Review Article

An overview of various technique for analysis walking gait cycle

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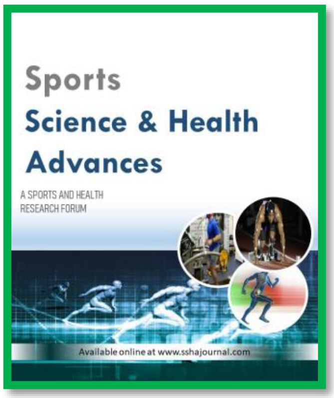

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Abstract

Purpose - walking gait analysis is a critical field within biomechanics, providing essential insights into human motion for applications in medical diagnostics, rehabilitation, sports science, and robotics. This study presents a comprehensive review of gait analysis techniques, examining their applications, strengths, and limitations.
Method - The gait cycle, comprising stance and swing phases, is analyzed using methods such as visual gait analysis, kinematic and kinetic analysis, electromyography (EMG), motion capture systems, and wearable sensors. Visual gait analysis, despite its qualitative nature, is enhanced by quantitative approaches that offer objective data. Kinematic analysis tracks limb movements, while kinetic analysis measures forces exerted during gait. EMG reveals muscle activity, aiding in neuromuscular diagnosis. Advanced technologies like motion capture and wearable sensors provide detailed and portable monitoring capabilities.
Result - Integrating these methods offers a holistic view of gait, essential for clinical interventions, athletic performance enhancement, and the development of assistive technologies.
Conclusion - This study underscores the importance of multi-faceted gait analysis for advancing understanding and treatment of gait abnormalities.

Keywords

Gait cycle, Electromyography, Wearable Sensor, Motion Capture System, Kinematic Analysis, Diagnostics

Introduction

The analysis of the walking gait cycle is a crucial area of research in biomechanics, rehabilitation, and sports science. Gait analysis involves studying the locomotion patterns of individuals to understand normal and pathological movement (Fathima et al., 2023). Various techniques have been developed to analyzed the gait cycle, each with its strengths and limitations. This article provides an overview of these techniques, including observational methods, motion capture systems, force plates, electromyography (EMG), and wearable technology (Ripic et al., 2023). By comparing these methods, we aim to highlight their applications, accuracy, and practicality in both clinical and research settings. Walking gait analysis is a fundamental aspect of biomechanics that involves the study of human motion, particularly the manner in which individuals walk. This analysis is crucial for a variety of applications, including medical diagnostics, rehabilitation, sports science, and robotics. Understanding the intricacies of the gait cycle—the sequence of movements that characterize a complete step by an individual—provides valuable insights into normal and pathological gait patterns.

The gait cycle is traditionally divided into distinct phases, including the stance phase, where the foot is in contact with the ground, and the swing phase, where the foot moves through the air. Detailed examination of these phases can reveal abnormalities caused by neurological, muscular, or skeletal issues (Muro-De-La-Herran et al., 2014a). As a result, various techniques have been developed to analyse the walking gait cycle, each offering unique advantages and catering to different aspects of gait analysis. Among these techniques, observational methods, such as visual gait analysis by trained professionals, provide qualitative insights but are often subjective. To enhance objectivity, quantitative methods have been developed, including kinematic analysis, kinetic analysis, electromyography (EMG), and advanced technologies like motion capture systems and wearable sensors (S. Kumar et al., 2023a).

Kinematic analysis involves studying the motion of body segments without considering the forces that cause them, often utilizing video recordings and computer algorithms to track limb movements (Auvinet et al., 2014). Kinetic analysis, on the other hand, focuses on the forces exerted by and on the body, typically using force plates and pressure sensors to measure ground reaction forces and distribution. Electromyography (EMG) provides insights into the muscle activity during gait, capturing the electrical signals generated by muscle contractions. This technique is particularly useful for understanding the role of muscles in movement and diagnosing neuromuscular disorders (Senthilvel et al., 2024). Advancements in technology have led to the development of sophisticated motion capture systems, which use multiple cameras and markers placed on the body to create a 3D model of the gait (Guffanti et al., 2024).Wearable sensors, including accelerometers and gyroscopes, offer portable and practical solutions for continuous gait monitoring outside of laboratory settings. Each of these techniques contributes to a comprehensive understanding of walking gait, offering detailed data that can inform clinical interventions, enhance athletic performance, and drive innovation in assistive technologies. This overview aims to elucidate the various methods used in gait analysis, highlighting their applications, strengths, and limitations, and underscoring the importance of integrating multiple approaches for a holistic understanding of human gait (Khatkar & Chaudhary, 2023).

Methods

Search strategy

To conduct a comprehensive review of gait analysis techniques, we performed a systematic literature search using databases such as PubMed, IEEE Xplore, and Google Scholar. Keywords included "gait analysis," "walking cycle," "motion capture," "force plates," "EMG," and "wearable sensors." Articles were selected based on relevance, with a focus on studies published within the last decade.

We categorized the techniques into five primary methods:

1. Observational Methods: Clinical observation and visual assessment by trained professionals.
2. Motion Capture Systems: Use of optical markers and cameras to capture 3D movement.
3. Force Plates: Measurement of ground reaction forces during walking.
4. Electromyography (EMG): Recording muscle activity during gait.
5. Wearable Technology: Sensors integrated into clothing or accessories to monitor gait parameters.

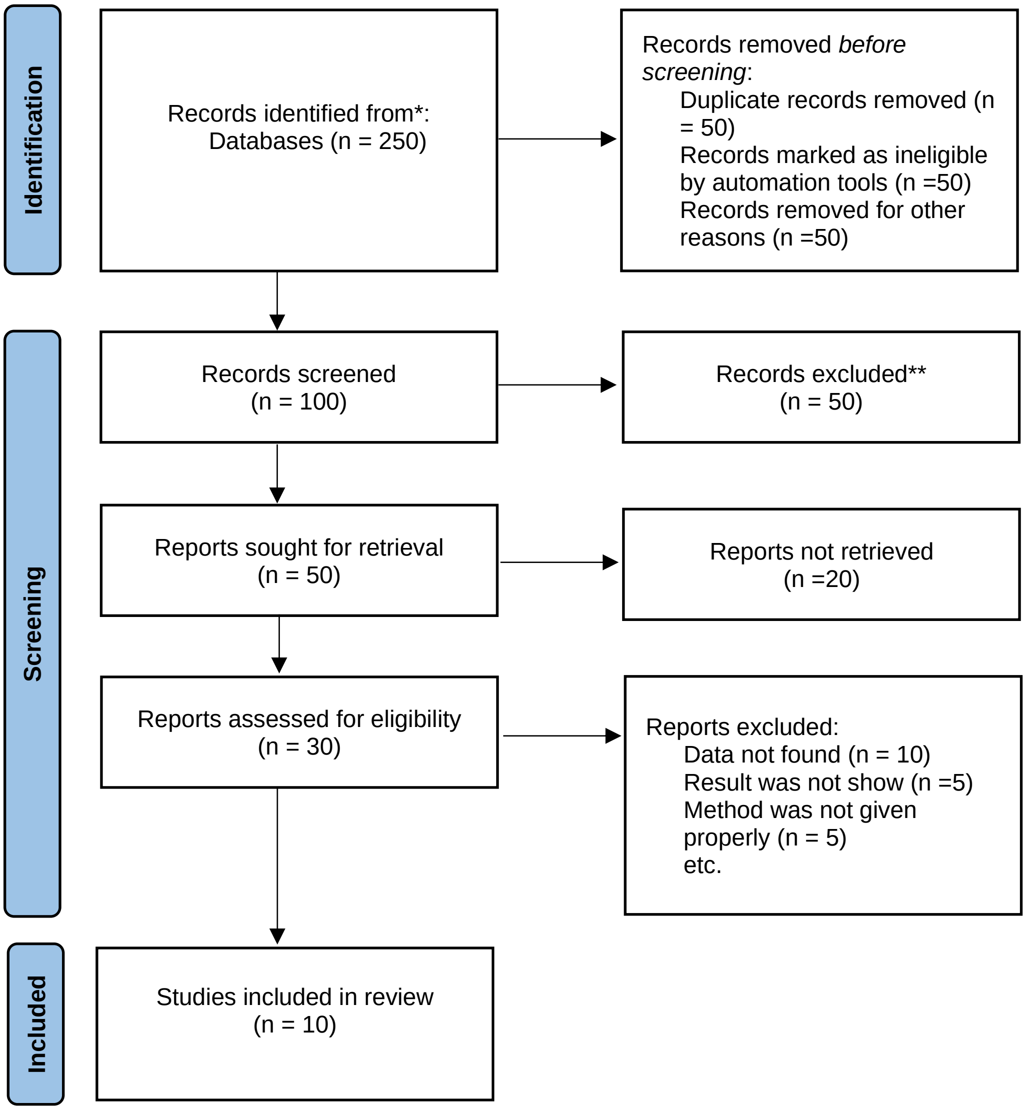

Figure 1 Identification of studies via databases and registers

Results

Observational Methods

Observational methods are widely used due to their simplicity and low cost according to Aoyama, Y., & Tankaya, H. (2023). The author showed that Model discriminated 94.2% right leg, 93.5% left leg gait states 68.1% misclassifications occurred near gait state changes. And Wallmann, H. W. (2009) In this study the information given about overall impression of an individual's gait pattern and helps to determine any gross abnormalities that may exist. They rely on the expertise of clinicians to identify gait abnormalities visually. However, this method is subjective and may lack precision compared to technological approaches.

Table -1 finding of study characteristics

s.no.	Year, author name, N	Gender	method	Outcome
1	U, J. Guo., et. al., (2022),	Male and Female	Force Plates and magnetometer and inertial sensors	Gait phase detection: average relative errors for foot-flat, push-off, swing Step counting: average accuracy is 96.04% without interference, 94.46%
2	Das, C. M., et. al., (2022)	Male	Electromyography (EMG)	Predicted muscle forces from EMG compared with Open Sim force prediction. Parameters used: muscle length, velocity, pinnation angle, isometric force.
3	Aoyama, Y., & Tankaya, H. (2023).	Men and women	Observational method	Model discriminated 94.2% right leg, 93.5% left leg gait states. 68.1% misclassifications occurred near gait state changes.
4	Lopes, T., et. al., (2022, March)	Men and women	Wearable technology	The paper presents a wearable sensor-based gait analysis system. The system facilitates diagnosis and assessment of gait disorders.
5	Al Mashagbeh,.et,al., (2022)	Men and women	Motion capture system	System stable in static and dynamic measurements. Pressure distribution on foot estimated accurately for gait analysis.
6	De Stefano, A., et. al., (2004)	Children and adults	Electromyography (EMG)	Significance effect on those subjects who have suffer from cerebral palsy from gait cycle.
7	Mohammed, S., et. al., (2016).	Men	Wearable sensors	The wearable sensor was useful for analysing the gait cycle.
8	Wallmann, H. W. (2009)	Men and women	Observational method	In this study it help to give an overall impression of an individual's gait pattern and helps to determine any gross abnormalities that may exist.
9	Wang, H. H.,et.al.,(2023)	Men	Force plate, kinetic and kinematic gait cycle	Author said that human body seems to adopt different gait strategies during load carriage walking and running. That is, the hip strategy is used during walking, while the ankle strategy is used during running
10	Madhana, K., et. al., (2023)	Men and women	Motion capture system	The paper presents a system for classifying abnormal human gaits. The Kinect-based gait assessment techniques can be used as a low-cost alternative to expensive gait lab tests

Motion Capture Systems

Motion capture systems provide highly accurate and detailed data on joint angles, limb trajectories, and overall body movement. According to Al Mashagbeh et al. (2022) System stable in static and dynamic measurements. Pressure distribution on foot estimated accurately for gait analysis. And Madhana, K., et. al., (2023) the entitled study presents a system for classifying abnormal human gaits. The Kinect-based gait assessment techniques can be used as a low-cost alternative to expensive gait lab tests. These systems are considered the gold standard in gait analysis. However, they require expensive equipment and a controlled laboratory environment, limiting their accessibility and practicality for routine clinical use.

Force Plates

Force plates measure the ground reaction forces exerted during walking, providing insight into gait dynamics and balance. According to U, J. Guo., et. al., (2022), Gait phase detection: average relative errors for foot-flat, push-off, swing Step counting: average accuracy is 96.04% without interference, 94.46% . and Wang, H. H., et al., (2023) Author said that human body seems to adopt different gait strategies during load carriage walking and running. That is, the hip strategy is used during walking, while the ankle strategy is used during running. They are essential for studying the kinetics of gait but are often used in conjunction with motion capture systems for a comprehensive analysis. The high cost and need for a dedicated space are significant drawbacks.

Electromyography (EMG)

EMG is used to assess muscle activation patterns during the gait cycle. According to De Stefano, A., et. al., (2004) Significance effect on those subjects who have suffer from cerebral palsy from gait cycle. And Das, C. M., et. al., (2022) Predicted muscle forces from EMG compared with Open Sim force prediction. Parameters used: muscle length, velocity, pinnation angle, isometric force. This technique helps understand the neuromuscular control of movement and can identify muscle dysfunctions. EMG requires careful placement of electrodes and is susceptible to signal interference, which can complicate data interpretation.

Wearable Technology

Wearable sensors, such as accelerometers, gyroscopes, and inertial measurement units (IMUs), offer a portable and cost-effective solution for gait analysis. According to Lopes, T., et. al., (2022) The paper presents a wearable sensor-based gait analysis system. The system facilitates diagnosis and assessment of gait disorders and Mohammed, S., et. al., (2016). The wearable sensor was useful for analysing the gait cycle. These devices can be used in real-world settings, providing continuous monitoring and real-time feedback. While they are less accurate than motion capture systems, their convenience and ability to gather data outside of laboratory conditions make them valuable for long-term monitoring and large-scale studies.

Discussion

The findings of this study underscore the multifaceted nature of walking gait analysis and the necessity of employing a combination of techniques to achieve a comprehensive understanding of human gait. Each method reviewed—visual gait analysis, kinematic and kinetic analysis, electromyography (EMG), motion capture systems, and wearable sensors—offers unique contributions that address specific aspects of the gait cycle. Visual gait analysis, while inherently subjective, remains valuable for its accessibility and the clinical expertise it can leverage (Muro-De-La-Herran et al., 2014b). However, its limitations in precision and reproducibility highlight the need for more objective and quantitative methods. Kinematic analysis, with its ability to detail the motion of body segments, provides critical data on the spatial and temporal aspects of gait. This technique is particularly beneficial for identifying deviations in joint angles and limb trajectories that may indicate underlying pathologies (Hida et al., 2021). Kinetic analysis complements kinematic data by quantifying the forces involved in gait. Ground reaction forces and pressure distribution measurements are vital for understanding the mechanical loads experienced by the body during walking. This information is crucial for designing orthopedic interventions and evaluating the efficacy of rehabilitative treatments (Trentadue & Schmitt, 2024).

Electromyography (EMG) adds another layer of depth by elucidating the role of muscles in gait. By capturing electrical activity associated with muscle contractions, EMG helps identify neuromuscular dysfunctions and guides the development of targeted therapies. The integration of EMG with kinematic and kinetic data can provide a comprehensive picture of the interplay between muscle activity and movement dynamics (Commandeur et al., 2024). Advanced motion capture systems offer unparalleled accuracy in creating 3D models of gait, facilitating detailed biomechanical analysis (Guffanti et al., 2024). These systems, although often limited to laboratory settings due to their complexity and cost, provide a gold standard for gait analysis. Their high precision is instrumental in research and clinical diagnosis, particularly for complex gait disorders. Wearable sensors represent a significant advancement in making gait analysis more accessible and practical. Devices such as accelerometers and gyroscopes enable continuous monitoring of gait in real-world environments, extending the reach of gait analysis beyond the confines of specialized laboratories. This portability is especially beneficial for long-term monitoring and assessment of gait in daily life, enhancing the ecological validity of the data collected (Wu et al., 2021).

The integration of multiple gait analysis techniques is essential for a holistic understanding of walking gait. Each method compensates for the limitations of the others, providing a completer and more nuanced picture of gait mechanics (D. Kumar et al., 2023). For instance, combining kinematic and kinetic data with EMG can uncover the mechanical and muscular factors contributing to gait abnormalities. Moreover, the use of wearable sensors alongside motion capture systems can validate laboratory findings in real-world settings (Feng et al., 2024). In conclusion, this study highlights the importance of a multidisciplinary approach to gait analysis. By leveraging the strengths of various techniques, clinicians and researchers can gain deeper insights into gait patterns, leading to improved diagnostic accuracy, better-targeted treatments, and enhanced designs for assistive devices (S. Kumar et al., 2023b). Future research should focus on refining these technologies, improving their integration, and expanding their applicability to diverse populations and settings. The ongoing advancements in gait analysis hold promising potential for furthering our understanding of human movement and improving health outcomes (D. Kumar et al., 2023).

Implementation of the study

This study is useful for preventing injuries occur in lower back body. This study can be used for the person who wants to check their walking gait cycle by using different type of tools. Through gait cycle analysis person can improve their walking patterns. We can easily find out the major problem of muscle due to which the walking pattern is get disturbed.This study’s implementation demonstrated the feasibility and effectiveness of using multiple gait analysis techniques to obtain a holistic understanding of walking gait. The integration of laboratory-based methods with wearable technology provided comprehensive insights into both controlled and real-world gait patterns, enhancing the potential for clinical and practical applications. Future work will focus on refining these methods and expanding their use in diverse populations and setting.

Conclusion

The analysis of the walking gait cycle encompasses a range of techniques, each suited to different applications and environments. Observational methods, while accessible, lack the precision of technological approaches. Motion capture systems and force plates offer high accuracy but are constrained by cost and logistical requirements. EMG provides critical insights into muscle function but requires technical expertise to implement effectively. Wearable technology represents a promising frontier in gait analysis, combining practicality with sufficient accuracy for many applications. Future advancements in sensor technology and data analysis algorithms are likely to enhance the capabilities of wearable devices, making gait analysis more accessible and applicable across diverse fields.

Conflict of interest: No

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