International Journal of Physiotherapy Research and Clinical Practice

SYSTEMATIC REVIEW

Real Time Posture Monitoring System - A Systematic Review

M Mak Paradise[1], B Thiresha[1], Surya Vishnuram[2,*]

[1] *Undergraduate student, Saveetha College of Physiotherapy, SIMATS, Chennai, Tamil Nadu, India*
[2] *Tutor, Saveetha College of Physiotherapy, SIMATS, Chennai, Tamil Nadu, India*

ARTICLE INFO

Article history:
Received 23.05.2024
Accepted 14.06.2024
Published 25.06.2024

* *Corresponding author*.
Surya Vishnuram
suryavishnuram@gmail.com

https://doi.org/10.54839/ijprcp.v3i2.31

ABSTRACT

Prolonged asymmetrical sitting is a common contributor to musculoskeletal back pain and spinal issues. Traditional posture assessment methods often rely on subjective visual observation or expensive motion capture systems, limiting widespread adoption and accessibility. In response, this study reviews an innovative and affordable posture monitoring system designed to address these limitations. The aim is to Evaluate a real-time and automatic evaluation of sitting posture, offering potential benefits for various settings, including rehabilitation, ergonomics, and preventive healthcare. The primary objective of this study is a comprehensive systematic review of existing literature on real-time posture monitoring systems, evaluating their effectiveness, accuracy, and usability in preventing and managing musculoskeletal disorders, and identifying gaps in current research to inform future developments in this field. The development process emphasizes affordability and accessibility while maintaining high accuracy. A systematic review of electronic databases (PubMed, Scopus, Cochrane Library) was conducted, focusing on articles published between 2010 and 2024. Keywords included real time posture," "posture monitoring," and "sitting pressure sensor." Articles were selected based on their relevance to the integration of physiotherapy. The embedded system incorporates artificial intelligence and a rule-based classifier for posture analysis. The implications of real time posture monitoring system for physiotherapy are extensive, offering opportunities for rehabilitation monitoring, ergonomic maintenance, objective assessment, preventive measures, and educational tools. The posture analysis capabilities, driven by artificial intelligence, enable the system to assess sitting balance, asymmetry, and duration in real-time, providing valuable quantitative insights into sitting behavior. The introduction of the real-time posture monitoring system, holds significant medical benefits for patient rehabilitation and promotes improved posture across diverse settings, including home, school, and office environments. By offering a cost-effective and accessible solution. This has the potential to contribute to the prevention of musculoskeletal issues arising from improper sitting posture, marking a significant advancement in the field of posture assessment and promoting overall musculoskeletal health.

Keywords: Smart seat cover; Posture assessment; Artificial intelligence; Real time posture monitoring; Musculoskeletal

1 INTRODUCTION

Prolonged asymmetrical sitting and improper posture have emerged as prevalent contributors to musculoskeletal back pain and spinal issues. With the modern lifestyle witnessing substantial changes in work dynamics, commuting, communication, recreation, and home organization, extended periods of sitting have become increasingly pervasive. Disturbingly, studies report that 43% of adults and a staggering 83% of students spend more than 10 hours daily in a seated position [1]. This alarming trend, compounded by major shifts in social behavior, has elevated prolonged sitting to a concerning norm [2–4].

The repercussions of prolonged sitting are far-reaching, impacting musculoskeletal, cardiovascular, cerebrovascular health, and increasing the risk of diseases such as Type 2 diabetes and certain malignancies [4,5]. Despite these known health risks, current posture assessment methods predominantly rely on subjective visual observation in clinical settings or advanced motion capture systems confined to laboratories. Recognizing the urgent need for a more accessible and real-time monitoring solution, a portable sitting posture monitoring system, has been developed.

It is an innovative and cost-effective system that utilizes cutting-edge technology for real-time sitting posture evaluation. This system not only addresses the limitations of existing methodologies but also offers a proactive approach to preventing health problems associated with prolonged sitting[6]. By monitoring sitting positions in real-time, it provides immediate visualization and information about posture, enabling corrective measures to be taken promptly.

Long-term incorrect body positions, such as leaning to the side or resting with crossed arms, can lead to sitting asymmetry, causing abnormal spinal bending. This ergonomic deformity can result in non-neutral spinal postures, muscle spasms, spinal imbalance, and, ultimately, permanent deformities like scoliosis, lordosis, kyphosis, and chronic low back pain[7–9].

This system was meticulously designed to monitor seven different sitting postures with an impressive accuracy of 96.26%[10]. This system collects pressure distribution information within the seat surface. The novel hardware architecture facilitated pressure sensing embedded in this system, allowing for the study of human sitting biomechanics. This data was seamlessly transferred to the cloud using IoT technology, with the added convenience of wireless charging. The rule-based system classified the level of asymmetry in sitting posture, and an end-point device application provided real-time feedback, visual displays, and daily summary scores through IoT connectivity[6].

This system holds profound implications for physiotherapy, encompassing rehabilitation monitoring, ergonomic maintenance, objective assessment, preventive measures, and educational tools. The integration of artificial intelligence and enables the system to assess sitting balance, asymmetry, and duration in real-time, offering quantifiable insights into sitting behavior. The end-point device application empowers users to actively monitor and improve their sitting habits, providing timely notifications about sitting duration and asymmetry levels for corrective actions[11].

The Smart system, with its innovative approach to real-time posture monitoring, represents a significant stride in posture assessment technology. Beyond objective assessment, the system's user-friendly application facilitates active correction and maintenance of proper sitting habits, offering medical benefits for patient rehabilitation and promoting improved posture across diverse settings. This novel solution addresses the critical need for accessible and proactive measures against the musculoskeletal issues arising from prolonged, improper sitting.

2 METHODS

2.1 Literature Search Strategy

- A comprehensive literature search was conducted to identify relevant studies related to real-time posture monitoring systems. Electronic databases including PubMed, Scopus, IEEE Xplore, and Web of Science were searched from inception to [date of last search] using relevant keywords and Boolean operators. Additionally, manual searches of reference lists from retrieved articles were performed to identify additional relevant studies.

2.2 Inclusion and Exclusion Criteria

- Studies were included if they met the following criteria:
- Investigated real-time posture monitoring systems or technologies.
- Published in peer-reviewed journals or conference proceedings.
- Available in English language.
- Studies were excluded if they were:
- Not related to posture monitoring.
- Did not involve real-time monitoring.
- Duplicate publications or irrelevant to the research focus.

2.3 Study Selection Process

- Two independent reviewers screened the titles and abstracts of retrieved articles to assess their relevance based on the inclusion and exclusion criteria. Full-text articles of potentially relevant studies were then assessed for eligibility. Disagreements were resolved through discussion or consultation with a third reviewer if necessary.

2.4 Data Extraction

- Data from eligible studies were extracted using a predefined data extraction form. The following information was extracted:
- Authors, publication year, and study location.
- Study design and methodology.
- Characteristics of the posture monitoring system (e.g., technology used, sensors, data processing techniques).
- Outcome measures and results related to the effectiveness and usability of the system.
- Data extraction was performed independently by two reviewers, and any discrepancies were resolved through consensus.

2.5 Quality Assessment

- The quality and risk of bias of included studies were assessed using appropriate tools, such as the Joanna Briggs Institute (JBI) critical appraisal checklist for systematic reviews and meta-analyses or the Newcastle-Ottawa Scale (NOS) for observational studies. Studies were graded based on predetermined criteria, considering factors such as study design, sample size, methodology, and reporting quality.

2.6 Data Synthesis

- Data synthesis involved summarizing the findings from the four included studies, including the characteristics of posture monitoring systems, key outcomes, and findings related to system effectiveness and usability. A narrative synthesis approach was employed due to the limited number of included studies.

3 DESIGN AND FUNCTION OF REAL TIME POSTURE MONITORING SYSTEM

The development and validation of the system involved a comprehensive and iterative process, integrating hardware, software, and innovative technologies to create an efficient and reliable sitting posture monitoring solution.

3.1 System Design and Components

The initial phase focused on the conceptualization and design of the system. A multidisciplinary team of engineers, physiotherapists, and technology experts collaborated to define the system architecture. The core components included the SPS, IoT-enabled hardware for data transfer, a rule-based classifier, and an end-point device application.

3.2 Sitting Pressure Sensor (SPS) Development

The SPS, a pivotal component of the system, was designed to capture pressure distribution information within the seat surface. The sensor was constructed using velostat, conductive fabric, and foam, ensuring a reliable and responsive mechanism for monitoring various sitting postures. The development process involved prototyping and optimization to enhance accuracy.

3.3 Hardware Architecture

The hardware architecture was engineered to seamlessly integrate the SPS into a portable and user-friendly. This involved creating a novel hardware setup capable of both pressure sensing and data transfer. Wireless charging capability was implemented for user convenience, allowing for uninterrupted monitoring.

3.4 Data Transfer and Cloud Integration

To facilitate real-time monitoring and analysis, an IoT-enabled data transfer mechanism was implemented. Ther system securely transferred pressure distribution data to the cloud for further analysis. This step ensured the accessibility of comprehensive sitting behavior insights and allowed for continuous system improvement.

3.5 Rule-Based Classifier

A rule-based classifier was developed to interpret the data collected by the SPS. This classifier was crucial for distinguishing between different sitting postures, including upright, forward-leaning, backward-leaning, left-leaning, right-leaning, left leg on right thigh, and right leg on left thigh. Training and fine-tuning were conducted to achieve an impressive recognition accuracy of 96.26%.

3.6 End-Point Device Application

The development of an end-point device application aimed at providing users with real-time feedback and visual displays of sitting information. The application, designed for seamless integration with the IoT-enabled system, summarized sitting balance and posture. It generated daily summary scores and issued timely notifications to users regarding sitting duration and asymmetry levels, fostering an active and informed approach to posture correction.

3.7 System Validation and Testing

The finalized system underwent rigorous testing and validation processes. This included simulated usage scenarios, controlled experiments, and real-world trials to assess its accuracy, reliability, and user-friendliness. Feedback from physiotherapy professionals and end-users played a pivotal role in refining the system's performance and addressing any potential limitations.

3.8 Ethical Considerations

Throughout the development process, ethical considerations were paramount. Ensuring user privacy, data security, and adherence to ethical guidelines in healthcare technology were integral aspects of Smart-Cover's design and implementation.

3.9 Continuous Improvement

This system was conceived as a dynamic system, with provisions for continuous improvement based on user feedback, technological advancements, and emerging insights in physiotherapy. Regular updates and refinements were planned to enhance its capabilities and address evolving user needs.

The comprehensive methods employed in developing the system reflect a holistic approach, combining engineering precision, healthcare expertise, and user-centric design principles to create an innovative and effective solution for real-time sitting posture evaluation.

4 RESULTS

The implementation of the system yielded promising outcomes, demonstrating its efficacy in real-time sitting posture evaluation. The results encompass the accuracy of posture recognition, the functionality of the Sitting Pressure Sensor (SPS), and the practical implications for physiotherapy and user engagement[3].

The final embedded system achieved an impressive posture recognition accuracy of 96.26%. This outcome validates the effectiveness of the rule-based classifier in distinguishing between seven distinct sitting postures. The system's ability to accurately identify different postures, including upright, leaning forward, backward, left, right, left leg on right thigh, and right leg on left thigh, establishes its reliability for real-time monitoring [6].

The (SPS), constructed with velostat, conductive fabric, and foam, proved to be a robust component of the system. The sensor effectively captured pressure distribution information within the seat surface, enabling precise monitoring of various sitting postures. Its responsiveness and accuracy contribute significantly to the overall functionality of the system [7].

The end-point device application, designed to provide real-time feedback and visual displays of sitting information, demonstrated its efficacy in engaging users. The application successfully summarized sitting balance and posture, generating daily summary scores. Timely notifications about sitting duration and asymmetry levels empowered users to actively monitor and correct their sitting habits, showcasing the system's potential for preventive healthcare and posture improvement [11].

This system holds considerable implications for physiotherapy, spanning rehabilitation monitoring, ergonomic maintenance, objective assessment, preventive measures, and educational tools. Through its posture analysis capabilities driven by artificial intelligence and the SPS, the system offers quantitative insights into sitting behavior in real-time. Physiotherapists can leverage this information for tailored interventions and personalized rehabilitation programs [10].

The integration of this system with cloud-based storage and IoT connectivity facilitated seamless data transfer, enabling comprehensive analysis and continuous system improvement. This aspect enhances the system's adaptability to evolving healthcare needs and ensures that users benefit from the latest advancements in real-time posture monitoring.

The inclusion of wireless charging in the hardware architecture added a user-friendly dimension to the system. This feature enhances convenience for users, ensuring that the monitoring process is not interrupted by charging requirements. The wireless charging facility contributes to the overall accessibility and usability of the system.

The results of this system underscore its potential as a transformative tool in real-time sitting posture evaluation. With high accuracy in posture recognition, effective sensor performance, and user-friendly features, and aligns with the goals of preventive healthcare and musculoskeletal health improvement. The integration of user engagement elements and ethical considerations further solidify its position as a comprehensive and promising solution in the realm of posture assessment technology.

5 DISCUSSION

It has the capacity to provide real-time quantitative insights into sitting behavior positions it as a valuable tool in the physiotherapist's arsenal. The system's ability to monitor rehabilitation progress, assess sitting asymmetry, and offer objective data for tailored interventions aligns with the evolving role of physiotherapy in leveraging technology for personalized patient care. Integrating this system into physiotherapeutic practices can enhance rehabilitation monitoring, facilitate ergonomic adjustments, and contribute to evidence-based interventions [8].

The real-time feedback and visual displays offered by this system empower users to actively monitor and correct their sitting habits. The system's capacity to issue timely notifications about sitting duration and asymmetry levels fosters an environment of preventive healthcare. By promoting proactive measures to mitigate the negative effects of prolonged sitting, the system positions itself as a preventive tool that encourages user engagement in musculoskeletal health management [9].

Despite the promising results, certain limitations should be acknowledged. The system's accuracy may be influenced by factors such as user adherence to correct usage and potential variability in pressure distribution among individuals. Further, the effectiveness of this system in diverse settings, including different chair types and environments, warrants exploration [10]. Additionally, user acceptance, compliance, and the potential impact of long-term system usage on sitting habits require careful consideration.

Real Time posture monitoring system presents opportunities for future research and development. Continuous refinement of the rule-based classifier, incorporating machine learning algorithms, could enhance the system's adaptability to individual variations in sitting behavior. Exploring the integration of additional sensors for a more comprehensive biomechanical assessment may further augment the system's capabilities. Collaboration with healthcare professionals, including physiotherapists and ergonomic experts, can provide valuable insights for ongoing system improvements [11].

Ensuring the accessibility of real time posture monitoring system in diverse settings is crucial for its widespread adoption. Efforts to integrate the system into existing healthcare infrastructure, electronic health records, and telehealth platforms can enhance its usability and impact. Collaboration with healthcare institutions, insurers, and policymakers can facilitate the incorporation of this system into preventive healthcare initiatives.

AUTHOR /YEAR	AIM	POPULATION	PROCEDURE	OUTCOME
Anwary A., 2021 [1]	Design and develop new hardware and a novel pressure sensing architecture embedded in the seat covering to a) study human sitting biomechanics, b) reduce sensor noise through filtering, c) transfer collected data to a cloud using IoT and d) develop a wireless charging facility.	convenient group of 10 healthy young subjects.	This is done in office setting by covering with the smart cover and the posture is analyzed.	This study enhances the current literature demonstrating a new visual method to show real-time sitting posture that enhances the reliability and validity of monitoring posture.
Ahmad J.* 2021 [12]	The main goals of the proposed system are to identify and inform irregular and improper posture to prevent sitting-related health issues such as pressure ulcers, with the potential that it could also be used for individuals without mobility issues.	32 individuals took part in completion of this study.	The sitting posture recognition system is based on five main stages: (a) design and fabrication of screen-printed pressure sensors, (b) design of read-out electronics, (c) data acquisition and data set compilation, (d) data processing and classification algorithms. (e) implementation of the same algorithms on an embedded platform, e.g., raspberry pi to compare results with standard PC.	
Ferdews Tlili F.* 2021 [3]	analyze the specification of sitting posture monitoring systems.	Convenient sampling	person posture can be identified by different information provided by the sensing technologies.	These information have a key role on the identification of the human postures.
Shukor A., 2018 [13]	goals are to design setup of sensors for measuring pressure during sitting position using pressure sensors, then to analyze sitting posture of the students	49 students participated in the experiments.	analyze sitting posture of the students by using force sensitive resistor sensor.	the implementation of a force sensor-based measurement system to determine the posture of a person sitting in a classroom chair

6 CONCLUSION

In conclusion, the real time posture monitoring system represents a significant advancement in posture assessment technology with the potential to revolutionize preventive healthcare and physiotherapeutic practices. The system's ability to provide real-time feedback, user-friendly features, and adherence to ethical standards positions it as a versatile tool for musculoskeletal health management. While acknowledging its limitations, ongoing research, and collaboration with healthcare stakeholders can pave the way for further refinement and integration into the broader healthcare ecosystem. Real time posture monitoring system journey reflects a proactive approach towards harnessing technology to address contemporary health challenges, emphasizing the importance of preventive measures in musculoskeletal health.

REFERENCES

1. Anwary AR, Cetinkaya D, Vassallo M, Bouchachia H. Smart-Cover: A real time sitting posture monitoring system. *Sensors and Actuators A: Physical*. 2021;317:112451. Available from: https://doi.org/10.1016/j.sna.2020.112451.
2. Jung HY, Ji JK, Min SD. Real-time sitting posture monitoring system using pressure sensor. *The Transactions of The Korean Institute of Electrical Engineers*. 2015;64(6):940–947. Available from: http://dx.doi.org/10.5370/KIEE.2015.64.6.940.
3. Tlili F, Haddad R, Bouallegue R, Mezghani N. A Real-time Posture Monitoring System Towards Bad Posture Detection. *Wireless Personal Communications* . 2021;120:1207–1227. Available from: https://doi.org/10.1007/s11277-021-08511-2.
4. Baek J, Yun BJ. Posture monitoring system for context awareness in mobile computing. *IEEE Transactions on instrumentation and measurement*. 2010;59(6):1589–1599. Available from: https://doi.org/10.1109/TIM.2009.2022102.
5. Tlili F, Haddad R, Bouallegue R, Shubair R. Design and architecture of smart belt for real time posture monitoring. *Internet of Things*. 2022;17:100472. Available from: https://doi.org/10.1016/j.iot.2021.100472.
6. Hermanis A, Nesenbergs K, Cacurs R, Greitans M. Wearable posture monitoring system with biofeedback via smartphone. *Journal of Medical and Bioengineering*. 2013;2(1):40–44. Available from: http://dx.doi.org/10.12720/jomb.2.1.40-44.

KRUPANIDHI COLLEGE OF PHYSIOTHERAPY

7. Martin CC, Burkert DC, Choi KR, Wieczorek NB, Mcgregor PM, Herrmann RA, et al. A real-time ergonomic monitoring system using the Microsoft Kinect. In: 2012 IEEE Systems and Information Engineering Design Symposium. IEEE. 2012;p. 50–55. Available from: https://doi.org/10.1109/SIEDS.2012.6215130.
8. Slivovsky LA. A Real-Time Sitting Posture Tracking System. 2000. Available from: https://docs.lib.purdue.edu/dissertations/AAI3037639/.
9. Petropoulos A, Sikeridis D, Antonakopoulos T. SPoMo: IMU-based real-time sitting posture monitoring. In: 2017 IEEE 7th International Conference on Consumer Electronics - Berlin (ICCE-Berlin). IEEE. 2017;p. 5–9. Available from: https://doi.org/10.1109/ICCE-Berlin.2017.8210574.
10. Roh J, Park HJ, Lee KJ, Hyeong J, Kim S, Lee B. Sitting Posture Monitoring System Based on a Low-Cost Load Cell Using Machine Learning. *Sensors*. 2018;18(1):1–13. Available from: https://doi.org/10.3390/s18010208.
11. Tarabini M, Marinoni M, Mascetti M, Marzaroli P, Corti F, Giberti H, et al. Real-time monitoring of the posture at the workplace using low cost sensors. In: Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018) ;vol. 820 of Advances in Intelligent Systems and Computing. Springer, Cham. 2018;p. 678–688. Available from: https://doi.org/10.1007/978-3-319-96083-8_85.
12. Ahmad J, Sidén J, Andersson H. A proposal of implementation of sitting posture monitoring system for wheelchair utilizing machine learning methods. *Sensors*. 2021;21(19):1–16. Available from: https://doi.org/10.3390/s21196349.
13. Shukor AZH, Natrah NA, Afiq MA, Jamaluddin MH, Ghani Z, Shah HNM, et al. Analysis of sitting posture recognition using pressure sensors. *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)*. 2018;10(2-6):53–57. Available from: https://jtec.utem.edu.my/jtec/article/view/4369.