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AI-ASSISTED GAIT ANALYSIS IN PHYSICAL THERAPY: A SYSTEMATIC REVIEW OF TOOLS AND REHABILITATION OUTCOMES

Systematic Review

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ABSTRACT

Background: Artificial intelligence (AI) is increasingly being integrated into rehabilitation medicine, particularly in gait analysis for individuals with mobility impairments. Conventional gait assessments often rely on subjective evaluation or limited sensor technologies, which may lack precision and adaptability. Although various AI-based tools have emerged, the clinical relevance and effectiveness of these technologies in improving rehabilitation outcomes remain inadequately consolidated in existing literature.

Objective: This systematic review aims to evaluate the effectiveness of AI-assisted gait analysis tools in physical therapy, focusing on their impact on treatment planning, functional recovery, and overall rehabilitation outcomes.

Methods: A systematic review was conducted according to PRISMA guidelines. Four electronic databases—PubMed, Scopus, Web of Science, and Cochrane Library—were searched for studies published between 2020 and 2024. Eligible studies included randomized controlled trials, cohort studies, and observational designs involving patients undergoing physical therapy for gait dysfunction, utilizing AI-based gait analysis tools. Data extraction and risk of bias assessment were performed independently by two reviewers using standardized forms and validated tools such as the Cochrane Risk of Bias Tool and Newcastle-Ottawa Scale.

Results: Eight studies met inclusion criteria, encompassing 644 participants with conditions including stroke, Parkinson's disease, and orthopedic impairments. AI technologies included wearable sensors, robotic trainers, and vision-based tracking systems. Most studies reported significant improvements in gait parameters such as cadence, stride length, and walking distance ($p < 0.05$), as well as better adherence and therapy personalization. Risk of bias was generally low to moderate, with some concerns related to performance blinding.

Conclusion: AI-assisted gait analysis tools show promising clinical value in enhancing rehabilitation outcomes and supporting individualized therapy planning. While current evidence is encouraging, further large-scale and methodologically rigorous studies are needed to validate these findings and guide broader implementation.

Keywords: Artificial Intelligence, Gait Analysis, Physical Therapy, Rehabilitation, Machine Learning, Systematic Review.

INTRODUCTION

The integration of artificial intelligence (AI) into clinical rehabilitation has gained significant momentum in recent years, particularly in the domain of gait analysis and physical therapy. Gait disturbances are prevalent across a broad range of neurological and musculoskeletal conditions, including stroke, Parkinson's disease, cerebral palsy, and osteoarthritis, all of which significantly impair mobility and quality of life (1,2). Globally, gait abnormalities contribute to a high burden of disability, particularly among aging populations, where fall-related injuries remain a leading cause of morbidity and hospitalization (3). Traditional gait assessment methods, while informative, often rely on subjective clinical observation and limited motion capture tools, which can lack precision and consistency across evaluators (4). Recent advancements in AI-based motion tracking technologies, including computer vision, machine learning algorithms, and wearable sensors, have introduced new possibilities for automated, objective, and real-time gait assessment. These systems offer clinicians detailed kinematic data and predictive analytics that can inform diagnosis, monitor progression, and tailor rehabilitation strategies with greater accuracy than conventional techniques (5). Despite these advancements, existing literature presents a fragmented view of the available tools and their clinical impact, often focusing on technical performance without adequately linking these innovations to patient-centered outcomes such as recovery speed, functional mobility, or treatment efficacy (6,7).

Moreover, while several studies have explored individual AI-driven systems, there remains a lack of consolidated evidence regarding their comparative effectiveness, implementation challenges, and therapeutic relevance. This fragmented understanding creates a critical gap for clinicians and decision-makers seeking to adopt AI-assisted tools in routine practice (8,9). The growing diversity of AI applications, ranging from smartphone-based gait tracking to fully immersive robotic platforms, further underscores the need for an organized synthesis of available data (10). To address these gaps, the current systematic review seeks to evaluate AI-assisted gait analysis tools used in physical therapy, focusing on how these interventions influence treatment planning and rehabilitation outcomes. The population of interest includes patients undergoing physical therapy for gait impairments across various etiologies (11,12). The interventions considered are AI-based gait analysis and motion tracking tools, compared with either traditional assessment methods or other digital systems, with primary outcomes including improvements in functional recovery, treatment personalization, and overall rehabilitation efficacy (13,14). This review will include both randomized controlled trials and observational studies published between 2018 and 2024, covering global research to capture diverse technological applications and clinical settings. In doing so, it aims to provide clinicians, researchers, and health technology stakeholders with evidence-based insights into the utility and limitations of AI in modern physical rehabilitation. Following PRISMA guidelines, this systematic review will not only identify leading technologies but also clarify their practical implications, thereby contributing to more informed decision-making in therapy planning and digital health adoption.

METHODS

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure methodological transparency and reproducibility. A comprehensive search strategy was developed to identify relevant literature from multiple electronic databases including PubMed, Scopus, Web of Science, and the Cochrane Library. The search was conducted using a combination of Medical Subject Headings (MeSH) and keywords such as "Artificial Intelligence," "Gait Analysis," "Motion Tracking," "Rehabilitation," "Physical Therapy," and Boolean operators like "AND" and "OR" to ensure a thorough search. An example of the query used was: ("Artificial Intelligence" OR "Machine Learning") AND ("Gait Analysis" OR "Motion Tracking") AND ("Physical Therapy" OR "Rehabilitation"). Additional manual searches of the reference lists of eligible articles were also conducted to identify studies not captured through database queries. Eligibility criteria for inclusion were defined a priori. Included studies were randomized controlled trials, prospective or retrospective cohort studies, and cross-sectional observational studies that investigated AI-assisted gait analysis tools in the context of physical therapy. Studies were included if they involved human participants with gait impairments undergoing physical rehabilitation and reported outcomes such as gait improvement, functional recovery, or treatment personalization. Participants of all ages and clinical conditions contributing to gait dysfunction (e.g., stroke, Parkinson's disease, orthopedic injuries) were considered. Studies were excluded if they were non-English, animal studies, editorials, conference abstracts without full text, or focused solely on technical validation without clinical outcomes.

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Study selection was conducted through a two-stage screening process. Titles and abstracts were independently screened by two reviewers, followed by full-text assessments of potentially eligible studies. Any discrepancies were resolved through consensus or consultation with a third reviewer. Reference management was performed using EndNote X9 to organize citations and remove duplicates. A PRISMA flow diagram was generated to visualize the study selection process. Data from included studies were extracted using a standardized data collection form developed for this review. Extracted information included study characteristics (authors, publication year, country), participant demographics (sample size, age, clinical condition), intervention details (type of AI system used, duration, setting), comparison groups (if applicable), outcome measures (e.g., gait speed, stride length, balance scores), and results. Where applicable, information on follow-up duration and adverse events was also recorded.

The methodological quality and risk of bias of the included studies were assessed using appropriate tools based on study design. Randomized controlled trials were evaluated using the Cochrane Risk of Bias Tool, while non-randomized studies were assessed using the Newcastle-Ottawa Scale. Key domains of bias assessment included selection bias, performance bias, detection bias, attrition bias, and reporting bias. Assessments were independently conducted by two reviewers, with disagreements resolved through discussion. Given the heterogeneity of study designs, populations, and outcomes, a qualitative synthesis was undertaken. Results were synthesized narratively, structured around types of AI interventions and their reported effects on rehabilitation outcomes. Where studies shared similar outcome metrics and methodological rigor, comparative observations were made, although formal meta-analysis was not feasible due to variability in outcome definitions and intervention protocols.

RESULTS

A total of 1,243 articles were identified through database searching across PubMed, Scopus, Web of Science, and the Cochrane Library. After removing 328 duplicates, 915 records remained for title and abstract screening. Of these, 852 studies were excluded based on irrelevance to the topic, leaving 63 full-text articles for eligibility assessment. Following a thorough evaluation against the predefined inclusion and exclusion criteria, 55 studies were excluded due to reasons such as non-reporting of clinical outcomes, non-English language, or absence of AI-based gait assessment tools. Ultimately, 8 studies were included in the final analysis. The study selection process was illustrated using a PRISMA flow diagram to ensure clarity and reproducibility. The eight included studies were published between 2020 and 2024 and varied in design, comprising three randomized controlled trials, three prospective cohort studies, and two cross-sectional observational studies. Sample sizes ranged from 28 to 154 participants, with patient populations including individuals recovering from stroke, Parkinson’s disease, musculoskeletal injuries, and age-related gait impairments. AI tools employed across studies included wearable sensors with machine learning algorithms, smart insoles, depth cameras, and robotic-assisted gait trainers. Primary outcomes assessed were gait speed, step length, cadence, balance scores, and rehabilitation responsiveness. Secondary outcomes involved patient adherence, usability of devices, and clinician satisfaction.

Risk of bias assessments revealed overall moderate to high methodological quality across studies. All three randomized trials demonstrated low risk in random sequence generation and outcome reporting but had unclear blinding processes for participants and personnel. The observational and cohort studies exhibited low risk in selection and comparability domains per the Newcastle-Ottawa Scale but were prone to potential confounding due to lack of control groups. A common limitation across studies was performance bias due to the inability to blind participants to intervention devices, particularly when using wearable or robotic systems. Regarding primary outcomes, AI-assisted gait analysis tools showed consistent effectiveness across diverse clinical contexts. A statistically significant improvement in cadence and balance following an 8-week intervention with smart insoles providing real-time feedback ($p<0.01$) (15). Similarly, a study found that robotic-assisted AI-guided therapy led to a measurable increase in 6-minute walking distance compared to conventional therapy ($p=0.03$) (16). Another study demonstrated enhanced adherence to therapy regimens due to AI-driven personalization of feedback and real-time corrections (17). In Parkinson’s patients, AI-based gait phase classification reached a precision of 94%, enabling more tailored rehabilitation planning (18). Across all studies, patient-centric benefits included earlier identification of abnormal gait patterns, more granular monitoring of improvement trajectories, and enhanced clinician decision-making supported by objective metrics. Taken together, the findings suggest that AI-assisted gait analysis technologies not only augment the diagnostic accuracy of clinicians but also offer tangible improvements in rehabilitation outcomes when compared with traditional assessment and monitoring approaches.

Table1: Summary of Included Studies on AI-Assisted Gait Analysis Tools in Physical Therapy and Their Clinical Outcomes

Author (Year)	Design	Sample Size	AI Tool Type	Population	Key Outcomes
Monteiro et al. (2023)	Systematic Review	94	Wearable sensors + ML	Stroke patients	Improved gait symmetry, faster recovery
Li et al. (2022)	Cohort Study	101	Vision-based gait tracker	Mixed neurological cases	Higher gait analysis precision
Chen et al. (2021)	Observational	76	Machine learning + sensors	Elderly with balance issues	Early identification of fall risk
Zhang et al. (2024)	Prospective Cohort	87	Feedback-driven gait platform	Mixed rehabilitation patients	Personalized gait correction and adherence
Lin et al. (2023)	RCT	72	Smart insoles with feedback	Elderly fall-prone patients	Significant improvement in cadence ($p<0.01$)
Santos et al. (2022)	RCT	58	Robotic gait trainer + AI	Post-stroke gait dysfunction	Increased walking distance ($p=0.03$)
Nakamura et al. (2020)	Observational	154	Deep learning classifier	Parkinson's disease	Accurate gait phase classification (94%)
Ahmed et al. (2021)	RCT	64	Depth-camera gait analysis	Orthopedic rehab patients	Improved stride length, balance ($p<0.05$)

DISCUSSION

This systematic review demonstrated that artificial intelligence-assisted gait analysis tools are effective in enhancing rehabilitation outcomes across various patient populations undergoing physical therapy. Across the eight included studies, AI-based interventions consistently yielded improvements in objective gait parameters such as step length, cadence, and walking speed, as well as in functional recovery markers including balance and therapy adherence. These tools provided clinicians with high-resolution, real-time data to inform personalized treatment plans, resulting in more efficient and responsive rehabilitation processes (19,20). The strength of the evidence is reinforced by the inclusion of multiple randomized controlled trials and well-designed observational studies, indicating a growing body of high-quality research supporting the integration of AI in rehabilitation settings. When compared to previous literature, the findings of this review align with earlier studies highlighting the potential of AI to transform conventional physical therapy practices (21,22). Prior systematic reviews have focused predominantly on the technical capabilities of AI systems without sufficiently exploring clinical impact. This review advances the literature by emphasizing patient-centered outcomes and providing a clinically grounded synthesis. For instance, studies emphasized the superior precision of AI systems in motion tracking, but this review extends that evidence by incorporating recent RCTs that connect these technological advancements to tangible patient improvements (23,24). Similarly, a study acknowledged the promise of wearable AI systems, the current findings of studies contribute new evidence on statistically significant clinical improvements, thus substantiating earlier hypotheses with stronger empirical support (25-27).

A notable strength of this review lies in its comprehensive and systematic methodology, adhering to PRISMA guidelines and employing a rigorous multi-database search strategy. The inclusion of diverse study designs and clinical populations enhances generalizability, while risk of bias assessments ensured that the quality of evidence was critically appraised. Additionally, the review captured studies employing a wide range of AI technologies—from wearable sensors to robotic trainers—thereby reflecting the heterogeneity and innovation in the field. Despite these strengths, several limitations warrant consideration. Sample sizes in many of the included studies were modest, which may affect the robustness of conclusions and limit generalizability to larger, more diverse populations. There is also the potential for publication bias, particularly given the rapid technological advancements and the tendency to publish positive findings over null results. Variability in intervention protocols, outcome measures, and patient populations also made it infeasible to conduct a meta-analysis, limiting the ability to quantify effect sizes or perform subgroup analyses. The findings of this review have significant implications for clinical practice and future research. AI-assisted gait analysis tools present a viable opportunity to enhance the precision and personalization of physical therapy, potentially reducing rehabilitation timelines and improving long-term mobility outcomes. For clinicians, these tools offer an evidence-based adjunct to traditional assessment, while for health systems, they present scalable solutions

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to address workforce shortages and standardize care delivery. Future research should aim to validate these findings in larger, multicenter trials, with particular attention to cost-effectiveness, integration into clinical workflows, and long-term outcomes. Investigating user experience, both from clinician and patient perspectives, will also be critical to supporting widespread adoption.

CONCLUSION

This systematic review highlights that AI-assisted gait analysis tools demonstrate considerable potential in improving clinical outcomes in physical therapy, particularly in enhancing gait parameters, promoting personalized rehabilitation, and facilitating more accurate monitoring of patient progress. The findings underscore the clinical value of integrating AI technologies into rehabilitation practice, offering an evidence-based approach to support more tailored and efficient therapy strategies. While the included studies collectively suggest beneficial effects, the overall reliability of the evidence is tempered by modest sample sizes and methodological variability. Consequently, further large-scale, high-quality research is warranted to confirm these findings, establish long-term effectiveness, and address practical considerations such as cost, integration into clinical workflows, and user experience.

AUTHOR CONTRIBUTION

Author	Contribution
Saniya Alam*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Hamza Shabbir	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Talha Nouman	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Filza Shoukat	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ali Abbas	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Abdul Aziz	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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