Digital Library, Scopus, Web of Science, plus Google Scholar for grey literature
Search terms used	Six key term clusters with Boolean operators: AI-related terms (“artificial intelligence” OR “AI” OR “machine learning”), virtual physiotherapy terms, home-based rehabilitation descriptors, sensor technology keywords, patient engagement indicators, and digital health terminology
Timeframe	6-year period (2018–2024) focusing on recent technological developments
Inclusion and exclusion criteria	<p>Included: Peer-reviewed articles, AI-driven rehabilitation systems, home-based applications, wearable sensor studies, patient engagement research, English language, full-text availability</p> <p>Excluded: Conference abstracts only, non-peer-reviewed publications, clinic-only studies, non-AI technologies, duplicates, pre-2018 studies, non-English publications</p>
Selection process	Dual independent review process: two reviewers (D.B.O. and K.K.A.) conducted title/abstract screening independently, followed by full-text assessment with disagreements resolved through structured discussion and consensus building
Any additional considerations	PRISMA guidelines adherence; narrative synthesis methodology selected due to study heterogeneity; 847 initial records reduced to 31 final studies through systematic exclusion; focus on technological capabilities, clinical applications, and implementation challenges

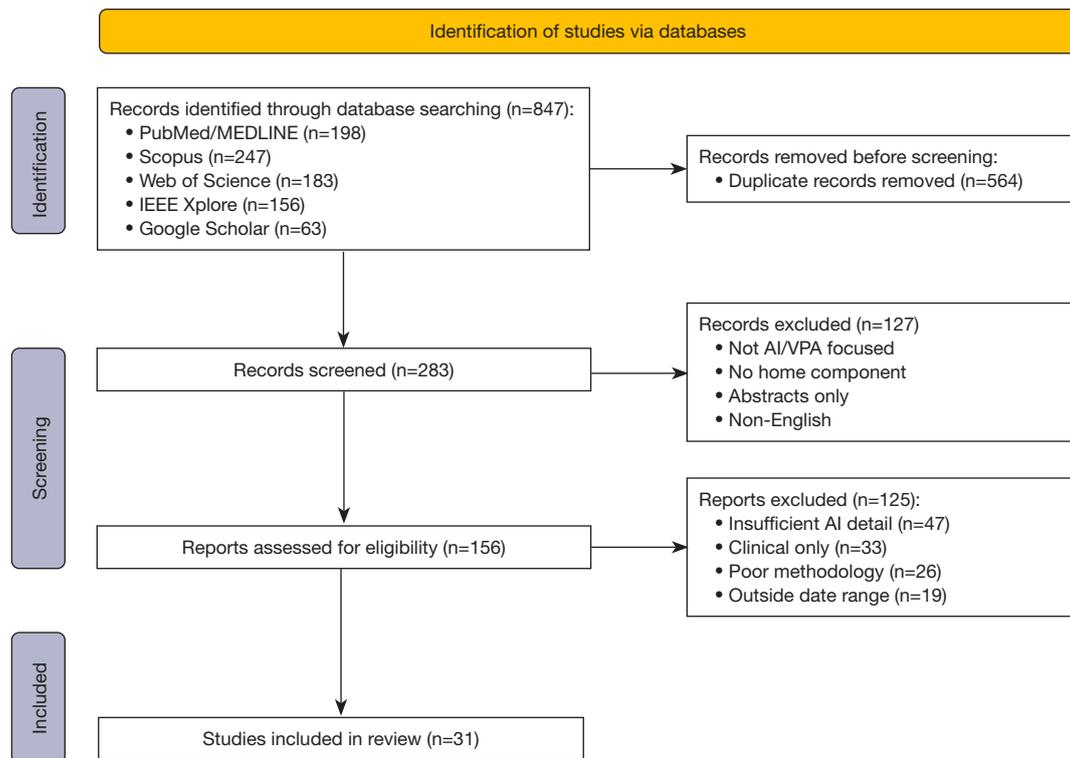


Figure 1 PRISMA flow diagram: AI-driven VPAs review. AI, artificial intelligence; VPA, virtual physiotherapy assistant.

Table 2 Summary of review contributions compared to previous knowledge

Aspect	Previous knowledge	Current review contributions
Role of AI in physiotherapy	AI has been explored in physiotherapy for movement analysis and the guidance of exercises (6)	This review consolidates evidence on AI-driven VPAs for home-based care
Wearable sensor accuracy	Prior studies have noted challenges in sensor precision that affect movement tracking (11)	Identifies current limitations in sensor accuracy and suggests improvements for more reliable tracking
Patient engagement challenges	Lack of therapist supervision affects patient adherence (18,24)	Discusses gamification and AI-driven motivation strategies to improve engagement and adherence
Cost and accessibility issues	AI-based rehabilitation is often costly and not widely accessible (20)	Explore strategies for reducing costs and improving accessibility through low-cost AI solutions
Integration with telehealth	Limited integration between AI physiotherapy assistants and telehealth platforms (25)	Advocates for deeper integration of telehealth for hybrid AI-assisted rehabilitation models
Future AI developments	AI systems provide real-time feedback but lack predictive capabilities (26)	Suggests future AI advancements, including predictive modelling to prevent injuries and optimise recovery

AI, artificial intelligence; VPA, virtual physiotherapy assistant.

- ❖ Technological capabilities and limitations of AI-driven VPAs.
- ❖ Clinical applications and effectiveness.
- ❖ Patient engagement and adherence factors.
- ❖ Cost and accessibility considerations.
- ❖ Security and privacy concerns.
- ❖ Future directions and research opportunities.

The synthesis focused on identifying patterns, contradictions, and gaps in the literature whilst maintaining a critical perspective on the quality and relevance of the evidence presented.

Table 2 provides a comparative summary of how this review builds upon existing knowledge in AI-driven VPAs for home-based rehabilitation. While previous research has explored AI applications in physiotherapy, challenges such as sensor accuracy, patient engagement, cost, and telehealth integration remain underdeveloped. This review consolidates findings on these critical areas, emphasising the need for improved sensor precision, the use of gamification strategies to enhance adherence, and the adoption of low-cost AI solutions to increase accessibility. Additionally, it highlights future opportunities, such as integrating virtual assistants with telehealth platforms and leveraging AI for predictive modelling to optimise rehabilitation outcomes. By addressing these gaps, this review contributes to

advancing AI-driven physiotherapy and shaping the future of home-based rehabilitation.

Results

AI-driven virtual assistants

AI-driven VPAs represent a significant innovation in rehabilitation. These digital platforms combine AI with wearable sensors or cameras to guide patients through therapeutic exercises (27,28). Typically accessible via mobile apps or computer programs, they offer real-time feedback, ensuring that patients perform exercises correctly (29). By processing data collected during movements, these systems can assess a patient's range of motion, posture, and speed, providing tailored advice that helps improve treatment outcomes. These AI-powered systems reduce the risks associated with improper exercise techniques, such as re-injury, and enhance adherence to prescribed rehabilitation routines.

The core of VPAs lies in wearable sensors such as smart bands, motion trackers, or pressure sensors (30,31). These devices collect detailed data about the patient's physical movements, which AI algorithms then analyze. The data points gathered from these sensors allow the system to monitor various metrics, including speed, posture, and

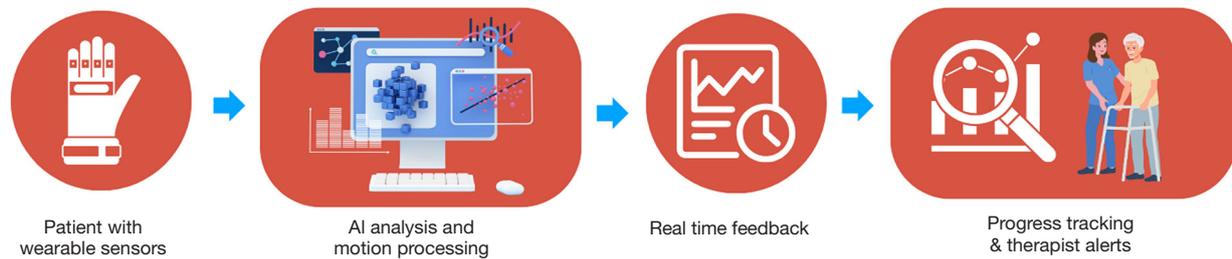


Figure 2 Workflow of AI-driven virtual physiotherapy assistant. AI, artificial intelligence.

range of motion. When the AI detects an error or improper form, it provides immediate corrective feedback to the patient, helping to maintain the accuracy and effectiveness of their exercises. This real-time monitoring and feedback ensure that patients can safely complete their rehabilitation exercises at home, mitigating the risks of unsupervised workouts (32). *Figure 2* illustrates the key components and process of an AI-driven VPA. The figure demonstrates how wearable sensors and AI algorithms work together to provide personalized rehabilitation guidance, ensuring accurate exercise performance and enabling remote monitoring by healthcare professionals. Each stage highlights the system's ability to collect, process, and respond to patient movement data, ultimately enhancing the effectiveness and safety of at-home physiotherapy interventions. In some cases, AI systems can alert the patient's physiotherapist when issues arise, allowing for timely intervention. For example, if the patient consistently performs an exercise incorrectly or if their progress stalls, the system can notify the therapist to adjust the rehabilitation plan or schedule a consultation.

Advantages of VPAs in home-based care

While challenges such as sensor accuracy, patient engagement, and cost remain, the potential of VPAs to improve accessibility, enhance personalization, and offer data-driven progress monitoring makes them a promising tool for the future of physiotherapy. As technology evolves, these systems will likely become even more integral to rehabilitation practices worldwide (33,34).

Improved accessibility and convenience

One of the primary advantages of AI-driven VPAs is their increased accessibility. Many patients, especially those with mobility challenges or who live in remote areas, face difficulties attending frequent in-person therapy sessions (10,16). VPAs address this by allowing patients to perform

their rehabilitation exercises at home, on their schedule, while still receiving real-time feedback and guidance. This flexibility enables patients to adhere more easily to their prescribed routines, improving recovery outcomes. Moreover, consistent guidance without travel significantly reduces traditional physiotherapy's physical and logistical burdens.

Enhanced personalization and adaptability

AI-powered virtual assistants also offer enhanced personalization compared to traditional in-person therapy. These systems can dynamically adjust exercise regimens based on the patient's progress (19,35). For example, if a patient demonstrates improved range of motion or strength, the AI can automatically increase the intensity or complexity of exercises to ensure continued progress. Conversely, if a patient struggles with a particular exercise, the system can suggest modifications or provide additional guidance. Based on real-time data, this level of adaptability allows for a more tailored approach to rehabilitation, keeping patients engaged and appropriately challenged throughout their recovery.

Real-time feedback and error correction

VPAs address this issue by providing real-time feedback and error correction (36,37). The AI system continuously monitors the patient's movements, ensuring they maintain proper posture and execute the exercises as intended. If an error is detected, the system can offer immediate guidance. This feature not only helps to prevent injuries but also enhances the overall effectiveness of the rehabilitation program by ensuring that patients perform each exercise correctly.

Reduced dependence on frequent clinic visits

VPAs help reduce the need for frequent clinic visits by enabling patients to perform exercises independently

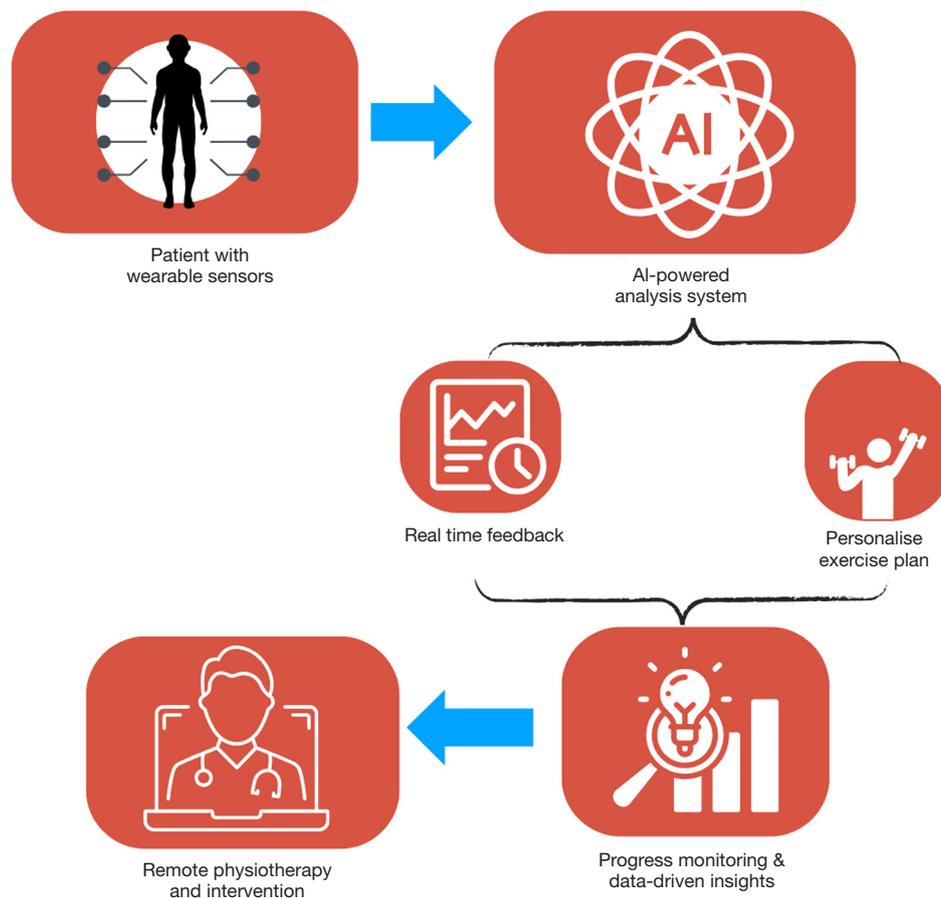


Figure 3 Workflow of AI-driven virtual physiotherapy assistants in home-based care. AI, artificial intelligence.

while still receiving support from the AI system (6). The detailed reports generated by the virtual assistant allow physiotherapists to monitor progress remotely, intervening only when necessary. This saves time and resources for patients and therapists, enabling healthcare providers to focus on more complex cases that require direct intervention.

Data-driven progress monitoring

VPAs generate vast amounts of data that can be used to track a patient's progress over time (25). The wearable sensors continuously collect data on movement patterns, adherence to prescribed routines, and overall performance. AI algorithms analyze this data to provide detailed insights into the patient's recovery trajectory. These insights enable physiotherapists to make informed decisions about adjustments to the treatment plan, ensuring that patients stay on track to meet their rehabilitation goals.

The data-driven approach also enables more personalized care, as therapists can identify patterns and trends that may require specific interventions or changes in therapy. *Figure 3* illustrates the key aspects of how AI-driven VPAs enhance home-based care, emphasizing the integration of technology, personalization, and professional oversight in the rehabilitation process. This figure illustrates the operational framework of AI-powered VPAs designed for home rehabilitation. It depicts the patient utilizing wearable sensors to collect movement data, which is analyzed by an AI system. The AI provides real-time feedback and generates personalized exercise plans tailored to the patient's progress. Continuous monitoring and data-driven insights facilitate effective rehabilitation, while remote oversight by physiotherapists ensures timely intervention when necessary. This integrated approach enhances accessibility, personalization, and the overall effectiveness of physiotherapy in a home setting.

Challenges and limitations

While VPAs offer numerous benefits, several challenges must be addressed to ensure widespread adoption and effectiveness.

Accuracy of wearable sensors

One of the critical factors determining the success of VPAs is the accuracy of the data collected by wearable sensors. These sensors are central in monitoring patient movements, providing feedback, and tracking progress. Current sensor technologies include inertial measurement units (IMUs) containing accelerometers, gyroscopes, and magnetometers; electromyography (EMG) sensors for muscle activity monitoring; pressure sensors for gait analysis; and optical motion capture systems using cameras and markers. Each sensor type presents specific accuracy challenges: IMUs may suffer from drift and calibration errors, EMG sensors can be affected by electrode placement and skin impedance variations, pressure sensors may have limited spatial resolution, and optical systems require controlled lighting conditions and unobstructed views. However, in some instances, sensors may struggle to capture nuanced movements or subtle changes in posture, particularly in complex or delicate rehabilitation exercises (28,38). For example, slight misalignments in posture or insufficient range of motion may go undetected, leading to inaccurate feedback from the system. This could result in improper exercise execution, potentially delaying recovery or causing harm. Therefore, ongoing advancements in sensor technology are crucial for enhancing the precision and reliability of data collection. Developers must focus on refining the sensitivity of wearable devices to ensure they can detect even the most minor deviations in movement patterns, ultimately enhancing the effectiveness of virtual physiotherapy systems.

User compliance and engagement

Although VPAs are designed to promote adherence to rehabilitation programs, maintaining patient engagement remains a significant challenge (24,39,40). Without the direct supervision of a physiotherapist, some patients may struggle with motivation or maybe less disciplined in following their prescribed exercise routines. Specific engagement strategies that have shown promise include personalised exercise recommendations based on patient preferences, adaptive difficulty levels that respond to performance data, social features enabling peer support and

competition, regular progress celebrations and milestone achievements, and integration of motivational messaging tailored to individual patient profiles. This can reduce the overall effectiveness of the rehabilitation process, as consistent participation is vital for optimal recovery. A critical factor in overcoming this challenge is ensuring that virtual physiotherapy platforms are user-friendly and engaging. Patients are more likely to stay committed to their treatment plan if the interface is intuitive and easy to navigate. Moreover, incorporating features such as progress tracking, reminders, or even gamification, where patients earn rewards or achieve milestones, can help sustain motivation over the long term. Fostering a sense of accomplishment and providing positive reinforcement could make the home-based therapy experience more rewarding for patients, thus improving compliance.

Cost and accessibility

The cost and accessibility of VPAs pose another barrier to widespread adoption. Although these systems can reduce the need for frequent clinic visits and may be cost-effective in the long term, the upfront expenses associated with purchasing wearable sensors and AI-driven platforms may be prohibitive for some patients. This is especially true in low-income areas or regions with limited access to advanced healthcare technology. Moreover, for the system to function effectively, patients need reliable access to the internet or compatible mobile devices, which can be another challenge for underserved populations. Ensuring that virtual physiotherapy systems are affordable and accessible is critical to achieving equitable healthcare. Innovations such as lower-cost sensors or mobile applications that can function on essential smartphones could help bridge the gap, making these tools more accessible to a broader range of patients.

Security and privacy concerns

VPAs collect and store significant patient data, including sensitive health information such as movement patterns, medical histories, and progress reports. This raises legitimate concerns about data security and patient privacy (41,42). Healthcare providers and technology developers must ensure that the data collected by these systems is securely stored, transmitted, and protected from unauthorized access or cyberattacks. Additionally, compliance with data privacy regulations, such as the General Data Protection Regulation (GDPR) in Europe or the Health Insurance Portability and Accountability Act

(HIPAA) in the United States, is essential to maintaining patient trust. Patients need assurance that their personal and medical information will be handled with the utmost care and confidentiality. Clear communication about how data will be used, along with robust encryption methods, is necessary to safeguard patient privacy within virtual physiotherapy platforms.

Discussion

The findings from this review reveal that AI-driven VPAs represent a transformative advancement in home-based rehabilitation, offering significant benefits whilst presenting notable challenges that require systematic addressing. The evidence suggests that these technologies have progressed beyond experimental stages to practical applications, although several critical issues must be addressed for widespread implementation.

The primary contribution of AI-driven VPAs lies in their ability to democratise access to physiotherapy services. Traditional rehabilitation models often exclude patients due to geographical, mobility, or scheduling constraints. Our analysis indicates that VPAs successfully address these barriers by providing personalized (43), real-time guidance that maintains therapeutic quality whilst offering unprecedented flexibility. The data-driven approach enables continuous monitoring and adaptive treatment protocols that may exceed the consistency possible in traditional care models.

However, the current limitations identified in this review underscore the need for substantial technological and methodological advancements. Sensor accuracy remains the most critical challenge, as inaccurate data collection undermines the entire therapeutic process. The heterogeneity of sensor technologies, ranging from IMUs to EMG systems, presents unique accuracy challenges that require targeted solutions. Future developments must prioritise sensor fusion techniques and machine learning algorithms that can compensate for individual sensor limitations whilst maintaining cost-effectiveness.

Patient engagement emerges as another complex challenge that extends beyond technological considerations to include psychological and social factors. The absence of direct human interaction, whilst offering convenience, may compromise the motivational support that traditional physiotherapy provides (44). The integration of gamification elements and AI-driven motivational strategies represents a promising approach; however, further research is needed to determine the optimal implementation methods for diverse

patient populations.

The cost-accessibility paradox identified in this review highlights a fundamental challenge in the deployment of healthcare technology. Whilst VPAs offer long-term cost savings through reduced clinic visits and improved outcomes, the initial investment barriers may prevent access for those who would benefit most. This suggests the need for innovative funding models, insurance coverage adaptations, and the development of tiered systems that provide basic functionality at lower cost points.

Privacy and security concerns represent not merely technical challenges but fundamental trust issues that could determine the success or failure of VPA adoption. The comprehensive health data collected by these systems requires robust protection mechanisms that comply with evolving regulatory frameworks while maintaining system functionality and user experience.

Future directions

AI-driven VPAs are rapidly evolving, offering immense potential for future advancements. As these systems become more refined and integrated into mainstream healthcare, several critical areas for innovation are emerging, each aimed at enhancing the effectiveness, accessibility, and user experience of virtual physiotherapy.

Integration with telehealth platforms

One of the most promising future directions is the integration of VPAs with broader telehealth services (25,34). This combination would allow for a more holistic approach to home-based care. By integrating video consultations with AI-powered virtual assistants, patients could benefit from real-time interaction with their physiotherapists while receiving guided exercises and feedback from the virtual system. This dual approach would foster a more personalized and cohesive treatment plan, as therapists could adjust exercises during live consultations based on real-time data from the virtual assistant. Moreover, such integration would streamline the patient's experience, ensuring they receive both human and AI-driven guidance seamlessly, enhancing overall care delivery.

Advancements in AI and machine learning

As AI and machine learning algorithms advance, VPAs are likely to become even more sophisticated in their

capabilities (26,45). Current AI-driven systems provide real-time feedback and error correction; however, future developments could enable these systems to predict potential injuries before they occur. By analyzing a patient's movement patterns over time, machine learning models could identify deviations that may indicate a risk of injury, enabling early intervention. Additionally, AI algorithms could adjust exercises based on current performance and forecast future rehabilitation needs based on predictive analytics. Machine learning could also enhance recovery outcomes by analyzing large datasets of patient information, identifying trends, and offering insights into best practices for different conditions. For example, virtual assistants could suggest the most effective treatment pathways by comparing data from thousands of patients with similar injuries (46). This data-driven approach would allow therapists to make more informed decisions and offer personalized care.

Enhanced user experience and gamification

Maintaining patient engagement is a critical aspect of successful rehabilitation, and one way to address this is by enhancing the user experience through gamification. Gamification involves turning tasks into challenges, rewards, or games to motivate users to participate more actively. In virtual physiotherapy, incorporating game-like elements into the exercise routines could significantly improve patient engagement (47). For example, patients could earn points, badges, or rewards for consistently completing their exercises or reaching certain milestones in their recovery. By creating a sense of achievement and progress, gamification could make the rehabilitation process more enjoyable and motivating, especially for younger patients or those who may struggle with discipline. In addition to rewards, virtual assistants could offer challenges or goals that are progressively harder to reach, keeping patients motivated and focused on their recovery. By combining these elements with visual feedback on progress, virtual physiotherapy systems can transform routine exercises into a dynamic and engaging experience, leading to better adherence and improved outcomes.

Accessibility improvements

One of the most significant areas for future development is improving accessibility to AI-driven VPAs, particularly for low-income populations and those living in remote areas (48). The cost of wearable sensors and AI-powered platforms can hinder widespread adoption. However, future

innovations could focus on lowering the cost of entry by developing more affordable sensors and simplifying the technology required to access virtual assistants. For example, researchers and developers could create low-cost yet accurate motion-tracking devices that integrate with essential mobile devices, making virtual physiotherapy more accessible to a broader population. Additionally, efforts should be made to ensure that virtual physiotherapy apps work on various devices, from high-end smartphones to more basic models, ensuring that patients in underserved communities are not excluded (49). *Figure 4* illustrates the key future directions for AI-driven VPAs. Addressing internet connectivity issues is also crucial, with the potential for offline functionality or data-light versions of apps that can operate in areas with unreliable internet access. By making these technologies more accessible, VPAs could play a key role in closing healthcare gaps and providing equitable access to rehabilitation services globally.

Limitations of the review

This review has several limitations that should be acknowledged when interpreting the findings. First, the narrative review methodology, whilst appropriate for synthesising diverse literature and identifying trends, does not provide the systematic quality assessment and risk of bias evaluation that would be available in a systematic review or meta-analysis. The heterogeneity of study designs, outcome measures, and technological implementations across the included studies precluded quantitative synthesis, limiting our ability to draw definitive conclusions about the effectiveness of specific VPA interventions.

Second, the rapidly evolving nature of AI and wearable sensor technologies means that some of the technological limitations identified in earlier studies may have been addressed by more recent developments not yet reflected in the published literature. The time lag between technological advancement and peer-reviewed publication may result in an underestimation of current capabilities, particularly in sensor accuracy and AI algorithm sophistication.

Third, the search strategy, whilst comprehensive, was limited to English-language publications and may have excluded relevant studies published in other languages, potentially introducing geographical and cultural bias in the findings. Additionally, the focus on peer-reviewed academic literature may have overlooked important developments in commercial VPA systems or grey literature sources that could provide valuable insights into real-world

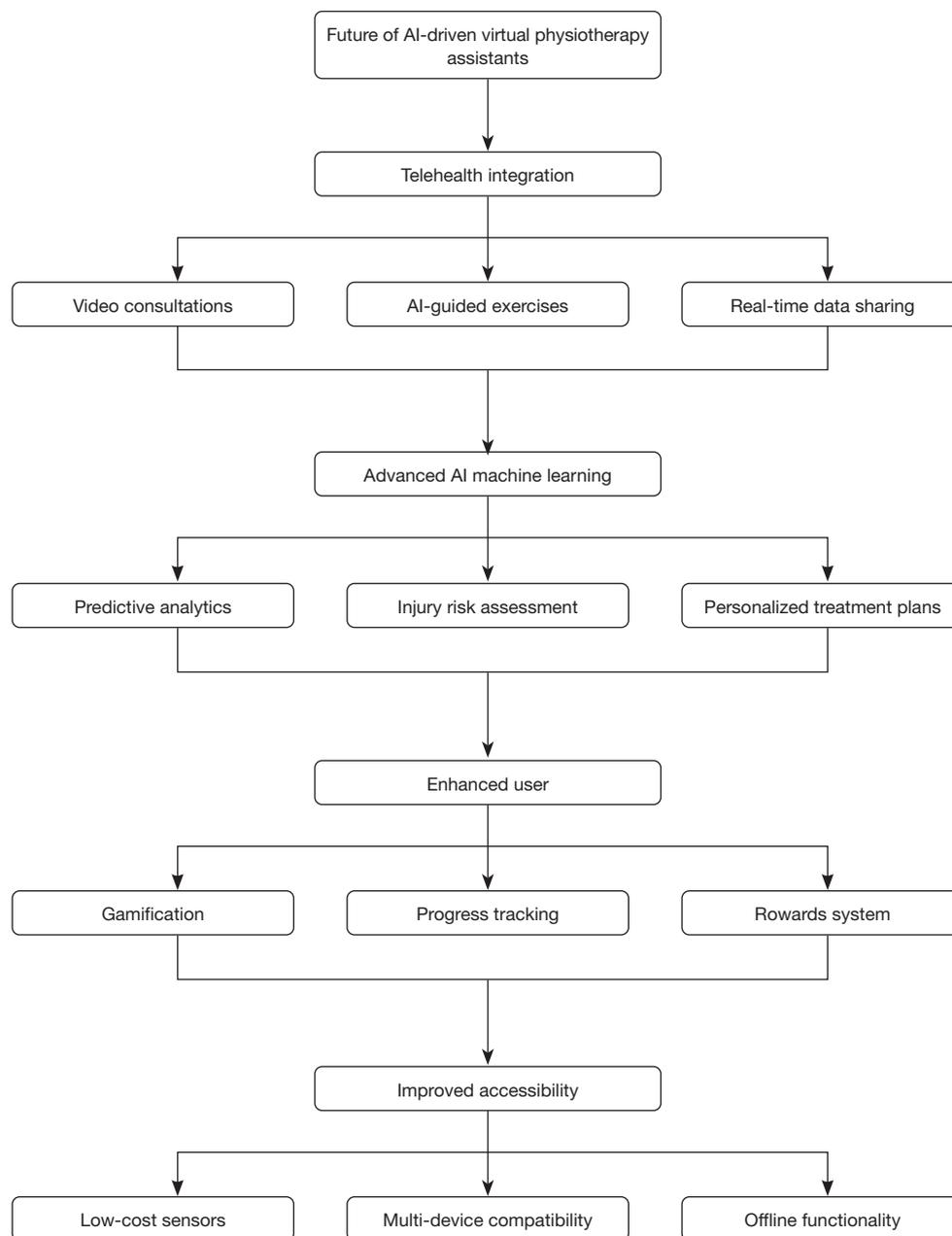


Figure 4 Future directions of AI-driven virtual physiotherapy assistants. This figure illustrates the interconnected nature of these advancements, highlighting how they build upon one another to create a more comprehensive and effective virtual physiotherapy experience. AI, artificial intelligence.

implementation challenges.

Fourth, the included studies exhibited significant variability in sample sizes, study populations, and outcome measures, making it difficult to establish clear recommendations for specific patient groups or conditions. Many studies were pilot projects or proof-of-concept

investigations with limited long-term follow-up data, which restricts our understanding of the sustained effectiveness and user acceptance of VPA systems over extended periods.

Finally, there is a notable lack of high-quality randomised controlled trials comparing VPA interventions directly with traditional physiotherapy or control conditions. Most

evidence is derived from observational studies, case series, or small pilot trials, which limits the strength of evidence for clinical effectiveness and cost-effectiveness conclusions. The absence of standardised outcome measures across studies also hampers the ability to make meaningful comparisons between different VPA approaches and technologies.

Conclusions

This review has provided a comprehensive analysis of AI-driven VPAs in home-based rehabilitation, revealing both significant opportunities and persistent challenges in this rapidly evolving field. The evidence demonstrates that these technologies offer substantial benefits, including improved accessibility, enhanced personalisation, real-time feedback capabilities, and comprehensive progress monitoring. However, critical limitations in sensor accuracy, patient engagement, cost-effectiveness, and data security must be systematically addressed to realise the full potential of these systems.

AI-driven VPAs represent a promising advancement in home-based care, offering patients greater flexibility, personalised treatment, and real-time feedback. By minimising the need for frequent clinic visits and supporting consistent adherence to rehabilitation exercises, these tools have the potential to significantly enhance recovery outcomes for diverse patient populations, including the elderly, individuals with mobility limitations, and those in rural or underserved areas. Nevertheless, to realise their full potential, several challenges must be addressed. This review has revealed that whilst current technologies demonstrate clinical efficacy, technological refinements are essential for widespread adoption. These include improving the accuracy and sensitivity of wearable sensors to detect subtle movement variations, developing more engaging and user-friendly interfaces to sustain patient motivation, and ensuring affordability and equitable access, particularly in low-resource settings. Additionally, safeguarding data privacy and aligning with regulatory frameworks is essential to maintain trust in these technologies.

The integration of multiple sensor modalities, advanced machine learning algorithms, and sophisticated engagement strategies represents the next phase of development for VPAs. Future systems must address the heterogeneity of patient needs whilst maintaining cost-effectiveness and technological accessibility. The development of predictive analytics capabilities, enhanced gamification features, and seamless telehealth integration will be crucial for creating

comprehensive rehabilitation ecosystems.

As AI, machine learning, and remote monitoring technologies continue to mature, VPAs could evolve into fully integrated components of the rehabilitation ecosystem. Future iterations may include predictive analytics to pre-empt complications, gamified modules to enhance motivation, and seamless integration with telehealth platforms to support hybrid care models. The evidence suggests that successful implementation will require coordinated efforts between technology developers, healthcare providers, regulatory bodies, and funding organisations to ensure that advances in AI-driven rehabilitation technologies translate into improved patient outcomes and equitable access to care.

In this context, AI-driven VPAs are more than just a technological tool; they represent a transformative shift toward more proactive, patient-centred, and data-informed rehabilitation. With continued innovation, investment, and clinical validation, these systems have the capacity to redefine physiotherapy delivery and expand access to high-quality rehabilitation care globally. However, the success of this transformation will depend on addressing current limitations through evidence-based approaches, ensuring that improvements match technological advancement in clinical effectiveness, patient safety, and healthcare equity.

Acknowledgments

The authors acknowledge support from the Research and Innovation department of Medway NHS Foundation Trust.

Footnote

Reporting Checklist: The authors have completed the Narrative Review reporting checklist. Available at <https://atm.amegroups.com/article/view/10.21037/atm-25-61/rc>

Peer Review File: Available at <https://atm.amegroups.com/article/view/10.21037/atm-25-61/prf>

Funding: None.

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at <https://atm.amegroups.com/article/view/10.21037/atm-25-61/coif>). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all

aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Open Access Statement: This is an Open Access article distributed in accordance with the Creative Commons Attribution-NonCommercial-NoDerivs 4.0 International License (CC BY-NC-ND 4.0), which permits the non-commercial replication and distribution of the article with the strict proviso that no changes or edits are made and the original work is properly cited (including links to both the formal publication through the relevant DOI and the license). See: <https://creativecommons.org/licenses/by-nc-nd/4.0/>.

References

- Jesus TS, Arango-Lasprilla JC, Kumar Kamalakannan S, et al. Growing physical rehabilitation needs in resource-poor world regions: secondary, cross-regional analysis with data from the global burden of disease 2017. *Disabil Rehabil* 2022;44:5429-39.
- Gimigliano F, Negrini S. The World Health Organization "Rehabilitation 2030: A call for action". *European Journal of Physical and Rehabilitation Medicine* 2017. doi: 10.23736/S1973-9087.17.04746-3.
- Dosky AH. Impact of Vitamin D Deficiency on Corneal Health upon Children with Rickets. *Physiother Rehabil Res* 2024;1:5.
- Picariello F, Carbone MM, Barni L, et al. The Physiotherapist: The Importance of Early Functional Recovery. In: Boccardi V, Marano L. editors. *The Frail Surgical Patient. Practical Issues in Geriatrics*. Springer; 2024;321-49.
- Moecke DP, Holyk T, Maddocks S, et al. First Nations Peoples' perspectives on telehealth physiotherapy: A qualitative study focused on the therapeutic relationship. *Rural and Remote Health* 2024. doi: 10.22605/RRH9022.
- Sumner J, Lim HW, Chong LS, et al. Artificial intelligence in physical rehabilitation: A systematic review. *Artif Intell Med* 2023;146:102693.
- Khalid UB, Naeem M, Stasolla F, et al. Impact of AI-Powered Solutions in Rehabilitation Process: Recent Improvements and Future Trends. *Int J Gen Med* 2024;17:943-69.
- Afyouni I, Einea A, Murad A. RehaBot: Gamified Virtual Assistants Towards Adaptive TeleRehabilitation. Adjunct Publication of the 27th Conference on User Modeling, Adaptation and Personalization, 2019:21-6. doi: 10.1145/3314183.3324988.
- Brepohl PCA, Leite H. Virtual reality applied to physiotherapy: a review of current knowledge. *Virtual Reality* 2023;27:71-95.
- Antico M, Balletti N, Ciccotelli A, et al. A Virtual Assistant for Home Rehabilitation: the 2Vita-B Physical Project. In: 2021 IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe). IEEE; 2021:1-6.
- Panwar M, Biswas D, Bajaj H, et al. Rehab-Net: Deep Learning Framework for Arm Movement Classification Using Wearable Sensors for Stroke Rehabilitation. *IEEE Trans Biomed Eng* 2019;66:3026-37.
- Fiorente N, Mojdehdehbaheer S, Calabrò RS. Artificial Intelligence and Neurorehabilitation: Fact vs. Fiction. *Innov Clin Neurosci* 2024;21:10-2.
- Gharaei N, Ismail W, Grosan C, Hendradi R. Optimizing the setting of medical interactive rehabilitation assistant platform to improve the performance of the patients: A case study. *Artif Intell Med* 2021;120:102151.
- Knox KB, Nickel D, Donkers SJ, Paul L. Physiotherapist and participant perspectives from a randomized-controlled trial of physiotherapist-supported online vs. paper-based exercise programs for people with moderate to severe multiple sclerosis. *Disabil Rehabil* 2023;45:1147-53.
- Jarvis K, Cook J, Bavikatte G, et al. A pilot exploration of staff and service-user perceptions of a novel digital health technology (Virtual Engagement Rehabilitation Assistant) in complex inpatient rehabilitation. *Disabil Rehabil Assist Technol* 2025;20:64-74.
- Heiyanthuduwa TA, Nikini Umasha Amarapala KW, Vinura Budara Gunathilaka KD, et al. VirtualPT: Virtual Reality based Home Care Physiotherapy Rehabilitation for Elderly. 2020 2nd International Conference on Advancements in Computing (ICAC), Malabe, Sri Lanka, 2020:311-6. doi: 10.1109/ICAC51239.2020.9357281.
- Aggarwal R, Ganvir SS. Artificial Intelligence in Physiotherapy. *Physiotherapy - The Journal of Indian Association of Physiotherapists* 2021;15:55-7. Chong DYK. Benefits and challenges with gamified multi-media physiotherapy case studies: a mixed method study. *Arch Physiother* 2019;9:7.
- Chong DYK. Benefits and challenges with gamified multi-media physiotherapy case studies: a mixed method study. *Arch Physiother* 2019;9:7.
- Lanotte F, O'Brien MK, Jayaraman A. AI in Rehabilitation Medicine: Opportunities and Challenges. *Ann Rehabil*

- Med 2023;47:444-58.
20. Ede CF, Fothergill-Misbah N, Ede SS. "Life has always been physical physical, now visual": an explorative study on the use of digital health technologies to promote physiotherapy home treatment programs among older people. *Physiotherapy Theory and Practice* 2025;41:337-50.
 21. Dicianno BE, Parmanto B, Fairman AD, et al. Perspectives on the evolution of mobile (mHealth) technologies and application to rehabilitation. *Phys Ther* 2015;95:397-405.
 22. Bower KJ, Verdonck M, Hamilton A, et al. What Factors Influence Clinicians' Use of Technology in Neurorehabilitation? A Multisite Qualitative Study. *Phys Ther* 2021;101:pzab031.
 23. Alowais SA, Alghamdi SS, Alsuhebany N, et al. Revolutionizing healthcare: the role of artificial intelligence in clinical practice. *BMC Med Educ* 2023;23:689.
 24. Kim DY. Engagement Methodologies for Improving Patient Adherence to Physical Rehabilitation. The University of Auckland; [Masters Theses]. 2022. Available online: <https://researchspace.auckland.ac.nz/handle/2292/62468>
 25. Howard IM, Kaufman MS. Telehealth applications for outpatients with neuromuscular or musculoskeletal disorders. *Muscle Nerve* 2018;58:475-85.
 26. Mohapatra A, Mohanty P, Pattnaik M, et al. Physiotherapy in the digital age: A narrative review of the paradigm shift driven by the integration of artificial intelligence and machine learning. *Physiotherapy - The Journal of Indian Association of Physiotherapists* 2024;18:63-71.
 27. Han X, Zhou X, Tan B, et al. AI-based next-generation sensors for enhanced rehabilitation monitoring and analysis. *Measurement* 2023;223:113758.
 28. Monge J, Ribeiro G, Raimundo A, et al. AI-Based Smart Sensing and AR for Gait Rehabilitation Assessment. *Information* 2023;14:355.
 29. Nussbaum R, Kelly C, Quinby E, et al. Systematic Review of Mobile Health Applications in Rehabilitation. *Arch Phys Med Rehabil* 2019;100:115-27.
 30. Ayed I, Ghazel A, Jaume-I-Capó A, et al. Vision-based serious games and virtual reality systems for motor rehabilitation: A review geared toward a research methodology. *Int J Med Inform* 2019;131:103909.
 31. Tan SY, Lam MC, Faburada J, et al. Immersive Virtual Reality: A New Dimension in Physiotherapy. *IJACSA* 2023. doi: 10.14569/IJACSA.2023.0141009.
 32. Rosenfeldt AB, Lopez-Lennon C, Suttman E, et al. Use of a Home-Based, Commercial Exercise Platform to Remotely Monitor Aerobic Exercise Adherence and Intensity in People With Parkinson Disease. *Phys Ther* 2024;104:pzad174.
 33. Keel S, Schmid A, Keller F, et al. Investigating the use of digital health tools in physiotherapy: facilitators and barriers. *Physiother Theory Pract* 2023;39:1449-68.
 34. Moecke DP, Holyk T, Maddocks S, et al. Physical Therapists' Perspectives on the Use of Telehealth With First Nations Peoples in Canada: A Qualitative Study. *Phys Ther* 2025;105:pzae175.
 35. Davids J, Lidströmer N, Ashrafian H. Artificial Intelligence for Physiotherapy and Rehabilitation. In: Lidströmer N, Ashrafian H, editors. *Artificial Intelligence in Medicine*. Cham: Springer International Publishing; 202:1789-807.
 36. Wei W, Lu Y, Rhoden E, et al. User performance evaluation and real-time guidance in cloud-based physical therapy monitoring and guidance system. *Multimed Tools Appl* 2019;78:9051-81.
 37. Calvaresi D, Calbimonte JP. Real-Time Compliant Stream Processing Agents for Physical Rehabilitation. *Sensors (Basel)* 2020;20:746.
 38. Pyun KR, Kwon K, Yoo MJ, et al. Machine-learned wearable sensors for real-time hand-motion recognition: toward practical applications. *Natl Sci Rev* 2024;11:nwad298.
 39. Glegg SMN, Levac DE. Barriers, Facilitators and Interventions to Support Virtual Reality Implementation in Rehabilitation: A Scoping Review. *PM R* 2018;10:1237-1251.e1.
 40. Arntz A, Weber F, Handgraaf M, et al. Technologies in Home-Based Digital Rehabilitation: Scoping Review. *JMIR Rehabil Assist Technol* 2023;10:e43615.
 41. Karabrahimoglu A, İnce F, Hassanzadeh G, et al. Ethical considerations in telehealth and artificial intelligence for work related musculoskeletal disorders: A scoping review. *Work* 2024;79:1577-88.
 42. Tariq MU. Integration of IoMT for Enhanced Healthcare: Sleep Monitoring, Body Movement Detection, and Rehabilitation Evaluation. In: Liu H, Tripathy RK, Bhattacharya P, editors. *Clinical Practice and Unmet Challenges in AI-Enhanced Healthcare Systems*. IGI Global Scientific Publishing, 2024:71-96. doi: 10.4018/979-8-3693-2703-6.ch004.
 43. Kyriazakos S, Schlieter H, Gand K, et al. A Novel Virtual Coaching System Based on Personalized Clinical Pathways for Rehabilitation of Older Adults-Requirements and Implementation Plan of the vCare Project. *Front Digit Health* 2020;2:546562.
 44. Tyrdal MK, Veierød MB, Røe C, et al. Neck and back

- pain: Differences between patients treated in primary and specialist health care. *J Rehabil Med* 2022;54:jrm00300.
45. Rowe M, Nicholls DA, Shaw J. How to replace a physiotherapist: artificial intelligence and the redistribution of expertise. *Physiother Theory Pract* 2022;38:2275-83.
 46. Liao Y, Vakanski A, Xian M, et al. A review of computational approaches for evaluation of rehabilitation exercises. *Comput Biol Med* 2020;119:103687.
 47. Randriambelonoro M, Perrin Franck C, Herrmann F, et al. Gamified Physical Rehabilitation for Older Adults With Musculoskeletal Issues: Pilot Noninferiority Randomized Clinical Trial. *JMIR Rehabil Assist Technol* 2023;10:e39543.
 48. Gatica-Rojas V, Cartes-Velásquez R. Telerehabilitation in Low-Resource Settings to Improve Postural Balance in Older Adults: A Non-Inferiority Randomised Controlled Clinical Trial Protocol. *Int J Environ Res Public Health* 2023;20:6726.
 49. Vibhuti, Kumar N, Kataria C. Efficacy assessment of virtual reality therapy for neuromotor rehabilitation in home environment: a systematic review. *Disabil Rehabil Assist Technol* 2023;18:1200-20.

Cite this article as: Olawade DB, Adeleye KK, Egbon E, Nwabuoku US, Clement David-Olawade A, Boussios S, Vanderbloemen L. Enhancing home rehabilitation through AI-driven virtual assistants: a narrative review. *Ann Transl Med* 2025;13(5):61. doi: 10.21037/atm-25-61