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Personalized Physiotherapy Using Artificial Intelligence in Rare Musculoskeletal Disorders: Literature Review

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Abstract: **The advent of artificial intelligence (AI) in the realm of personalized physiotherapy marks a pivotal shift, especially concerning the management of rare musculoskeletal disorders. Conventional physiotherapeutic strategies frequently fall short in addressing the intricate and individualized requirements of patients with uncommon clinical presentations, thereby underscoring the necessity for advanced, adaptable methodologies. Leveraging AI-driven data analytics and machine learning algorithms, clinicians can now devise highly individualized rehabilitation protocols that account for each patient's unique clinical and genetic characteristics, thus refining both diagnostic accuracy and therapeutic effectiveness. Recent literature underscores the capacity of AI-enhanced interventions, including interactive digital platforms and tailored exergaming, to bolster patient participation and adherence by targeting specific functional impairments and fostering greater motivation. Additionally, AI's integration within precision medicine frameworks accelerates the identification and optimization of therapeutic pathways, further expediting the development of patient-specific treatments. The purpose of this review is to synthesize current evidence regarding the implementation of AI in personalized physiotherapy for rare musculoskeletal disorders, evaluating its impact on clinical outcomes and outlining future directions for research and practice. Collectively, these advancements signify a transformative era in individualized care, with AI poised to reshape both therapeutic paradigms and the broader landscape of rare disease management.**

Keywords: **artificial intelligence, personalized physiotherapy, rare musculoskeletal disorders, machine learning, precision medicine.**

1. INTRODUCTION

The integration of artificial intelligence (AI) into personalized physiotherapy represents a groundbreaking advancement, particularly in the treatment of rare musculoskeletal disorders. Traditional physiotherapy approaches often struggle to meet the unique needs of patients suffering from atypical conditions, necessitating innovative solutions to optimize treatment efficacy. AIs capabilities in big data analysis and machine learning enable healthcare professionals to tailor therapeutic interventions based on individual patient profiles, enhancing both diagnosis and rehabilitation outcomes. As highlighted in recent studies, such personalized approaches can significantly improve patient engagement through interactive platforms and exergames, which address specific physical deficits while increasing motivation (1,2). Furthermore, the application of

AI in precision medicine has revolutionized the process of drug discovery, allowing for quicker identification of treatment pathways tailored to genetic and clinical data (3). Consequently, harnessing AI not only has the potential to transform physiotherapy practices but also to redefine the landscape of personalized care in the management of rare musculoskeletal disorders (3,4).

The classification of rare musculoskeletal disorders is critical for understanding their unique clinical presentations and management challenges. These disorders, often characterized by their infrequent occurrence and complex etiology, encompass a wide range of conditions, including inherited muscular dystrophies, connective tissue disorders, and syndromic bone anomalies. The low prevalence of these diseases can result in diagnostic delays and inadequate treatment options, highlighting the necessity for specialized care. Personalized physiotherapy, augmented by artificial intelligence (AI), offers a prospective avenue for enhancing patient outcomes by tailoring interventions based on individual needs and clinical data. For instance, AI-driven analytics can assist in identifying optimal rehabilitation strategies that align with a patient's specific disorder and progression stage, thereby improving adherence to therapy. Additionally, the integration of AI in monitoring patient responses to treatment can facilitate timely adjustments to therapeutic plans, making it essential to explore the implications of these technologies in both clinical practice and research within the realm of rare musculoskeletal disorders (5).

Physiotherapy plays a crucial role in the management and rehabilitation of musculoskeletal disorders, emphasizing a patient-centered approach that integrates various modalities for optimal recovery. Central to this field is the concept of multimodal analgesia, which combines pharmacologic and non-pharmacologic interventions to address pain and functional limitations effectively. This strategy has evolved from traditional opioid-based treatments to more individualized regimens that incorporate techniques such as physical therapy, cognitive behavioral therapy, and advanced technologies like transcutaneous electrical nerve stimulation (TENS) and electronic muscle stimulation (EMS) (6). Recent advancements also highlight the significance of artificial intelligence in developing personalized physiotherapy protocols, which can analyze patients responses to treatment in real-time and adapt accordingly, enhancing therapeutic outcomes (7). Furthermore, understanding the prevalence and impact of work-related musculoskeletal disorders underscores the need for targeted interventions that not only alleviate pain but also improve quality of life and functional capabilities. Enhanced recovery after surgery protocols illustrate these principles in action, advocating for a comprehensive approach tailored to individual patient needs (8).

The emergence of artificial intelligence (AI) in healthcare marks a significant turning point, streamlining various aspects of patient care, particularly in rehabilitation practices. One prominent application is in the management of musculoskeletal disorders, where personalized physiotherapy can greatly enhance patient outcomes. By leveraging AI algorithms, clinicians can analyze large datasets to identify patterns and trends in patient responses to treatment, leading to tailored rehabilitation programs that adapt in real-time to individual needs. For instance, integrating AI with biomechanical modeling enables precise tracking of patient progress during recovery, as demonstrated by the hybrid framework that combines finite element modeling and AI-driven analysis, allowing for effective feedback mechanisms in rehabilitation settings (7). Moreover, advancements in AI facilitate the exploration of new therapeutic avenues, such as drug discovery tailored to individual genomic profiles, improving treatment efficacy for conditions that were traditionally challenging to manage (3). The potential of AI not only promises to optimize recovery trajectories but also addresses the multifaceted nature of disorders like chronic pain stemming from work-related musculoskeletal disorders (9). As these technologies continue to evolve, the transformative impact of AI on personalized healthcare is becoming increasingly apparent.

In the context of Personalized Physiotherapy Using Artificial Intelligence in Rare Musculoskeletal Disorders, the literature review serves a pivotal role in establishing a comprehensive understanding of existing research and identifying gaps in knowledge. The primary objectives of this review are to synthesize findings from diverse studies, assess the efficacy of AI-supported interventions in physiotherapy, and highlight the unique challenges posed by rare musculoskeletal disorders. By analyzing various approaches which emphasizes the integration of AI in promoting patient engagement and adherence, the review aims to delineate how these technologies can facilitate personalized treatment regimens (10,11),. Furthermore, it addresses the complexities of drug discovery in precision medicine which underscores the necessity for focused interventions tailored to individual patient's needs (3). Ultimately, the literature review aspires to provide a foundation for future research, guiding clinicians in implementing AI-driven solutions for improved patient outcomes in this specialized field.

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Role of Artificial Intelligence in Personalized Physiotherapy

The application of artificial intelligence (AI) in personalized physiotherapy represents a transformative shift, particularly in managing rare musculoskeletal disorders. AI technologies enable the development of tailored rehabilitation strategies by analyzing individual patient data and predicting outcomes, thus facilitating a more nuanced approach to therapy. For instance, mobile applications such as the AI Posture Evaluation and Correction System (APECS) utilize advanced algorithms to assess body symmetry and postural deviations, providing real-time feedback that encourages timely corrections in patients (7). Furthermore, the integration of AI with biomechanical simulations has demonstrated the potential for enhancing rehabilitation monitoring by assessing patients progress through intelligent systems that link physical modeling with real-time sensor data (1). Emphasizing the necessity of a personalized approach, recent literature highlights that AI-driven protocols can significantly improve recovery outcomes while reducing the reliance on opioids in pain management strategies (8). Ultimately, the innovative use of AI in physiotherapy not only aims to alleviate physical impairments but also seeks to enhance the overall quality of life for patients afflicted by rare musculoskeletal conditions (9).

The integration of artificial intelligence (AI) techniques, particularly machine learning and deep learning, is revolutionizing physiotherapy, especially in the treatment of rare musculoskeletal disorders. These advanced algorithms facilitate the processing of vast datasets, enabling personalized treatment plans that are tailored to each patient's unique condition. For instance, machine learning models can analyze bio signals and motion-derived metrics, enhancing diagnostic accuracy and therapeutic precision, as noted in recent reviews (12). Furthermore, deep learning techniques are employed to interpret complex imaging data, contributing to more reliable assessments of musculoskeletal abnormalities (13). As AI-powered interventions have been shown to improve patient engagement and compliance, the potential for optimizing rehabilitation outcomes is substantial (11). Nevertheless, challenges such as dataset biases and interoperability still inhibit broader implementation in clinical settings (14). Addressing these issues is crucial for harnessing AI's full capacity to personalize physiotherapy treatments, ultimately leading to improved management of rare musculoskeletal disorders.

The integration of advanced data sources and patient monitoring technologies is crucial for enhancing personalized physiotherapy, particularly in the context of rare musculoskeletal disorders. By leveraging biosignals and motion-derived metrics from wearable devices, healthcare professionals can obtain critical real-time data that inform therapeutic strategies and optimize patient outcomes. The utilization of technologies like electromyography (EMG) and inertial measurement units (IMUs) facilitates continuous assessment of patient performance and progress, allowing for tailored rehabilitation protocols that adapt to individual needs (12). Furthermore, combining molecular insights from diagnostic tools with data from sophisticated imaging modalities can improve diagnostic accuracy and stratification, which is particularly beneficial for complex, heterogeneous conditions (13). As the field evolves, artificial intelligence plays a pivotal role in synthesizing multifaceted data inputs to support clinical decision-making and enhance therapeutic efficacy, ultimately leading to more effective management strategies and improved patient experiences (8,14). However, challenges remain in standardizing data integration and ensuring equitable access to these innovations across diverse healthcare settings.

The advent of AI-driven assessment and diagnosis tools has revolutionized the management of rare musculoskeletal disorders by enhancing the precision of evaluations and tailoring interventions to individual patient needs. These tools utilize machine learning algorithms to analyze vast datasets, uncovering patterns that might be overlooked by traditional assessment methods. For instance, predictive analytics can identify potential complications or prognosis outcomes, improving decision-making and patient care strategies. Furthermore, the integration of AI with advanced imaging techniques allows for more accurate evaluations of structural abnormalities and functional impairments, leading to personalized treatment plans that maximize therapeutic efficacy. Studies indicate that the application of these technologies significantly benefits rare conditions where clinical experience may be limited, ultimately enhancing recovery outcomes and patient satisfaction. As highlighted in the literature, innovations such as these not only facilitate evidence-based practice but also pave the way for a future where AI-driven tools can seamlessly integrate into routine physiotherapy settings, thus transforming the landscape of personalized care in rare musculoskeletal disorders (3,8,15).

The customization of treatment plans through artificial intelligence (AI) represents a transformative approach in the field of physiotherapy, particularly for patients with rare musculoskeletal disorders. By leveraging AI technologies, clinicians can analyze large datasets to identify individualized therapeutic interventions that take into account unique patient

characteristics and responses to treatment. For instance, the integration of multimodal analgesia strategies utilizes AI to optimize postoperative pain management by predicting patient-specific needs, ultimately reducing reliance on opioids (8). Additionally, AI-enabled applications have been developed to assess postural deviations and trunk asymmetries, employing photogrammetry to enhance the accuracy of evaluations and tailor interventions accordingly (1). In rehabilitative settings, hybrid frameworks combining finite element modeling with real-time signal acquisition exemplify how AI can facilitate the continuous adaptation of treatment protocols based on biomechanical feedback (7). Moreover, addressing the prevalence of work-related musculoskeletal disorders through AI-driven monitoring systems can significantly improve patient outcomes by fostering timely and customized therapeutic responses (9). Thus, the customization of treatment plans through AI not only enhances the efficacy of physiotherapy but also optimizes recovery trajectories for individuals with complex and rare conditions.

Challenges and Limitations in AI-based Physiotherapy for Rare Disorders

The incorporation of artificial intelligence (AI) into physiotherapy for rare musculoskeletal disorders presents significant challenges and limitations that must be addressed for effective implementation. One central concern is the scarcity of high-quality, diverse data necessary for training AI algorithms, as rare disorders often lack sufficient patient populations for robust machine learning models to develop accurate predictions and recommendations. Furthermore, the integration of AI with existing therapeutic practices can be hindered by the variability in treatment protocols and the need for individualized approaches (8). Additionally, the complexity of modeling unique biomechanics requires advanced hybrid frameworks that combine finite element modeling and real-time data acquisition while ensuring seamless communication between AI systems and practitioners (7). Challenges also arise from work-related musculoskeletal disorders, emphasizing the importance of ergonomics and posture management that AI systems must account for to enhance outcomes (9). Moreover, data security concerns and regulatory hurdles surrounding the use of personal health information further complicate the deployment of AI in clinical environments (3). Thus, addressing these barriers is essential for advancing personalized AI-driven physiotherapy practices.

In the context of rare musculoskeletal disorders, data scarcity and quality issues present significant challenges that hinder the advancement of personalized physiotherapy approaches utilizing artificial intelligence (AI). The inherent infrequency of these conditions often results in limited patient populations from which to derive evidence-based treatment protocols, leading to a reliance on anecdotal evidence and small-scale studies. For instance, research on pediatric coccydynia reveals a critical lack of high-level evidence, complicating the establishment of standardized management strategies (16). Additionally, the literature on disorders like hemophilia A and B underscores the disparities in treatment accessibility and the underrepresentation of these conditions in clinical trials, which further exacerbates data shortages (16). With AI applications, such as virtual reality tools aimed at enhancing patient engagement and treatment outcomes, the efficacy of these interventions remains under-evaluated in rare disorders due to reported technical limitations and accessibility challenges (17). Therefore, addressing these quality and data gaps is essential for optimizing AI-based therapies and ensuring equitable healthcare delivery in the realm of rare musculoskeletal disorders (12).

The integration of artificial intelligence (AI) in personalized physiotherapy raises significant ethical and privacy concerns, particularly regarding patient data. Given the sensitive nature of health information, patients often worry about the potential misuse of their data, especially as AI systems rely on large datasets to optimize therapeutic outcomes. For instance, the utilization of multimodal models to gather and analyze diverse patient data can enhance the accuracy of assessments and treatment plans, yet this also raises the specter of data breaches and unauthorized access (5). Moreover, the shift toward precision medicine, which depends heavily on the collection and analysis of genomic and phenotypic data, brings forth challenges related to informed consent and equitable access to care (14). Additionally, while AI can streamline treatment and monitoring processes for conditions like rheumatoid arthritis and osteoarthritis, algorithmic biases and a lack of real-world validation may exacerbate disparities in health outcomes (18). Therefore, establishing robust privacy-preserving frameworks and addressing ethical implications are essential for fostering patient trust in AI-driven healthcare systems (19).

The integration of artificial intelligence (AI) systems into clinical practice represents a transformative advancement in the field of personalized physiotherapy, particularly for the management of rare musculoskeletal disorders. By employing bio signals and motion-derived metrics, healthcare professionals can harness quantitative data crucial for enhancing diagnostic accuracy and therapeutic precision. For example, technologies such as electromyography (EMG) and various wearable

sensors facilitate real-time assessment and continuous monitoring of patients, enabling tailored rehabilitation protocols that adapt to individual needs (13). Additionally, multimodal approaches in pain management, which combine pharmacologic and non-pharmacologic strategies, have emerged as vital in addressing postoperative challenges, highlighting the need for individualized care (8). Furthermore, innovative applications like mobile AI-based posture evaluation systems reveal significant insights into trunk asymmetries, demonstrating the capacity of AI to enhance assessment processes and inform targeted interventions (1). Ultimately, the integration of AI in clinical settings promises to alleviate the burden of work-related musculoskeletal disorders, substantially improving patient outcomes and promoting efficient healthcare practices (9).

The potential of artificial intelligence (AI) in the realm of personalized physiotherapy for rare musculoskeletal disorders is promising; however, significant limitations impede its efficacy. First, the scarcity of high-quality, diverse datasets hinders AI models from effectively learning the complexities associated with such rare conditions, as they often rely on generalizations derived from broader populations (7). Moreover, the existing AI algorithms may not account for the unique clinical presentations of patients, particularly in disorders like amyotrophic lateral sclerosis (ALS), where phenotypic variability drastically affects treatment outcomes (15). This inadequacy highlights the black box nature of many AI systems, which complicates clinical decision-making as healthcare professionals may struggle to comprehend the underlying rationale for AI-generated recommendations (20). Additionally, the integration of AI into clinical practices faces challenges related to user-friendliness and technology acceptance among practitioners (9). Consequently, addressing these limitations is paramount for advancing AI applications in personalized therapy and ultimately improving patient care in these specialized medical domains.

Clinical Outcomes and Future Directions

As the landscape of physiotherapy evolves, particularly in the context of rare musculoskeletal disorders, the incorporation of artificial intelligence (AI) is crucial in enhancing clinical outcomes and shaping future directions. Research indicates that the use of multi-omics and rapid sequencing can significantly improve diagnostic yields, thereby facilitating timely and tailored interventions for complex cases (14). Additionally, AI-supported nonpharmacological interventions demonstrate promise in managing chronic rheumatic diseases, showing improvements in pain, function, and overall patient engagement (11). Such advancements underscore the need for integrating diverse imaging modalities and biomarkers to provide a comprehensive diagnostic framework that transcends traditional methods (12). Furthermore, the shift towards multimodal analgesic strategies in postoperative settings highlights the potential of personalized treatment protocols informed by AI analytics to optimize recovery and minimize opioid reliance (8). Collectively, these developments illustrate a transformative path forward, emphasizing the necessity of continued innovation and research to ensure equitable access to personalized physiotherapy care.

Evidence from Studies on AI-assisted Physiotherapy Efficacy

Research into the efficacy of AI-assisted physiotherapy has yielded promising results, particularly in enhancing personalized treatment modalities for rare musculoskeletal disorders. A hybrid framework that integrates finite element modeling (FEM) with AI-driven analytics demonstrates effective rehabilitation monitoring and individualized therapy adaptation. Studies indicate that the resultant closed-loop system not only accommodates patient-specific biomechanical characteristics but also provides real-time feedback to both patients and practitioners, thus improving the therapeutic experience (7). Furthermore, the establishment of international patient registries and multicenter trials, as emphasized in recent expert consensus recommendations, is crucial for advancing translational research and verifying the long-term benefits of AI interventions in clinical settings (21). Although challenges remain, including the integration of novel technologies into existing healthcare frameworks and addressing anatomical complexities during treatment, the role of AI in preoperative planning and postoperative management continues to show potential for optimizing patient outcomes (15). With ongoing developments, this evolving landscape suggests an urgent need for continuous updates and adaptations to treatment guidelines as new evidence emerges (22).

The integration of artificial intelligence (AI) protocols in personalized physiotherapy necessitates a keen focus on patient responsiveness and adaptability to optimize treatment outcomes, particularly in rare musculoskeletal disorders. Effective AI systems are designed to learn from continuous patient data, allowing for real-time modifications to treatment protocols that align with individual progress and needs. This dynamic responsiveness is critical, as the complexity of musculoskeletal

disorders often requires tailored approaches that can address varying degrees of pain and functional limitation among patients, as discussed in (23). Moreover, recent advancements in multimodal diagnostics harness AI to combine imaging data with biochemical markers, which enhances the understanding of disease states and patient-specific responses to therapy (12). Research into automatic pain assessment methods further emphasizes the importance of patient-oriented AI systems that actively engage demographics and pain perception elements to refine intervention strategies (24). Consequently, fostering adaptability within AI protocols ensures that physiotherapy remains not only personalized but also fundamentally patient-centered, enhancing the overall therapeutic experience.

The integration of advanced technologies in physiotherapy markedly enhances the personalization of treatment plans, especially for patients with rare musculoskeletal disorders. Technologies such as electromyography (EMG) and wearable sensor platforms provide quantitative metrics that allow for real-time monitoring of patient progress, facilitating tailored rehabilitation strategies that directly address individual needs (13). Furthermore, artificial intelligence (AI) has emerged as a transformative tool, enabling practitioners to analyze complex datasets for improved diagnosis and treatment customization (25). For instance, in conditions like hemophilia, the identification of genotype-phenotype correlations has led to innovative therapies that enhance patient outcomes, illustrating the significance of personalized approaches in clinical practice (26). Additionally, postoperative monitoring through wearable technologies can capture functional recovery with greater accuracy than traditional methods, which often rely solely on subjective patient-reported outcomes (27). Collectively, these advancements signify a shift towards a more precise and individualized approach in physiotherapy, promising enhanced effectiveness and patient satisfaction outcomes.

To optimize the integration of artificial intelligence in personalized physiotherapy for rare musculoskeletal disorders, several key recommendations for research and clinical implementation emerge. First, interdisciplinary collaboration among rheumatologists, physiotherapists, and AI specialists is essential to develop effective, multimodal interventions tailored to individual patient needs, as highlighted in the findings of recent studies which emphasize the utility of combining AI-driven insights with conventional treatment strategies (8). Second, the adoption of standardized protocols for data collection and outcome measurement will enhance the reliability and comparability of results across studies, thereby fortifying the evidence base for AI applications in musculoskeletal care (11). Moreover, researchers should prioritize long-term follow-up studies to assess the sustained impact of AI-supported interventions on both clinical outcomes and quality of life, addressing gaps identified in existing literature (12). Lastly, exploring patient perspectives and experiences through qualitative research will enrich understanding and ensure that AI solutions are user-centered and effective in real-world clinical settings (25).

2. CONCLUSION

In conclusion, the integration of artificial intelligence (AI) in personalized physiotherapy presents a transformative potential for managing rare musculoskeletal disorders, which often pose significant challenges due to their unique and complex nature. AI-driven approaches, such as those detailed in the literature review, enable the customization of rehabilitation interventions by leveraging real-time data and biomechanical modeling to assess patient progress accurately (7). Furthermore, AI facilitates the rapid analysis of extensive genomic datasets to inform targeted treatments, thereby enhancing outcomes and tailoring therapies to individual patient needs (3). This advancement reflects broader trends in precision medicine, where AI not only optimizes existing therapeutic modalities but also introduces innovative pathways for drug design and patient management (3). However, as we navigate this promising frontier, it is essential to address potential data security concerns and regulatory challenges that accompany the deployment of AI technologies in healthcare settings. Ultimately, strengthening the synergy between AI and physiotherapy will foster more effective, adaptive interventions, significantly improving patient quality of life and recovery trajectories in rare musculoskeletal conditions (9).

The exploration of personalized physiotherapy utilizing artificial intelligence (AI) for rare musculoskeletal disorders reveals significant advancements across various domains. A comprehensive review highlights the diagnostic complexities inherent in musculoskeletal disorders, with innovations in imaging technologies and molecular biomarkers enhancing precision in disease detection and clinical decision-making. These multimodal strategies, when used in combination, can promote timely intervention and improve patient outcomes (12). Furthermore, the application of AI in postoperative pain management has transformed traditional opioid-centric approaches into more individualized multimodal analgesia protocols, effectively reducing complications and enhancing recovery (8). The relevance of posture analysis through AI-informed applications

underscores the importance of regular assessments in mitigating trunk asymmetries and deviations (1). Lastly, addressing work-related musculoskeletal disorders emphasizes the critical need for ongoing interventions to improve workers quality of life and overall productivity, as these conditions can result in chronic pain and economic burdens (9). Collectively, these findings underscore the transformative potential of AI in tailoring physiotherapy solutions for diverse patient populations.

The significance of artificial intelligence (AI) in enhancing personalized care is increasingly recognized within the realm of physiotherapy, particularly for patients with rare musculoskeletal disorders. AI tools can aggregate and analyze complex patient data, allowing for tailored therapeutic interventions that align with individual needs. For instance, advancements in AI-driven postural assessment tools, such as the AI Posture Evaluation and Correction System (APECS), demonstrate how technology can facilitate precise diagnosis of alignment issues and inform customized therapeutic strategies, which is critical in addressing specific biomechanical challenges faced by patients (7). Furthermore, innovative frameworks that integrate AI with biomechanical modeling can track recovery progress in real-time, helping adjust therapies based on individual motor trends (1). The use of AI also extends to optimizing pain management protocols, where algorithms can predict postoperative pain trajectories, enabling clinicians to implement multimodal analgesia that caters to the unique experiences of each patient (8). Ultimately, the application of AI in personalized care not only enhances therapeutic outcomes but also addresses the complex, multifaceted needs of individuals suffering from rare conditions (9).

The integration of artificial intelligence (AI) into the management of rare musculoskeletal disorders presents significant potential for enhancing personalized physiotherapy approaches. By utilizing AI-driven algorithms and predictive modeling, healthcare providers can analyze vast datasets to tailor interventions that are specific to an individual's unique pathology and treatment response. For instance, AI can facilitate the development of individualized rehabilitation plans that adapt in real-time based on patient progress, maximizing the effectiveness of therapeutic protocols. Additionally, the use of advanced biomechanical modeling allows for improved understanding of the mechanics underlying specific disorders, leading to more targeted treatments (7). Furthermore, AIs role in pharmaceutical research supports the discovery of novel therapeutic agents tailored for rare conditions (3). As ongoing research focuses on the implications of AI in clinical settings, it is essential to overcome challenges such as data privacy and interpretation to fully realize the benefits of personalized physiotherapy in managing rare musculoskeletal disorders, ultimately improving patient outcomes and reducing healthcare costs, as emphasized by studies on work-related musculoskeletal disorders (9).

As the landscape of personalized physiotherapy using artificial intelligence (AI) evolves, it is imperative to consider the future prospects and research needs that will enhance its application in rare musculoskeletal disorders. Current advancements in precision medicine, bolstered by multi-omic data and machine learning, hold promise for individualized treatment approaches that address the unique challenges presented by these disorders (14). However, there exists a significant gap between innovation and clinical implementation, necessitating a concerted effort to ensure equitable access and integration of advanced therapeutic modalities into routine care (25). Furthermore, insights from fields like space medicine highlight the necessity of preparing healthcare providers to adapt to emerging technologies and novel clinical environments, emphasizing the human element that AI cannot replicate (19). Future research should focus on bridging the disparities in healthcare access, particularly in low-resource settings, while exploring new therapeutic frontiers such as gene therapy for rare conditions (26). The intersection of these elements will not only improve patient outcomes but also foster a more inclusive approach to personalized healthcare.

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