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

A Critical Review of Sensor-Based Gait Analysis Methods for Assessing Pregnancy-Related Sciatica

Mamidipaka Hema[1] Department of ECE, JNTU Gurajada Vizianagaram, Dwarapudi, A.P, India
A.Sampath Dakshina Murthy[2],**J.Sudhakar**[2] Department of ECE, Vignan's Institute of Information Technology (A), Visakhapatnam, A.P, India

Email Id: hema.phd476@gmail.com ,sampathdakshinamurthy@gmail.com , sudhakar.jyo@gmail.com

Abstract: Pregnancy-related sciatica is a common musculoskeletal disorder affecting 50–80% of pregnant women, necessitating an early and accurate diagnosis. Traditional methods, like physical examinations and imaging techniques, often lack sensitivity, necessitating the development of objective and quantitative tools. This review critically examines sensor-based gait analysis methods for assessing pregnancy-related sciatica, focusing on sensor technology, gait analysis algorithms, assessment metrics, and potential applications in clinical practice and research. The review also looks at how wearable sensors can be used to analyze a pregnant woman's gait when she has sciatica. It focuses on the different types of sensors, the parameters that can be extracted from her gait, the analysis methods, and how well they work for figuring out how bad her sciatica is and how well her treatment is working. The findings contribute to understanding the potential and limitations of sensor-based gait analysis in pregnancy-related sciatica management, guiding future research, and facilitating the development of robust tools for early and accurate diagnosis.

Keywords: Pregnancy-related sciatica, Gait analysis, Wearable sensors, Machine learning, early detection.

I Introduction

Pregnancy-related sciatica (PRS) is a prevalent condition affecting 50–80% of pregnant women, causing radiating pain along the sciatic nerve pathway. This condition significantly impacts daily life, leading to mobility limitations, difficulty performing tasks, and a reduced quality of life. Traditional diagnostic methods often lack sensitivity, leading to delayed diagnosis and inappropriate treatment. Early identification of PRS allows for simple and effective treatment options, such as physical therapy, stretching exercises, NSAIDs, and lifestyle modifications. Gait analysis, a detailed examination of walking patterns, can identify changes associated with PRS, such as asymmetry, decreased gait speed, reduced joint range of motion, and increased inconsistency in stride length and gait patterns. Sensor-based gait

analysis uses wearable sensors to capture and quantify gait parameters, providing a more accurate assessment. Machine learning algorithms can be applied to analyze collected data, enabling automated PRS detection and classification. This research paper aims to explore the potential of machine learning for a more accurate and objective diagnosis of PRS, ultimately improving the quality of life for pregnant women affected by this condition analysis between Pregnant Women and PRS Affected in figure 1.

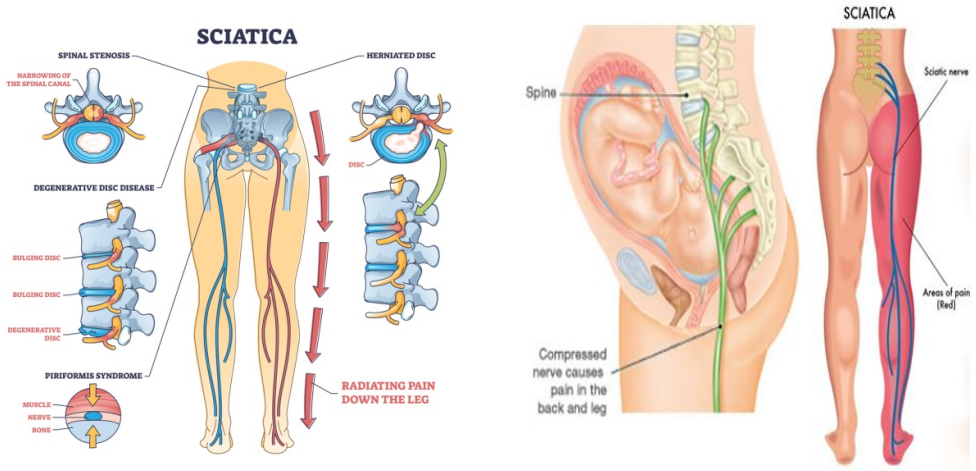

Figure 1 Representation of Sciatica pregnant women

Gait deviations are a hallmark of PRS, which can result from things like hormonal changes, muscle weakness, and nerve impingement. Traditional diagnostic methods often fail to detect early-stage cases, leading to delayed diagnosis and treatment. Sensor-based gait analysis, which looks closely at how people walk, has become an interesting way to test for PRS because it can pick up on small changes in walking patterns that are linked to pain and nerve impingement. Machine learning algorithms can classify gait data with high accuracy, enabling early diagnosis and timely intervention.

This review critically analyses existing methodologies for sensor-based gait analysis in PRS assessment, paving the way for further research and the development of reliable methods for early detection and improved patient outcomes figure 2. Pregnancy-related sciatica (PRS) is a common condition affecting 50–80% of pregnant women, causing compression of the sciatic nerve from the lower back to the leg. Hormonal changes, posture changes, and the developing foetus are just a few causes of this compression. PRS can cause

severe pain, numbness, tingling, and leg weakness, making it difficult to walk or sit. It can also cause bladder control issues.

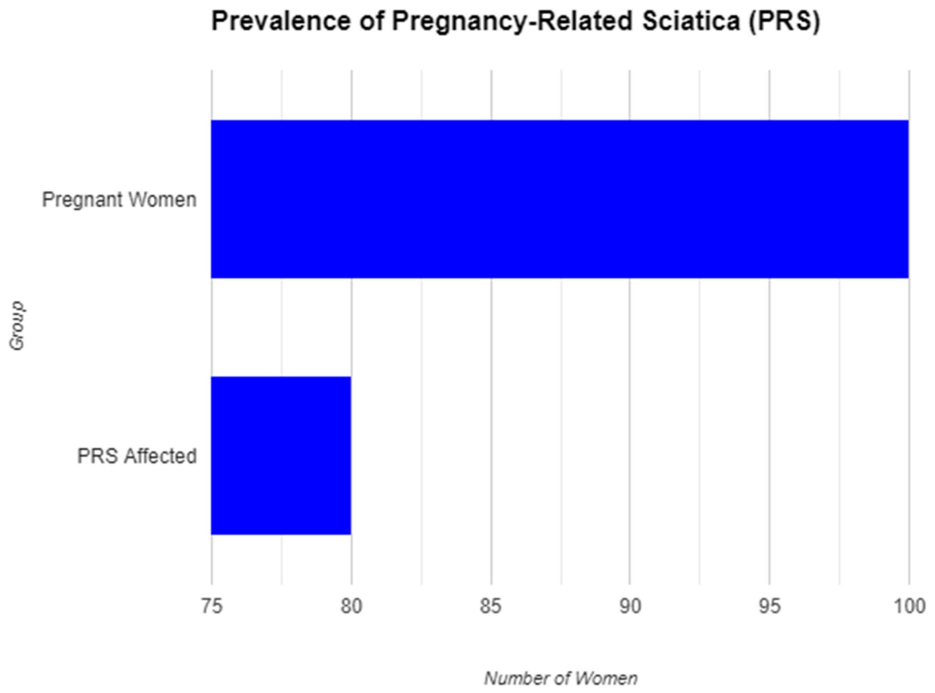

Figure 2 Pregnancy Related Sciatica vs PRS affected

Diagnosis is based on symptoms and medical history, but tests like an MRI or nerve conduction study can confirm diagnosis. There is no cure for PRS, but treatments like physical therapy, medication, and lifestyle changes can help relieve symptoms. Surgery may be necessary in some cases. PRS is painful and debilitating, so it is crucial to see a doctor for diagnosis and treatment.

II Literature Survey

Pregnancy-related sciatica (PRS) is a prevalent musculoskeletal disorder that affects a significant portion of pregnant women. Early and accurate diagnosis of PRS is crucial for managing symptoms and improving patient outcomes. Sensor-based gait analysis has

emerged as a promising approach for assessing PRS by capturing subtle gait deviations associated with the condition. However, cost-effectiveness analysis is needed to evaluate the cost-effectiveness of implementing this technology in real-world clinical settings. Ethical considerations such as data privacy, security, and user consent are crucial for developing and deploying this technology [1-10].

Several studies have investigated the potential of sensor-based gait analysis for PRS assessment, employing various wearable sensors to collect gait data during walking. Machine learning algorithms have been implemented to automatically classify gait data and identify PRS with high accuracy. A comprehensive literature survey showed promising results with high accuracy and sensitivity in identifying early-stage PRS. However, several areas require further investigation and development: standardization of methodologies, integration of clinical data, longitudinal studies, cost-effectiveness analysis, and ethical considerations [11-19].

A literature survey was conducted to identify studies published within the past decade that utilized sensor-based gait analysis for assessing pregnancy-related sciatica (PRS). Key remarks for recovery and analysis included sensor modality, gait parameters, machine learning algorithms, and performance evaluation metrics. Sensors used include Inertial Measurement Units (IMUs), pressure sensors, electromyography (EMG), 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. Machine learning algorithms include support vector machines (SVMs), random forests; deep neural networks (DNNs), K-nearest neighbours (KNNs), naive bayes, and decision trees. Performance evaluation metrics include accuracy, sensitivity, specificity, F1-score, and area under the ROC curve (AUC) [20-25].

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. 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 PRS [25-30].

III Methodology

The detection of pregnancy-related sciatica (PRS) is a complex task that requires a combination of sensor modalities, gait parameter extraction, machine learning algorithms, and wearable technology. Sensor fusion, sensor selection optimization, and wearable sensor advancements can improve the accuracy of PRS detection. Advanced feature engineering and personalized feature selection can enhance the effectiveness of ML models. Real-time gait analysis can enable immediate feedback and personalized intervention strategies.

The comprehensive approach to sensor-based gait analysis addresses challenges such as data collection methods, extraction of gait parameters, machine learning, ethical considerations, and data security. It discusses clinical validation, real-world implementation, and cost-effectiveness analysis. Machine learning algorithms like SVMs, Random Forests, and DNNs are used for classifying gait data and identifying PRS. Wearable technology like IMUs, pressure sensors, and EMG sensors is also discussed. Smart shoes with pressure sensors, smart insoles, and smartphone-based gait analysis applications are also mentioned. Future research should explore combining sensor data with other clinical data, exploring advanced machine learning methods, making personalized treatment plans, and conducting long-term follow-up studies to understand the impact of sensor-based gait analysis on patient outcomes and healthcare costs.

Machine learning algorithms, such as ensemble methods and explainable AI, can improve the overall performance and robustness of the system. Support Vector Machines (SVMs) are good at binary classification tasks like finding PRS. On the other hand, random forests and deep neural networks are better at dealing with large datasets and the complicated connections between gait features and PRS. IMU-based sensors offer cost-effective and unobtrusive options for capturing spatiotemporal gait parameters and joint angles. Pressure sensor insoles provide valuable insights into foot pressure distribution and gait symmetry, particularly helpful for identifying altered loading patterns associated with PRS. EMG sensors can assess muscle activity and fatigue, potentially helping differentiate PRS from other musculoskeletal conditions.

Combining data from different sensors can provide more comprehensive images of gait patterns and enhance PRS detection accuracy. Ethical concerns include data privacy, security, patient consent, and transparency regarding data usage. Smart devices, such as smart shoes and insoles, smartphones with built-in sensors and mobile applications, and wearable cameras for detailed analysis, can help overcome these challenges and improve the effectiveness of gait analysis.

IV Conclusion

In conclusion, sensor-based gait analysis has the potential to revolutionize the diagnosis and management of PRS. By addressing identified limitations and exploring future research directions, researchers can develop robust and reliable tools for early and accurate PRS detection, leading to improved patient outcomes and a better quality of life for pregnant women suffering from this condition. Future research should focus on developing personalized gait analysis models, exploring multi-sensor fusion, investigating deep learning models, large-scale clinical trials, and collaboration between researchers, clinicians, patients, and regulatory bodies.

V Future Scope

Sensor-based gait analysis is a promising technology for early and accurate assessment of Pregnancy-Related Syndrome (PRS), using various sensor modalities and machine learning algorithms for classification. This technology can improve diagnosis and treatment outcomes for pregnant women affected by PRS. Future research can refine this technology, leading to broader clinical adoption and improved quality of life for affected women. By addressing challenges and pursuing future directions, sensor-based gait analysis has the potential to revolutionize PRS diagnosis and management.

References

[1]. Aparicio, Virginia A., Nuria Marín-Jiménez, Marta Flor-Alemany, Pedro Acosta-Manzano, Irene Coll-Risco, and Laura Baena-García. "Effects of a concurrent exercise training program on low back and sciatic pain and pain disability in late pregnancy." Scandinavian Journal of Medicine & Science in Sports 33, no. 7 (2023): 1201-1210.

[2]. Hall, Helen, Romy Lauche, Jon Adams, Amie Steel, Alex Broom, and David Sibbritt. "Healthcare utilisation of pregnant women who experience sciatica, leg cramps and/or varicose veins: a cross-sectional survey of 1835 pregnant women." Women and Birth 29, no. 1 (2016): 35-40.

[3]. Trager, Robert J., Sarah E. Prosak, Patrick J. Getty, Richard L. Barger, Shahrazad T. Saab, and Jeffery A. Dusek. "Ischial osteochondroma as an unusual source of pregnancy-related sciatic pain: a case report." Chiropractic & Manual Therapies 30, no. 1 (2022): 1-12.

[4]. Achanta, S.D.M., Karthikeyan, T. & Vinothkanna, R. A novel hidden Markov model-based adaptive dynamic time

warping (HMDTW) gait analysis for identifying physically challenged persons. Soft Computing 23, 8359–8366 (2019). https://doi.org/10.1007/s00500-019-04108-x

[5]. Sampath Dakshina Murthy, Achanta, Thangavel Karthikeyan, and R. Vinoth Kanna. "Gait-based person fall prediction using deep learning approach." Soft Computing (2021): 1-9. https://doi.org/10.1007/s00500-021-06125-1.

[6]. Achanta, Sampath Dakshina Murthy, Thangavel Karthikeyan, and R. Vinoth Kanna. "Wearable sensor based acoustic gait analysis using phase transition-based optimization algorithm on IoT." International Journal of Speech Technology (2021): 1-11.https://doi.org/10.1007/s10772-021-09893-1

[7]. Achanta, S.D.M., T., K. and R., V.K. (2020), "A wireless IOT system towards gait detection technique using FSR sensor and wearable IOT devices", International Journal of Intelligent Unmanned Systems, Vol. 8 No. 1, pp. 43-54. https://doi.org/10.1108/IJIUS-01-2019-0005

[8]. A.Sampath Dakshina Murthy, T. Karthikeyan, B. Omkar Lakshmi Jagan, "Clinical Model Machine Learning for Gait Observation Cardiovascular Disease Diagnosis", International Journal of Pharmaceutical Research , Volume 12, Issue 4, Pages 3373 – 3378 October-December 2020 . doi.org/10.31838/ijpr/2020.12.04.460

[9]. Murthy, A., B. Jagan, K. Raghava Rao, and P. Satyanarayana Murty. "A virtual reality research of Gait analysis in the medicine fields." In AIP Conference Proceedings, vol. 2426, no. 1. AIP Publishing, 2022.

[10]. Sampath Dakshina Murthy, T. Karthikeyan, B. Omkar Lakshmi Jagan et al., Novel deep neural network for individual re recognizing physically disabled individuals, Materials Today: Proceedings 33, pp. 4323-4328, https://doi.org/10.1016/j.matpr.2020.07.447.

[11]. Ahammad, S.H., Sampath Dakshina Murthy, A., Ratna Raju, A., Rajesh, V., Saikumar, K. (2023). Magnetic Resonance Images for Spinal Cord Location Detection Using a Deep-Learning Model. In: Agarwal, P., Khanna, K., Elngar, A.A., Obaid, A.J., Polkowski, Z. (eds) Artificial Intelligence for Smart Healthcare. EAI/Springer Innovations in Communication and Computing. Springer, Cham. https://doi.org/10.1007/978-3-031-23602-0_24

[12]. C. Kumari, A. Usha, B. Sampath Dakshina Murthy, M. Prasanna, and A. K. Pala Prasad Reddy, "An automated detection of heart arrhythmias using machine learning technique: SVM," Materials Today: Proceedings, vol. 45, pp. 1393–1398, 2021.

[13]. Sampath Dakshina Murthy, P. Satyanarayana Murthy, V. Rajesh, Sk. Hasane Ahammad, B. Omkar Lakshmi Jagan, "Execution of Natural Random Forest Machine Learning Techniques on Multi Spectral Image Compression", International Journal of Pharmaceutical Research Volume 11, Issue 4, Pages 1241 - 1255, ISSN - 0975-2366. https://doi.org/10.31838/ijpr/2019.11.04.0499

[14]. Neha Sharma, A. Sampath Dakshina Murthy, T. Karthikeyan, B. Omkar Lakshmi Jagan et al., Gait Diagnosis Using Fuzzy Logic With Wearable Tech For Prolonged Disorders Of Diabetic Cardiomyopathy, Materials Today: Proceedings, 2020 https://doi.org/10.1016/j.matpr.2020.10.623

[15]. M.Hema, K.Babulu, and N.Balaji "Gait Based Person Recognition Including the Effect of Covariates" Lecture Notes in Electrical Engineering book series (LNEE, pp105-112, volume 434), Springer, Singapore, 2018.

[16]. M.Hema, "Model Free Approach For Suspect Monitoring Using Dynamic Gait Recognition Technique", published in SurajPunj Journal For Multidisciplinary Research, Volume 8, Issue 11, ISSN NO: 2394-2886pp. 252-262, 2018.

[17]. M.Hema, K.Babulu, and N.Balaji "A Study on Human Observer Classification and Ou-Isir Database for Gender and Age Estimation", International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-7, Issue-6, March 2019.

[18]. M.Hema, K.Babulu, and N.Balaji," Gait Recognition and Classification Using Random Forest Algorithm" Journal of Advanced Research in Dynamical & Control Systems, Vol. 11, No. 2, ISSN 1943-023X , PP281-289, 2019.

[19]. M.Hema, K Babulu, and N Balaji, "Recognition of Gender using Gait Energy Image Projections Based on Random Forest Classifier", International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278–3075 (Online), Volume-8, Issue-12, pp: 1518-1523, Oct. 2019.

[20]. M.Hema, and P.Suhitha "Human Age Classification Based On Gait Parameters Using A Gait Energy Image Projection Model" 3rd IEEE International conference on trends in Electronics and Informatics (ICOEI – 2019), ISBN: 978-1-5386-9439-8, 23-25 April 2019.

[21]. M.Hema, and E Rachel "Gender Perception based on Support Vector machines using Gait Energy image Projections" 4th IEEE International Conference on Communication and Electronics Systems (ICCES 2019), Coimbatore, India, 17-19 Jul. 2019.

[22]. M. Hema, K. Babulu, N. Balaji, "Individual Gait Recognition Using Particle Swarm Template Segmentation", International Journal of Advanced Science and Technology, Vol. 29, No. 6 ,pp. 2684 – 2697,2020,2207-6360

[23]. Jami Venkata Suman, Mamidipaka Hema, Bandi Jagadeesh "Linear frequency modulated reverberation suppression using time series models" Indonesian Journal of Electrical Engineering and Computer Science Vol. 26, No. 3, June 2022, pp. 1395~1401 ISSN: 2502-4752, DOI: 10.11591/ijeecs.v26.i3.pp1395-1401

[24]. Mamidipaka Hema, Jami Venkata Suman, Boddepalli Kiran Kumar, Adisu Haile ,
Design and Development of "Polymer-Based Optical Fiber Sensor for GAIT Analysis" International Journal of Polymer Science, Volume 2023, Year 2023

[25]. Mr.A.Sampath Dakshina Murthy, Dr. M.Hema, Dr. J Sudhakar, Mr B.Omakar Lakshmi Jagan Smart Shoe Application No: 6300158, Authority: United Kingdom.

[26]. Mr.A.Sampath Dakshina Murthy, Dr. M.Hema, J.Vijayasree, Dr. Lokireddi Venkata Venu Gopala Rao, Dr. Palli Srihari,"A Method For Performing Gait Analysis To Identify Physically Disabled Individuals"Application No 2023/00903 South Africa Granted.

[27]. A. Sampath Dakshina Murthy,Hema, M., Lakshmi Jagan, B. Omkar "Gait Recognition in the Modern Era" Lambert publications 2023.

[28]. Sampath Dakshina Murthy Achanta, Sudhakar Jyothula , M. Hema, VLSI Design for Gait Analysis: Challenges and Future Directions: Exploring the Boundaries of Wearable Technology, Lambert publications 2023.

[29]. A.Sampath Dakshina Murthy, L Sai Poojitha, L Sravya, Mamatha Kumari, M Vamsi Krishna, Impact of Backpack Disorders on Schools and College Students, Industrial Engineering Journal, Volume: 52, Issue 11, November : 2023 UGC CARE Group-1Page No 273-281.

[30]. A.Sampath Dakshina Murthy, R.Sindhusha , V Niketh, Palisetti Sowjanya, Sattaru Gnana Pranay, Cloud Databases for Gait Networking, Industrial Engineering Journal, Volume : 52, Issue 11, November : 2023 UGC CARE Group-1,Page No:282-290.