Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 12, December : 2023

Integrating Wearable Sensors and AI for Gait Analysis-Based Sciatica Early Detection and Prediction

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Abstract: This research aims to integrate wearable sensors and artificial intelligence (AI) for gait analysis-based early detection and prediction of sciatica. By capturing subtle gait deviations associated with sciatica, this system will enable early diagnosis and facilitate preventive measures. The proposed approach involves data collection from individuals with confirmed sciatica and healthy controls using spatiotemporal parameters, joint kinematics, and muscle activity. Advanced AI algorithms will analyze the collected gait data, identifying subtle deviations indicative of sciatica. Machine learning models will be developed to predict the likelihood of sciatica based on extracted gait features, with deep learning and other AI techniques explored for improved accuracy. A user-friendly mobile application or wearable device will be developed for data collection, analysis, and prediction, enabling real-time monitoring of gait patterns for early detection and risk assessment. This research has the potential to revolutionize sciatica diagnosis and management, reducing healthcare costs, improving patient outcomes, and enabling personalized interventions and preventative measures.

Keywords: Sciatica, Gait Analysis, Wearable Sensors, Artificial Intelligence, Early Detection, Prediction.

I Introduction

Sciatica, a debilitating pain condition, affects millions of people worldwide. Early diagnosis is crucial to prevent long-term complications and improve patient outcomes. Traditional diagnostic methods, such as physical examinations and imaging techniques, often lack sensitivity, necessitating novel approaches. Wearable sensors offer several advantages for sciatica detection through gait analysis, including non-invasive and continuous monitoring, real-time analysis and feedback, portability and user-friendliness, and cost-effectiveness [1].

Wearable sensors can analyse your steps and find small problems that are not normal for people who have sciatica, like uneven walking, slower and less variable steps, changes in the way your joints move, and changes in how your muscles work. AI algorithms can learn to identify patterns associated with sciatica with high accuracy, enabling early detection and timely intervention. Advances in miniaturisation and low-power electronics have simplified wearable sensor hardware development, with commercially available sensors like IMUs, pressure sensors, and EMG sensors being easily integrated into user-friendly wearable devices. Open-source hardware platforms and software libraries further facilitate the development of custom sensor systems tailored to specific research needs in figure 1.

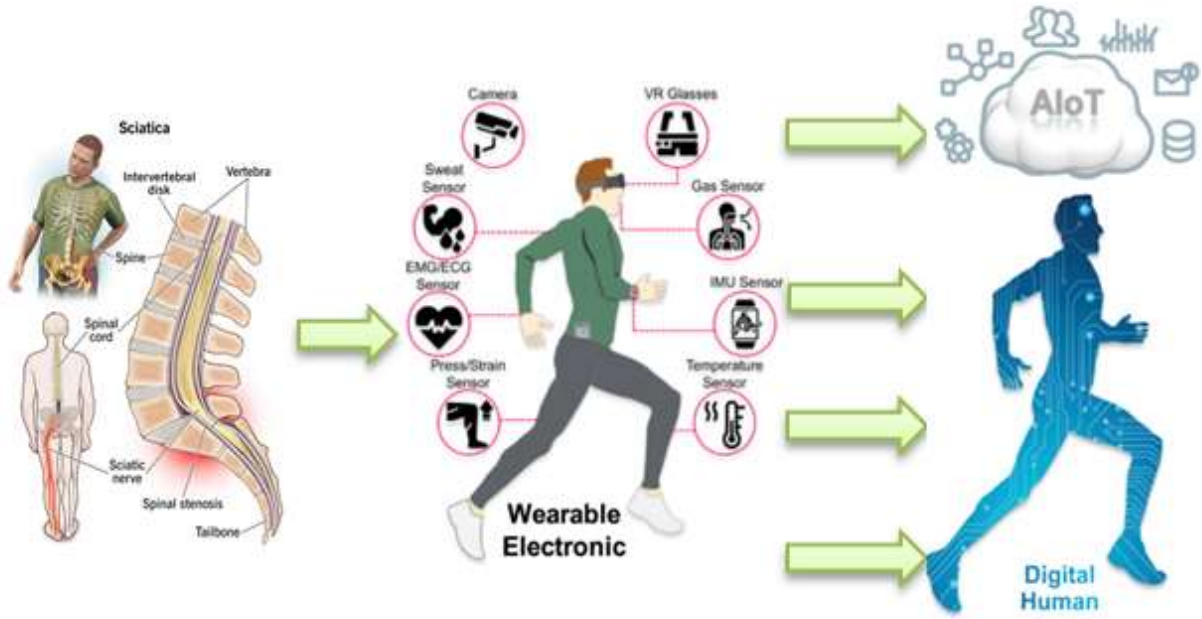

Figure 1 Wearable Sensor and AI for gait sciatica early detection and prediction

Sciatica often manifests through subtle deviations in gait patterns, such as altered gait symmetry, reduced gait velocity, increased gait variability, and changes in joint kinematics. These gait deviations can be accurately captured and analyzed through wearable sensors, providing objective evidence for early detection. Open-source platforms like Arduino and Raspberry Pi offer readily available hardware components and software libraries, reducing development time and costs. Modular sensors, pre-built sensor kits, and 3D printing technology facilitate customization and rapid prototyping.

By integrating wearable sensors with advanced AI algorithms, it will revolutionize the landscape of sciatica diagnosis. By analysing gait data and identifying subtle deviations, machine learning models can be developed for the early and accurate detection of sciatica. AI-powered prediction models hold promise in identifying individuals at risk of developing sciatica, enabling preventative measures and intervention before symptoms manifest. This research presents a ground-breaking approach to sciatica diagnosis, offering a practical and effective solution for early detection and prediction [2].

However, challenges remain, such as standardising data collection protocols, achieving high accuracy in model prediction, addressing ethical considerations regarding data privacy, and ensuring practical implementation and integration of the technology within healthcare systems. Future research should focus on overcoming these challenges to translate this promising technology into clinically relevant tools for early and effective sciatica management in figure 2.

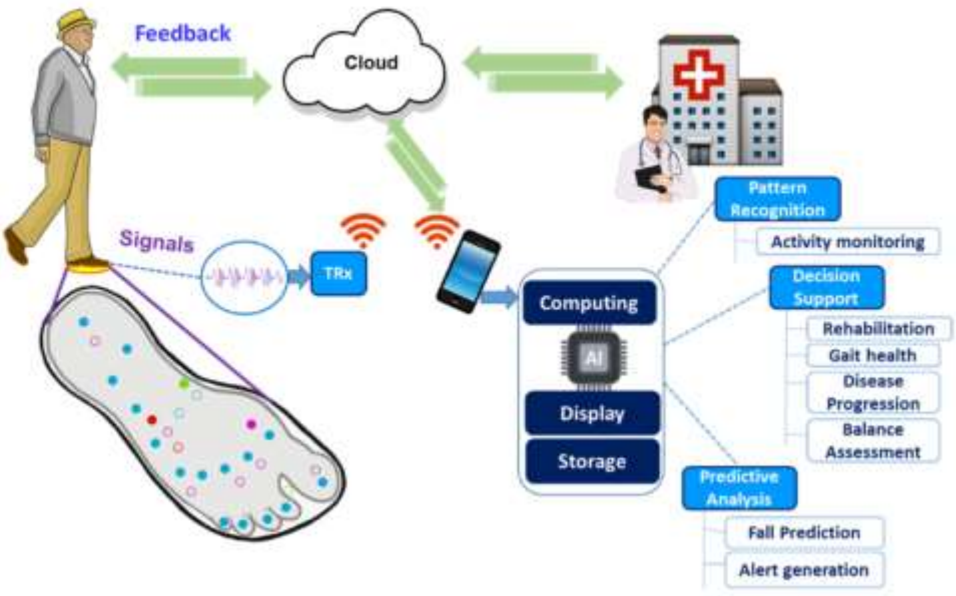

Figure 2 overview of wearable sensor function through cloud [3]

II Literature Survey

A literature review identifies studies on wearable sensors for gait analysis and AI algorithms for early detection and prediction of sciatica. Key points include wearable sensor modality, gait parameters, AI algorithms, and performance evaluation metrics. Inertial

Measurement Units (IMUs) capture spatiotemporal parameters and joint angles, while pressure sensors provide insights into foot pressure distribution and gait symmetry. Electromyography (EMG) assesses muscle activity and fatigue. Other sensors explored include cameras, accelerometers, gyroscopes, and force plates. Gait parameters include stride length, cadence, gait velocity, swing/stance time ratios, joint kinematics, gait variability, EMG signals, foot pressure distribution, gait symmetry, and gait cycle time [4-10].

AI algorithms used for classification and prediction tasks include machine learning (SVMs, random forests, and deep neural networks), K-nearest neighbors (KNNs), naive bayes, and decision trees. Performance evaluations include accuracy, sensitivity, specificity, F1-score, and area under the ROC curve (AUC). Limited sample size, lack of standardized data collection protocols, ethical considerations regarding data privacy and security, and the need for further validation in larger clinical trials are limitations. More research needs to be done on comparing different types of sensors, looking into more advanced gait parameters and analysis methods, creating personalized AI models for better accuracy and risk assessment, combining gait analysis with other clinical data for more complete diagnosis and prediction, and running large-scale clinical trials to prove that this technology works in real-life medical settings [11-20].

Machine learning algorithms like Support Vector Machines (SVMs), Random Forests, Deep Neural Networks (DNNs), K-nearest neighbors (KNNs), Naive Bayes, and Decision Trees are employed for performance evaluation. The reported accuracy for sciatica detection varies between studies, ranging from 70% to 95%. Factors influencing performance include sensor selection, gait parameter extraction, and machine learning algorithm choice.

Challenges and limitations include limited sample size, a lack of standardized data collection protocols, ethical considerations regarding data privacy and security, and the need for further validation in larger clinical trials. We need to do more research on comparing different types of sensors, looking into more advanced gait parameters and analysis methods, creating personalized machine learning models, combining gait analysis with other clinical data for a more complete diagnosis, and running large-scale clinical trials to prove that sensor-based gait analysis works in the real world for sciatica [21-31].

III Methodology

The methodology for developing a wearable gait tracking device utilizes the benefits of Internet of Things (IoT) technology. The system uses primary sensors like Inertial Measurement Units (IMUs) for capturing spatiotemporal parameters and joint kinematics and secondary sensors like pressure sensors and EMG sensors for assessing muscle activity and fatigue. Data is collected and processed using a microcontroller unit (MCU) like an Arduino or Raspberry Pi and wireless communication via Bluetooth Low Energy (BLE) for efficient data transfer.

Power management is crucial, with battery selection and energy-efficient sensors and components being key factors. Wireless charging capabilities can enhance user convenience and reduce dependence on battery replacements. The IoT platform integration includes a secure cloud-based platform for data management, analysis, and integration with machine learning models for sciatica prediction. A user-friendly mobile application provides real-time feedback on gait patterns and potential risks, promoting user engagement and data visualisation. Security and privacy are essential, with encryption protocols and secure authentication mechanisms protecting user data during transmission and storage.

IV Conclusion and Future Scope

Combining wearable sensors with AI for gait analysis-based sciatica detection and prediction has a lot of potential for finding people who are at high risk of getting sciatica early on, so they can get help right away and have better outcomes. However, further research is needed to address the identified challenges and limitations. The integration of IoT can create a scalable and user-friendly solution for sciatica diagnosis and patient outcomes. Optimizing hardware design, sensor selection, and data security protocols are crucial for widespread adoption and maximizing the impact of this innovative technology. By implementing the proposed methodology, researchers and developers can create user-friendly and cost-effective hardware systems for early detection, personalized interventions, and improved patient outcomes. Future research will focus on optimizing hardware design, exploring advanced sensor technologies, and refining AI models for superior accuracy and prediction capabilities. This technology has the potential to revolutionize healthcare management, improve patient outcomes, and reduce healthcare costs.

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