

Non-Invasive bio- sensors for continuous and glucose and vital monitoring: The future of chronic disease management

Elavarasi E¹, Sophiya Rajakumari², Subulakshmi³, Rajaselvi G⁴, Prema K⁵, Suriyakala S⁶

¹Associate Professor, Department of Medical Surgical Nursing, Shri Sathyasai College of Nursing, Shri Balaji Vidhyapeeth University.

²Principal, Al Ameen College of Nursing.

³Vice - Principal, Al Ameen College of Nursing.

⁴Vice - Principal, Kamaraj College of Nursing.

⁵Principal, Shri Sathyasai College of Nursing, Shri Balaji Vidhyapeeth University.

⁶Ph.D Scholar, Saveetha College of Nursing, Saveetha Institute of Medical Science and Technology

ABSTRACT

The global rise in chronic diseases, particularly diabetes, demands innovative, patient-friendly monitoring systems to improve disease management and outcomes. Non-invasive biosensors, especially wearable technologies, offer a promising alternative to traditional blood-based glucose monitoring by enabling continuous, real-time tracking of physiological markers without the discomfort or risks associated with invasive methods. This manuscript explores the current advancements in non-invasive glucose monitoring (NGM) technologies, with a focus on electrochemical, optical, electromagnetic, and sonochemical sensors. Emphasis is placed on transdermal devices that use body fluids like sweat and tears, as well as techniques such as Raman spectroscopy and infrared sensing. The review addresses the shift from semi-invasive Continuous Glucose Monitoring (CGM) systems (e.g., Dexcom, FreeStyle Libre) to truly non-invasive alternatives under development, such as the MUS-IR and fluorescent-based sensors. Integration with digital health ecosystems through AI and machine learning is highlighted as a key factor in enhancing data analysis, providing personalized feedback, and enabling remote care. However, challenges remain, including sensor sensitivity, environmental interference, data overload, regulatory hurdles, and clinical adoption barriers. Despite these limitations, ongoing research and development in NGM technologies suggest significant potential for transforming diabetes management through painless, accurate, and user-friendly monitoring solutions.

KEYWORDS: Non-invasive glucose monitoring, Continuous glucose monitoring (CGM), Wearable biosensors, Electrochemical sensors, Digital health, Diabetes management, Artificial intelligence, Sensor accuracy, Sweat-based sensors, Raman spectroscopy, Data overload, Regulatory challenges.

How to Cite: Elavarasi E, Sophiya Rajakumari, Subulakshmi, Rajaselvi G, Prema K5, Suriyakala S, (2025) Non-Invasive bio-sensors for continuous and glucose and vital monitoring: The future of chronic disease management, Vascular and Endovascular Review, Vol.8, No.8s, 188-190.

INTRODUCTION

Effective management techniques are necessary to enhance patient outcomes due to the increasing burden of chronic diseases, especially diabetes. Wearable biosensors and other non-invasive alternatives provide a major benefit by enabling real-time monitoring without the discomfort that comes with conventional blood collection techniques. By measuring glucose levels in bodily fluids like perspiration, biosensor technologies in particular, electrochemical sensors improved by surface chemistry have demonstrated great promise in non-invasive glucose monitoring.⁽¹⁾ The goal of recent developments in biosensor technology is to provide dependable and all-inclusive glucose monitoring solutions by improving accuracy, biocompatibility, and usability.⁽²⁾ Advances in electrochemical, optical, electromagnetic, and sonochemical sensors have led to the creation of transdermal glucose monitoring devices, demonstrating the substantial evolution of biosensor technology. By tackling the issues with conventional glucose monitoring techniques, these advancements seek to offer real-time monitoring with enhanced sensitivity, selectivity, and accuracy.⁽⁵⁾ Numerous biosensor technologies, such as wearable gadgets that make use of sensing technologies like accelerometers and heart rate monitors, are being investigated to offer non-invasive monitoring alternatives. By providing real-time vital sign assessments without intrusive procedures, these innovations seek to enhance the management of type 2 diabetes.⁽⁷⁾

OVERVIEW:

Devices known as non-invasive biosensors track physiological markers without requiring invasive procedures like blood draws. ⁽¹⁾ The following are fundamental ideas of non-invasive biosensing technologies: Optical methods: These employ light to measure the amount of glucose in different body fluids. Techniques that use microwave sensing to measure glucose concentrations are known as electromagnetic techniques. Techniques such as iontophoresis may be used in electrochemical approaches to make glucose measurement easier. ⁽²⁾ Wearable electrochemical sensors that track blood glucose and lactate levels are an example of a non-invasive biosensor; these are especially helpful for athletes and diabetes patients.

The study highlights ongoing research and development efforts in innovative diabetes care with non-invasive glucose monitoring

devices, but it does not give particular examples of non-invasive biosensors that are now on the market.⁽⁸⁾ A comparison of invasive and non-invasive techniques is suggested, with the latter being characterized as less invasive and more user-friendly for diabetics.⁽⁸⁾ Although particular examples of non-invasive biosensors that are now on the market are not given in the text, the paper's goal is to discuss various non-invasive glucose monitoring (NGM) methodologies and devices, suggesting continued research in this area.⁽⁹⁾ Non-invasive biosensors under development include the MUS-IR unit, which measures blood glucose levels via the skin using modulated ultrasonic and infrared technologies.⁽¹⁰⁾ Fluorescent-based continuous glucose monitoring devices have been in the research and development phase since 2008.⁽¹⁰⁾

CONTINUOUS GLUCOSE MONITORING:

Semi-invasive techniques like Dexcom and FreeStyle Libre, which involve some kind of skin penetration for glucose measurement, are among the current technologies for Continuous Glucose Monitoring (CGM).⁽¹⁾ With an emphasis on sweat-based and tear-based monitoring techniques, as well as approaches like Raman spectroscopy, emerging non-invasive CGM technologies are being developed with the goal of providing glucose readings without intrusive procedures.⁽²⁾ The significance of blood glucose monitoring, especially for those with diabetes and other related illnesses, is covered in the research report. With an emphasis on the benefits of non-invasive biosensors, it draws attention to the differences between invasive and non-invasive glucose monitoring techniques.⁽³⁾ Although invasive glucose monitoring systems are known for their accuracy, the hazards and inconveniences associated with the removal of body fluids are significant. Understanding noninvasive measures requires a thorough understanding of glucose metabolism routes and how they differ in various bodily fluids, which is provided in this work.⁽⁴⁾ It assesses the fundamental elements and working principles of contemporary wearable glucose sensors, which may incorporate comparable technologies (such as tear- or sweat-based sensors). Accuracy, lag time, and calibration issues in glucose monitoring are also covered in the review, along with important prospects for further study in this developing area.⁽⁹⁾

Current Continuous Glucose Monitoring (CGM) technologies include semi-invasive devices that require some skin penetration, including Dexcom and FreeStyle Libre. New non-invasive CGM systems are being developed, with an emphasis on techniques like Raman spectroscopy and sweat- and tear-based monitoring. Among the difficulties in glucose monitoring are problems with precision, reading lag, and the requirement for calibration to guarantee accurate data.⁽¹⁰⁾ The regulatory environment surrounding glucose monitoring devices is changing, with an emphasis on clinical validation to guarantee the efficacy and safety of both new and current technology.⁽¹⁰⁾ Numerous non-invasive glucose monitoring devices have been developed using a variety of physical concepts. By eliminating the discomfort and dangers connected with conventional techniques, these non-invasive devices seek to provide frequent, painless, and risk-free testing.⁽¹¹⁾

INTEGRATION WITH DIGITAL HEALTH ECOSYSTEMS:

The development of successful non-invasive glucose monitoring technology is complicated by the difficulties listed, which include the unique characteristics of each non-invasive technique and the different reactions of diabetic patients in comparison to healthy people¹². In order to analyze the data gathered from these non-invasive monitoring systems and create dynamic compensation for glucose levels and customized calibration models, artificial intelligence (AI) and machine learning are essential. - Based on the monitoring data, real-time notifications can be produced, enabling prompt treatments and remote glucose level monitoring for patients. These technologies' incorporation into cloud-based systems brings up significant privacy and data security issues, guaranteeing the protection of private health data while facilitating easy access to medical professionals.⁽¹³⁾ The creation of a non-invasive blood glucose sensor and the combination of various sensing technologies for glucose measurement are the main topics of the research study. - As a result, no pertinent data is available in the contexts given to address the inquiry about integration with digital health ecosystems⁽¹⁴⁾

TECHNICAL AND CLINICAL CHALLENGES

The precision and sensitivity of sensors, which are essential for accurate glucose readings, present difficulties for non-invasive glucose monitoring devices. Sweat, movement, and other environmental factors can interfere with these devices' functionality, making their application in practical situations more challenging. Continuous monitoring can produce enormous volumes of data, which raises concerns about data overload and makes clinical interpretation difficult for medical professionals.⁽¹⁾ Since they have a direct bearing on the dependability of glucose readings, sensor sensitivity and accuracy are crucial issues in continuous glucose monitoring (CGM) systems. Sweat, activity, and other outside influences can interfere with CGM systems' functionality, potentially resulting in inaccurate glucose readings. - Clinical interpretation is hampered by data overload since medical professionals may find it difficult to properly evaluate and use the enormous volumes of data produced by CGM devices.⁽⁴⁾ The problem of data overload is brought on by the comprehensive information that CGM systems provide, which can make clinical interpretation and decision-making more difficult for medical professionals. The commercialization and broad acceptance of novel CGM systems are hampered by regulatory obstacles, such as gaining FDA or CE approval. - For CGM systems to be implemented successfully, patient uptake and education are essential⁽⁷⁾.

CONCLUSION

In conclusion, non-invasive biosensors allow for continuous, painless, real-time glucose and vital parameter monitoring, which is a revolutionary development in the management of chronic diseases. These new technologies have the ability to assist individualised treatment plans, improve early detection of health abnormalities, and increase patient compliance. Non-invasive biosensing systems are positioned to become essential instruments in long-term illness management and preventive healthcare, ultimately enhancing patient outcomes and quality of life, as advances in materials science, nanotechnology, and data analytics continue to progress.

REFERENCES

1. Chen, Z. (2024). Surface Chemistry-Enhanced Wearable Biosensors: A Novel Approach for Non-Invasive Continuous Health Monitoring. *International Journal of Social Sciences and Public Administration*, 5(1), 159–162.
2. Zhang, H. (2024). Application of Biosensors in Non-invasive Blood Glucose Monitoring. *E3S Web of Conferences*, 553, 05001.
3. Yu, Y., Dai, J., Wang, B., Yan, L., Long, Z., Zhang, W., Su, X., Ji, W., Huang, L., & Li, L. (2025). Wearable Noninvasive Glucose Biosensors: Biological Metabolism, Chemical Sensing, and Biological Applications. *Advanced Materials and Technologies*.
4. Mohamad Yunus, M. F. A., & Nordin, A. N. (2020). Non-invasive glucose monitoring devices: a review. *Bulletin of Electrical Engineering and Informatics*, 9(6), 2609–2618.
5. Dua, A. K., Debnath, A., Dubey, A., Mazumder, R., Mazumder, A., Singh, R. K., Mangal, S. K., Sanchitra, J., Khan, F., Tripathi, S. K., Vishwas, S., Chaudhary, H., Sharma, P., & Srivastava, S. (2024). Advancements of Glucose Monitoring Biosensor: Current State, Generations of Technological Progress, and Innovation Dynamics. *Current Pharmaceutical Biotechnology*, 25.
6. Piet, A., Jablonski, L., Onwuchekwa, J. I. D., Unkel, S., Weber, C., Grzegorzec, M., Ehlers, J., Gaus, O., & Neumann, T. (2023). Non-Invasive Wearable Devices for Monitoring Vital Signs in Patients with Type 2 Diabetes Mellitus: A Systematic Review. *Bioengineering*.
7. Kim, J. D., & Kim, B. K. (2021). Trends in Non-invasive Continuous Glucose Monitoring Technology. 36(5), 9–20.
8. Li, Y., & Chen, Y. (2023). Review of Noninvasive Continuous Glucose Monitoring in Diabetics. *ACS Sensors*.
9. Kalaiselvi, P., Anand, M., Ajithkumar, P., & Arvind, A. (2016). A study of continuous blood glucose monitoring using non invasive technique. 03(01), 49–54.
10. Chowdhury, K., Srivastava, A., Sharma, N., & Sharma, S. (2014). Prospective Analysis of Developing Noninvasive Blood Glucose Monitoring Biosensors for Diabetic Population. *Biosciences, Biotechnology Research Asia*, 11(3), 1639–1647.
11. Zhang, H. (2024). Application of Biosensors in Non-invasive Blood Glucose Monitoring. *E3S Web of Conferences*, 553, 05001.
12. Ciudin, A., Hernández, C., & Simó, R. (2012). Non-Invasive Methods of Glucose Measurement: Current Status and Future Perspectives. *Current Diabetes Reviews*, 8(1), 48–54.
13. Chowdhury, K., Srivastava, A., Sharma, N., & Sharma, S. (2014). Prospective Analysis of Developing Noninvasive Blood Glucose Monitoring Biosensors for Diabetic Population. *Biosciences, Biotechnology Research Asia*, 11(3), 1639–1647.
14. Wu, K. (2025). Non-Invasive Glucose Monitoring Technologies Innovations Applications and Future Directions. *MATEC Web of Conferences*, 410, 04002.
15. Lopez Albalat, A., Sanz Alaman, M. B., Dejoz Diez, M. C., Martinez-Millana, A., & Traver Salcedo, V. (2019). Non-Invasive Blood Glucose Sensor: A Feasibility Study. *International Conference of the IEEE Engineering in Medicine and Biology Society*, 2019, 1179–1182.
16. Mansour, M., Darweesh, M. S., & Soltan, A. (2024). Wearable devices for glucose monitoring: A review of state-of-the-art technologies and emerging trends. *Alexandria Engineering Journal*.