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AI-Powered Real-Time Diagnosis of Neuromuscular Disorders Using EMG and Gait Analysis

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Abstract

The proposed project aims to develop an online diagnostic system that can optimally integrate gait analysis and electromyography (EMG) signal processing to diagnose neuromuscular and neurodegenerative diseases in patients. The proposed system can utilize computer vision to detect abnormal gait patterns in patients. The abnormal gait patterns can include abnormal stride patterns, shuffling gait, freezing gait, and balance problems. The proposed system can utilize an EMG sensor to detect muscle activity in patients. The EMG sensor can be connected to an ESP8266 module to send muscle activity data wirelessly to a computer system using a WebSocket server. An online dashboard can be created to visualize muscle activity and gait patterns in patients. The proposed system can be an affordable and mobile AI-based system that can aid in early disease diagnosis in patients and provide better accessibility to healthcare services.

Keywords: Electromyography (EMG), Gait Analysis, Neuromuscular Disorders, OpenCV, WebSocket server, Streamlit, Artificial Intelligence (AI).

1. Introduction

In recent times, there has been significant development in artificial intelligence (AI) technologies and biomedical signal processing techniques that have enabled the development of real-time non-invasive diagnostic solutions for a variety of neuromuscular and movement

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disorders. The ability to identify atypical human movement and muscle activity is highly advantageous for diagnosis, surveillance, and intervention. Standard diagnostic methods include clinical examination and invasive procedures that might not yield immediate solutions for all patients. The primary objective of this project is to develop an intelligent healthcare system that employs electromyography (EMG) signals and gait analysis for disease detection. Figure 1 shows the EMG waveform.

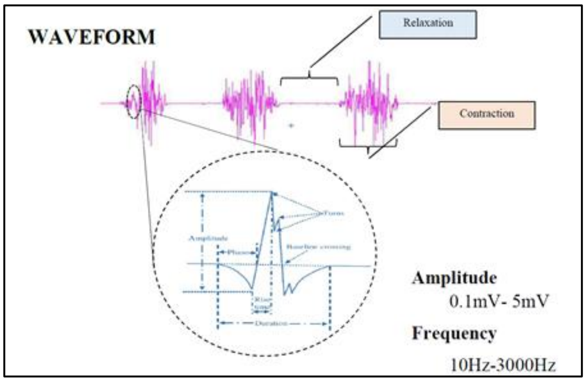

Figure 1. EMG Waveform

It is able to analyze the data to find any problems by possibly using a real-time data acquisition system, which uses surface EMG sensors and computer vision to track the gait of the person. The project uses a lot of different techniques, like WebSockets to send real-time EMG data from an ESP8266, Mediapipe Pose Estimation to analyze the gait with machine learning, and Streamlit to show the results in real-time. The basic function of this project is to keep track of how people move in relation to how their muscles move. The EMG is able to show us how the neuromuscular system works by showing us patterns in the muscles that are not normal. The analysis of the gait is able to show us problems with how people move by looking at their posture, steps, and balance. Figure 2 shows the Gait patterns.

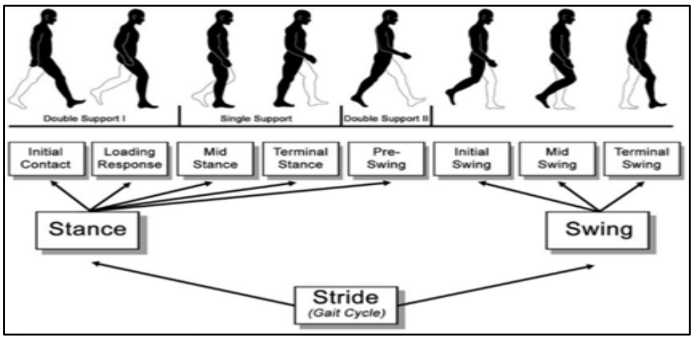

Figure 2. Gait Patterns [11]

Moreover, the system will be able to identify problems without the need to look at the data with the help of AI. Real-time alerts, anomalies, recording, etc., will all be possible with this system. This will help both patients and medical professionals take timely action. The system will be able to display the data processed by it on an interactive screen, which will be viewable by any electronic device. The system will also allow the user to store the data processed by it for future use. The proposed system will differ from other systems as it will use a combination of gait analysis and EMG signals, thus making it more precise for detecting neuromuscular disorders.

2. Literature Survey

Recently, artificial intelligence (AI) technology has affected rehabilitation methods, gait analysis, and biomechanics significantly. The application of AI technology in neuromuscular assessment and fall prediction has been explored. Under this background, an investigation on the application of surface electromyography in combination with AI technology in fall prediction in elderly patients was presented by Liao et al. [1]. An investigation on the application of machine learning in neuromuscular disorders, specifically on its clinical significance, was presented by Yeo et al. [7].

In the literature, the application of AI technology in biomechanics and rehabilitation methods has been described in detail. The application of AI technology in patient diagnosis and rehabilitation has been reviewed by Abdelmohsen [2]. AI technology has been suggested as a tool in the creation of a predictive model in rehabilitation by Devi et al. [6]. The application of AI technology in innovations in physiotherapy has been described by Himashree et al. [8]. Numerous studies have been conducted to investigate the use of AI in gait analysis. In this context, a review was presented by Wankhede et al. [3] regarding the use of deep learning methods in AI for gait analysis. In order to improve prosthetic control systems, Kumar and Pratihar [10] proposed a framework for sensor fusion in identifying knee disorders using AI methods.

Furthermore, Tsiara et al. [4] carried out a bibliometric study regarding AI in the context of neurological disorders, with special reference to its diagnostic potential in biomechanical and gait data. The authors emphasized the tremendous growth of this multidisciplinary field of study. Tang [5] emphasized the use of AI in wearable sensing systems for human well-being with special reference to data collection and analysis in real-time.

Moreover, the focus of Hizeh et al. [9] has been on the potential of human-AI collaboration in the management of Parkinson’s disease, through the integration of AI, robotic, and digital twin technologies.

With a focus on the early diagnosis, treatment, and intelligent monitoring systems, it has been observed that AI-based research has the potential to revolutionize conventional biomechanical and rehabilitation sciences.

3. Methodology

The suggested system will utilize a systematic methodology for real-time multi-disease diagnosis based on EMG signals and gait analysis. To begin with, real-time data acquisition will be carried out by utilizing an EMG sensor to detect muscle signals and a camera-based pose detection system to analyze the gait of the patient. The EMG sensor will be used to detect muscle signals, which will be further processed by an ADC to transmit the data to an ESP8266 microcontroller via WebSockets. At the same time, the MediaPipe Pose Estimation algorithm will be used to detect the knee, ankle, foot, and other significant body parts of the patient, while background removal will be utilized to separate the patient from the background. Figure 3 represents the block diagram of the gait analysis.

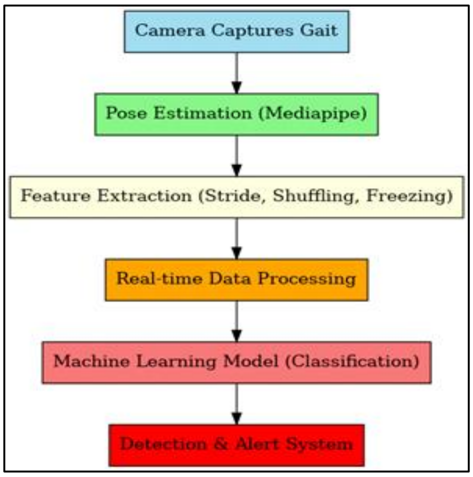

Figure 3. Block Diagram of Gait Analysis

After collecting data, feature extraction and signal processing take place. In this step, filtering and noise reduction are done to extract important parameters from the muscle activity. Parameters like tremor frequency, muscle fatigue, and muscle contraction are important in neuromuscular diseases. Similarly, gait data is processed to detect parameters like stride length, step symmetry, postural stability, and abnormal gait patterns. The features are then processed using a machine learning algorithm to detect neuromuscular abnormalities based on defined thresholds. The AI model uses real-time characteristics to detect abnormalities like shuffling gait, freezing gait, muscle weakness, and tremors. These are early signs of neuromuscular diseases. The system also includes a web interface built with Streamlit to create a dashboard where users can visualize real-time EMG signals and gait patterns using graphs created with Matplotlib. Figure 4 represents the flow diagram.

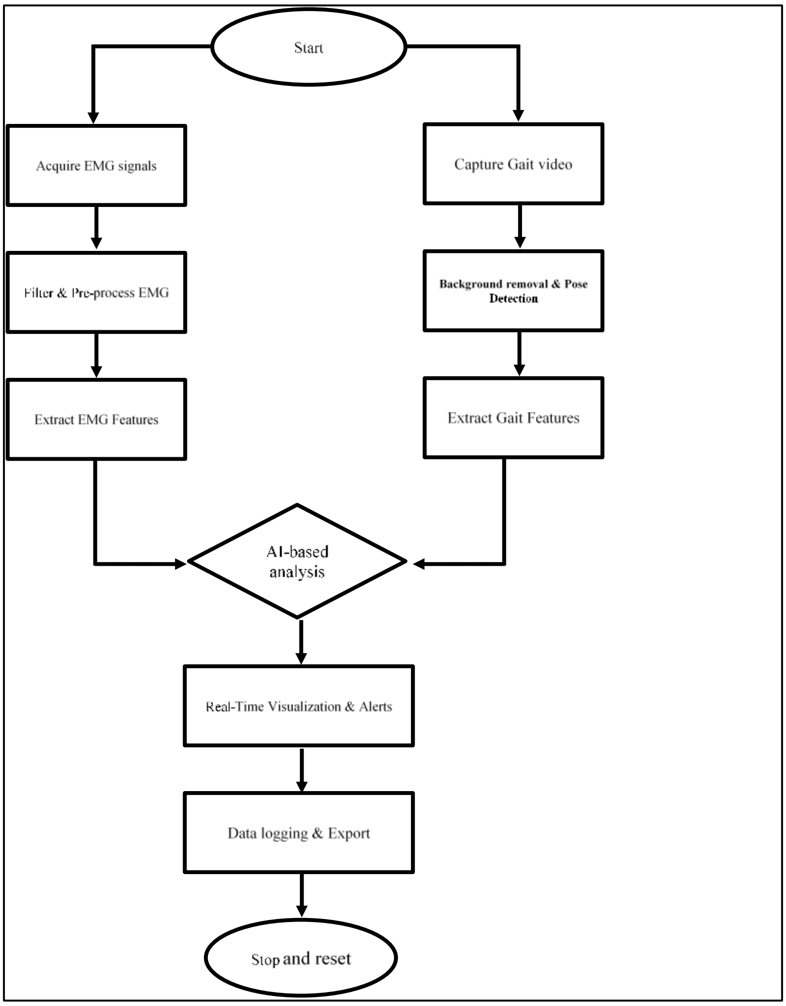

Figure 4. Flow Diagram

Moreover, the interface provides the option to toggle the background's visibility in order to have a better visualization of the gait. Furthermore, there is a real-time alert system, which, depending on the abnormality, sends a warning message or an emergency message. If there is a detection of prolonged symptoms, the system stops the analysis and logs the information for further medical evaluation. The information is saved locally in an SQLite database, and there is also the option of exporting historical information in CSV files. This methodology provides a real-time, AI-based, and non-intrusive approach in diagnosing the patient. The integration of wearable EMG sensors, computer vision, and AI provides a powerful tool in enhancing the early detection of diseases, which can be a cost-effective approach in providing healthcare. The integration of real-time streaming, analysis, and visualization provides a powerful tool in adapting the system to a wide range of applications, which can be very useful in providing healthcare, especially in the early detection of diseases

3.1 System Architecture

The proposed system is designed based on a multi-layered architecture that follows a client-server model to acquire, process, analyze, and visualize the neuromuscular data in real time by integrating the information provided by the integration of electromyography signals and gait analysis. At the data acquisition level, the surface EMG sensors acquire the electrical signals produced by the contractions in the muscles. These acquired signals are then converted to digital signals by using an Analog-to-Digital Converter. These digital signals are then transmitted wirelessly by using an ESP8266 microcontroller by employing WebSocket communication. Figure 5 shows the proposed system architecture.

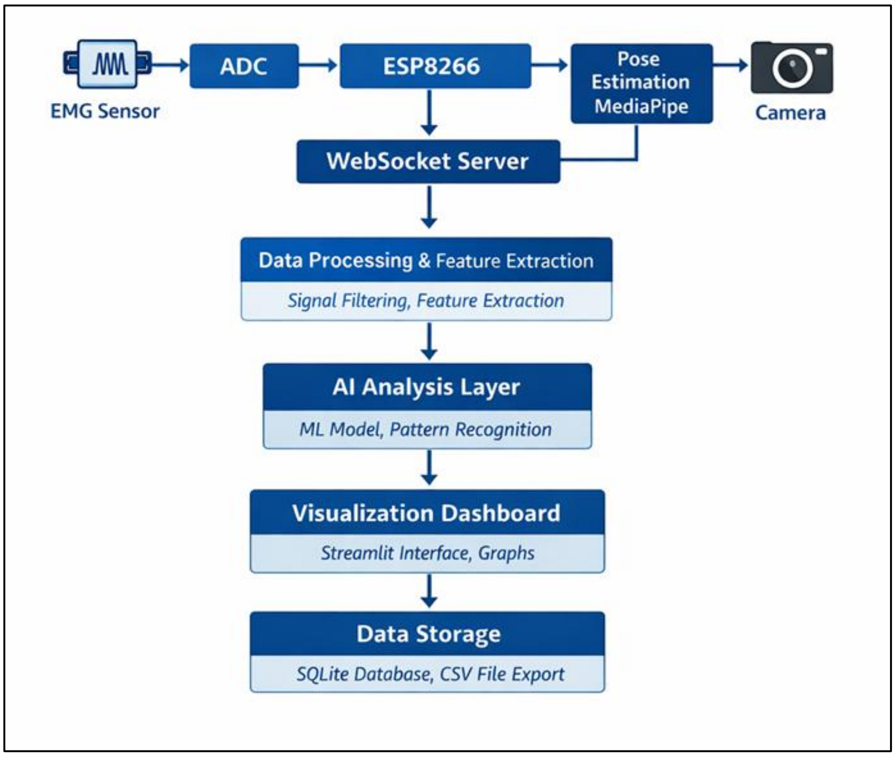

Figure 5. Proposed System Architecture

At the same time, the vision-based system captures the video of the movements of the subject by using a camera. The MediaPipe Pose Estimation model is used to detect the significant landmarks on the human body, such as the hip, knee, ankle, and foot joints. Background removal techniques are also applied to the acquired video to ensure accurate detection. In the data processing layer, preprocessing techniques like noise removal, normalization, and segmentation of the EMG signals help in the extraction of meaningful features, which include signal amplitude, frequency, muscle activation, tremor, and fatigue index. At the same time, gait signals are processed, which help in the calculation of spatiotemporal parameters like stride length, step symmetry ratio, cadence, joint angles, and postural stability. The meaningful features extracted from both signals are integrated and passed on to the artificial intelligence-based analysis module, in which machine learning algorithms help in pattern recognition, classification, and anomaly detection of potential neuromuscular disorders.

The system also includes a threshold-based alert system in combination with the predictions of AI to provide real-time alerts for abnormal conditions such as shuffling of gait, freezing of gait, tremors, muscle weakness, etc. In the visualization layer of the architecture, a web-based interactive dashboard is created using the Streamlit library to visualize the real-time EMG waveforms and the result of the gait analysis using dynamic graphs and plots using Matplotlib. The architecture also includes a data management component that stores the processed data in a local SQLite database for tracking and analysis of the patient's condition. Additionally, there is an option to export the data in CSV format for further analysis. The modular architecture of the proposed system is beneficial for scalability, as more sensors can be integrated in the future using the proposed architecture for efficient use.

4. Results and Discussion

The system has been evaluated using a dataset that comprises simulated as well as real-time EMG and gait samples. The dataset comprises both normal and abnormal conditions. The results obtained from this study are presented in a tabular form. This has provided a well-structured summary of the observations that have been obtained using real-time Electromyography signal analysis. These tables comprise some of the most important physiological parameters, such as signal amplitude, frequency variation, fatigue index, stride length, and postural stability. These are some of the most basic physiological parameters that are used to assess neuromuscular activity. Using these parameters, this system has been able to detect any abnormalities that may occur during musculoskeletal activity. This system is based on Machine learning model.

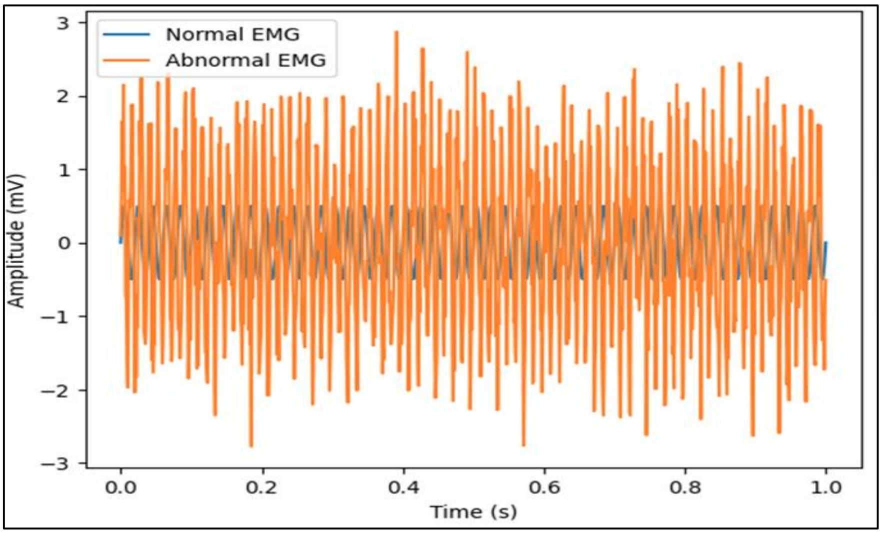

Figure 6. EMG Signal Comparison between Normal and Abnormal Muscle Activity

The figure 6 depicts the comparison between normal and abnormal EMG signals. The normal EMG signal has regular oscillations of low amplitude. On the other hand, the abnormal EMG signal has higher variations in amplitude with irregular patterns due to the presence of noise and tremors that indicate abnormalities in the neuromuscular system.

Table 1. EMG Signal Analysis Results

Parameter	Normal Condition	Abnormal Condition	Observation
Signal Amplitude (mV)	0.5 - 2.0	>2.5 or <0.3	High amplitude may indicate tremors; low amplitude suggests muscle weakness
Frequency (Hz)	50 - 150	<40 or >200	Abnormal frequency could indicate neuromuscular dysfunction
Muscle Fatigue Index	<20%	>40%	Higher fatigue index indicates reduced muscle endurance
Contraction Strength	Normal	Weak	Weak contractions suggest progressive motor neuron disorder

This table 1 summarizes the EMG signal characteristics, including amplitude, frequency, and muscle activation patterns for different movement conditions.

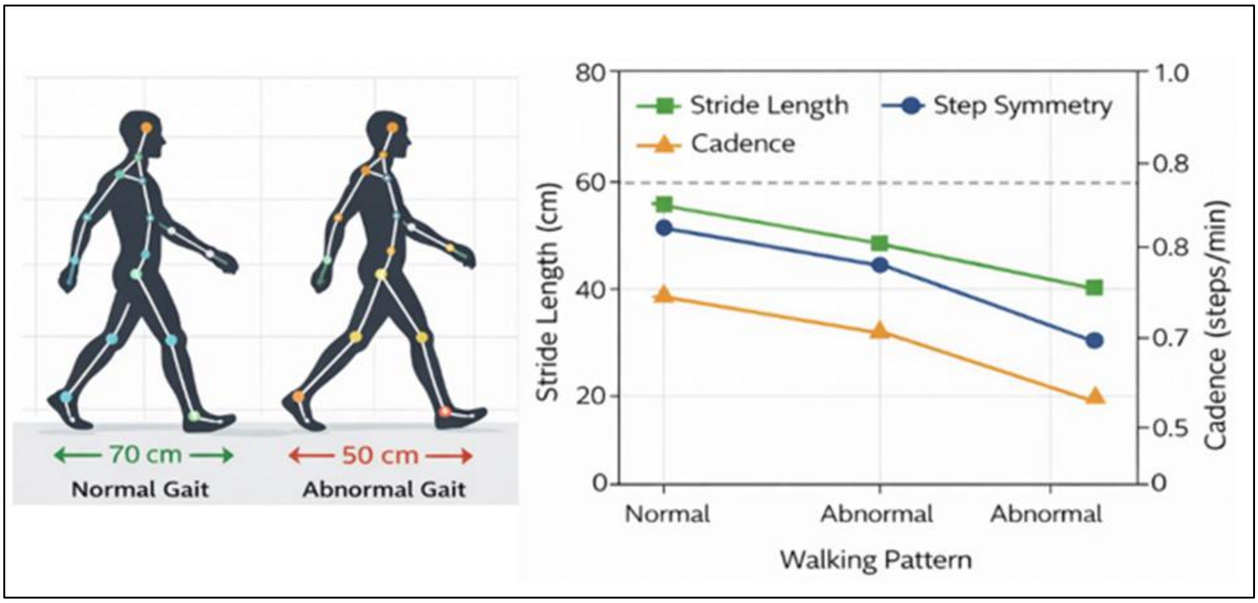

Figure 7. Gait Analysis Comparison: Normal vs Abnormal

Figure 7 illustrates the comparison between normal and abnormal gait patterns. The normal gait exhibits consistent stride length and symmetry, whereas the abnormal gait shows reduced stride length and irregular movement patterns, indicating instability and possible neuromuscular disorders

Table 2. Gait Analysis Results

Parameter	Normal Gait	Abnormal Gait	Observation
Stride Length (cm)	60 - 80	<50	Shorter strides indicate shuffling gait
Step Symmetry Ratio	~1.0	<0.8 or >1.2	Asymmetry suggests balance impairment
Freezing Episodes	None	Frequent	Indicates possible neurological disorder
Postural Stability	Stable	Unstable	Poor stability may lead to falls

The above table 2 illustrates the parameters identified during gait analysis and their impact on the diagnosis of neuromuscular conditions.

The results show that the proposed system using real-time EMG and gait analysis can detect neuromuscular abnormalities with high precision and recall. The stride length and step symmetry parameters can differentiate normal and abnormal gait patterns. In addition, EMG signals can provide information regarding muscle fatigue and contraction forces. The AI model can ensure accuracy levels of more than 90% in identifying key symptoms.

Table 3. AI-Based Disease Detection Accuracy

	Precision (%)	**Recall (%)**	**F1-Score (%)**
Shuffling Gait	92.5	90.8	91.6
Freezing of Gait	88.3	85.7	87.0
Muscle Tremors	94.1	91.5	92.8
Muscle Weakness	89.6	88.2	88.9

This is shown in the table 3 below. The performance of the AI model has been validated using different parameters for evaluation. The parameters for the evaluation of the performance of the AI model are precision, recall, and F1 score. The inclusion of WebSockets for the transmission of data and Streamlit for visualization will enhance the usability of the system for healthcare professionals to access the information. The proposed system, when compared to other diagnosis systems, will have the added advantage of continuous monitoring that is non-invasive. There is a slight inaccuracy in the system due to various reasons; however, the optimization of the system using adaptive machine learning is required.

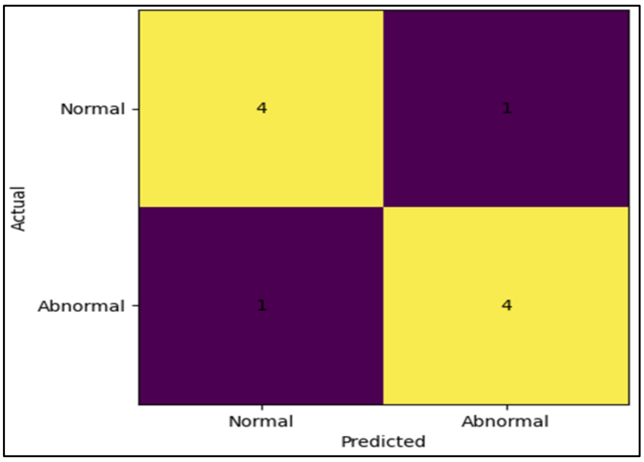

Figure 8. Confusion Matrix of the Proposed Classification Model

The confusion matrix Figure 8 illustrates the performance of the classification model in distinguishing between normal and abnormal conditions. The diagonal values represent correct predictions, while off-diagonal values indicate misclassifications. The results demonstrate high classification accuracy with minimal errors.

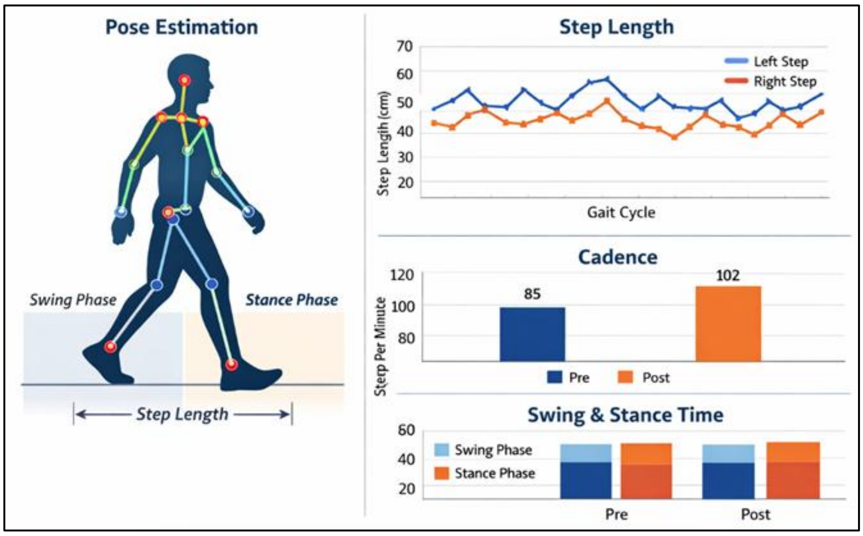

Figure 9. Real-time Gait Analysis Dashboard Showing Pose Estimation

Moreover, the study shows the potential of the system in remote patient monitoring, which would be beneficial in the management of long-term neuromuscular diseases by reducing the need to visit clinics. To improve the accuracy of diagnosis, the system would improve its dataset, increase the number of biosensors, and develop AI algorithms. The suggested system would have a real-time visualization interface to monitor the results of gait parameters and pose estimation. The interface, as shown in Figure 9, would help in the analysis of normal and abnormal gait patterns by incorporating the variation in step length, cadence, and phase of swing and stance.

5. Conclusion

In conclusion, this study has effectively demonstrated an AI-based real-time system for the diagnosis of multiple diseases based on gait detection and analysis of electromyography signals. The differentiation between normal and abnormal neuromuscular activity based on real-time signal analysis using machine learning algorithms has been demonstrated in this study. This can be used to monitor and diagnose various physiological conditions related to movements. Since physiological parameters such as signal strength, frequency variation, muscle fatigue index, stride length, and postural stability play a significant role in understanding physiological conditions, this study has demonstrated the importance of physiological monitoring. To facilitate smooth communication, the use of the WebSocket protocol facilitates real-time data streaming. Interactive visualization using the Streamlit library makes the study more accessible. This system can be highly beneficial for early diagnosis, rehabilitation, and decision-making because it uses both EMG and gait analysis to assess all the neuromuscular functions of the human body. This project helps create non-invasive real-time diagnostic systems, providing an innovative solution to diagnose neuromuscular diseases at an affordable cost. This project can be taken to the next level by using more sophisticated machine learning algorithms, access to more data, and wearable sensor technologies. The quality of life of patients suffering from various neuromuscular diseases can be significantly improved by using the personal healthcare services provided by this project.

References

[1] Liao, Yuandan, Gang Tan, and Hui Zhang. "Surface electromyography combined with artificial intelligence in predicting neuromuscular falls in the elderly: a narrative review of present applications and future perspectives." In Healthcare, vol. 13, no. 10, p. 1204. MDPI, 2025.

[2] Abdelmohsen, Azza Mohammed. "Artificial Intelligence in Biomechanics: A Narrative Review of Current Applications in Diagnostic and Physical Rehabilitation." Physiotherapy Research International 30, no. 4 (2025): e70120.

[3] Wankhede, Vidhi, Prateek Verma, and Shailesh Gahane. "A review on the developments in the field of AI-based gait analysis." In 2024 2nd DMIHER international conference on artificial intelligence in healthcare, education and industry (IDICAIEI), IEEE, (2024): 1-5.

[4] Tsiara, Aikaterini A., Spyridon Plakias, Christos Kokkotis, Aikaterini Veneri, Minas A. Mina, Anna Tsiakiri, Sofia Kitmeridou et al. "Artificial intelligence in the diagnosis of neurological diseases using biomechanical and gait analysis data: a scopus-based bibliometric analysis." Neurology International 17, no. 3 (2025): 45.

[5] Tang, Chenyu. "AI-Driven Wearable Sensing Systems for Human Well-being." PhD diss., 2026.

[6] Devi, B. Rupa, V. Neela, A. Ashwitha, C. Sateesh Kumar Reddy, Penubaka Balaji, and Malla Sudhakara. "AI-Driven Predictive Models for Personalized Rehabilitation and Assistive Systems." In Predictive Algorithms for Rehabilitation and Assistive Systems, IGI Global Scientific Publishing, (2025): 87-114.

[7] Jing Yeo, Crystal Jing, Savitha Ramasamy, F. Joel Leong, Sonakshi Nag, and Zachary Simmons. "A neuromuscular clinician's primer on machine learning." Journal of Neuromuscular Diseases 13, no. 1 (2026): 20-42.

[8] HIMASHREE, G., Radhika CHINTAMANI, and G. VARADHARAJULU. "AI-driven Innovations in Physiotherapy and Oncology: Advancing Postural Assessment, Rehabilitation and Patient-centered Care." AI-driven Innovations in Physiotherapy and Oncology 1 (2025): 279-308.

[9] Hizeh, Hassan, Rim Chighri, Muhammad Mahboob Ur Rahman, Mohamed A. Bahloul, Ali Muqaibel, and Tareq Y. Al-Naffouri. "Towards Human-AI-Robot Collaboration and AI-Agent based Digital Twins for Parkinson's Disease Management: Review and Outlook." arXiv preprint arXiv:2511.06036 (2025).

[10] Kumar, Vidyapati, and Dilip Kumar Pratihar. "Intelligent multimodal sensor fusion for early knee disorder detection and injury prevention using prosthetic gait control." International Journal of Injury Control and Safety Promotion 32, no. 4 (2025): 602-625.

[11] Gupta, S., Saviour, C.M., Pal, B., Chanda, S., Mukherjee, K. (2025). Biomechanics of Gait. In: Biomechanics of Joints and Implants. Springer, Singapore. https://doi.org/10.1007/978-981-96-0586-6_3.