Received: 31 December 2024, Revised: 02 March 2025, Accepted: 19 March 2025 Published Online: 04 August 2025

Journal of Chronic Disease Epidemiology

DOI: https://doi.org/10.62160/JCDE22

REVIEW ARTICLE

Wearable Technology for Early Disease Detection: Enhancing Preventive Public Health

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Abstract: Wearable technology has emerged as a powerful tool in the realm of preventive public health, offering the potential to detect diseases at an early stage, monitor health continuously, and ultimately improve health outcomes. These devices, which include smartwatches, fitness trackers, and biosensors, can collect real-time data on various physiological parameters such as heart rate, activity levels, sleep patterns, and even biochemical markers. By analyzing this data, wearable technology can identify deviations from normal health patterns, allowing for the early detection of conditions such as cardiovascular diseases and diabetes. The integration of wearable technology into public health strategies not only enhances individual health monitoring but also provides valuable data for population-level health interventions. However, challenges such as data privacy, accuracy, and the digital divide must be addressed to fully realize the full potential of wearables in public health. This review explores the role of wearable technology in early disease detection, discusses its potential to enhance preventive public health, and examines the challenges associated with its widespread adoption.

Keywords: *Wearable technology, Early disease detection, Preventive public health, Health monitoring, Biosensors*

1. Introduction

In the recent past, there has been an increased focus on wearable technology as a possible means of supporting and improving the preventive public health sector. These devices include smartwatches, fitness trackers, biosensors, and other portable devices that can be used to capture biological data in real time, including a variety of physiological parameters. The information that can be derived from this includes the health status of an individual, thereby helping in identifying diseases at an early stage and thus prompt intervention (1,2). The use of wearable technology is becoming popular in society as a way of managing health, and this is a major change from the past, where health management was rather reactive, and interventions were made only after the symptoms had appeared.

The evolution of wearable health monitoring devices powered by advanced technology has enabled more precise health data collection than ever before. Modern wearables can track vital metrics such as heart rate, physical activity, sleep patterns, and even blood glucose levels, providing valuable insights for personal health management (3,4). From this data, the healthcare providers and the individuals themselves can be able to determine the variations from the expected health status that could signal the beginning of a disease. This capability is especially helpful for long-term diseases, including cardiovascular diseases, diabetes, and cancers, since the treatment is more effective when detected at the initial stages, and with the use of health data, there is an opportunity to reduce the costs that are incurred in the treatment process (5).

Wearable devices are increasingly being integrated into public health management, allowing health authorities to collect large-scale data from diverse populations. This extensive data collection enables the identification of disease trends, potential health risks, and emerging public health concerns, facilitating more informed decision-making and targeted interventions (6). This data can then be used in the development of public health strategies, for example, specific interventions and health promotion campaigns, which in the end may enhance health outcomes in society. Also, wearable technology can also be used to mitigate the problem of inequality in

healthcare systems by enabling the monitoring of patients from a distant setting, thus enabling the delivery of healthcare services to people in areas that are difficult to access (7).

However, some barriers to the adoption of wearable technology in even improving though preventive it public has health. A major potential setback is the issue of data privacy and security since wearable devices accumulate personal health information (8). This raises questions on how this information is being stored, shared, and protected since it is of a sensitive nature. This paper has identified data protection and privacy of wearable technology as key to the acceptance of the technology by the public. Also, the accuracy and reliability of wearable devices are the most important factors that define the efficacy of these devices in the detection of disease in the early stage. Although, many of the wearable devices have been found to be accurate, there is a difference in the quality of data that is gathered by various gadgets, and this may affect their efficacy in the clinical practice (8).

Another big problem is the digital divide, which can be defined as the difference between those people who have easy access to digital technologies and those who do not. Wearable technology can also worsen health inequalities if only specific groups of the population gain access to these devices (9). Therefore, important to ensure that everyone has an equal opportunity to use wearable technology in order to improve the health of the general population. This involves considering issues to do with the cost of the devices, the level of digital literacy, as well as the accessibility of quality internet connection, especially in areas with limited resources. This review aims to examine the part taken by wearable technology in the detection of disease with an emphasis on how it can improve preventive public health. It also looks at the issues that are likely to hinder the uptake and use of wearable technology and how these can be addressed so that the technology can have the desired impact on public health.

2. Methodology

This review is based on a selective literature review aimed at providing a comprehensive overview of the role of wearable technology in early disease detection and its potential to enhance preventive public health. The review process involved searching academic databases such as PubMed, IEEE Xplore, and Google Scholar using keywords like "wearable technology," "early disease detection," "preventive public health," "health monitoring," and "biosensors." The search focused on studies published in the last decade and included only English-language publications. Inclusion criteria

were established to select studies that provided empirical data, theoretical insights, or practical guidelines relevant to the use of wearable technology in public health. Peer-reviewed articles, conference papers, and government reports were prioritized, while opinion pieces without empirical backing were excluded. Relevant data were extracted from the selected studies and organized by key themes, including the applications, challenges, and potential of wearable technology in early disease detection and preventive public health. A narrative synthesis approach was used to integrate findings from the literature, providing a cohesive overview of the current state of wearable technology in public health.

3. Applications of Wearable Technology in Early Disease Detection

Wearable devices have many uses in the field of health care, especially in the detection of diseases in the early stages, the management of cardiovascular diseases and diabetes, and other chronic diseases. The following applications have the possibility of greatly improving preventive public health to the level of continuous health monitoring and early treatment.

3.1 Cardiovascular Health Monitoring

Wearable devices are one of the most common gadgets used in the management of cardiovascular diseases. Some of the features of these devices include heart rate, heart rate variability, and even identification of abnormal heart rhythms since they are equipped with sensors. For instance, smartwatches with ECG sensors are capable of identifying atrial fibrillation, which is an abnormal heart rhythm disorder that poses a high risk of stroke (10). This way, the wearable technology can identify such conditions at the initial stage, thus urging people to visit the doctor before it becomes worse.

Apart from arrhythmias, wearable devices can also track other CV risk factors, including physical activity, sleep, and stress. For example, if the physical activity is low, the sleep quality is poor, and the stress levels are high, this may indicate the presence of CV risk factors (11). Thus, the data collected by wearable technology can assist both patients and healthcare professionals in recognizing the mentioned risk factors and making necessary changes in one's lifestyle or treatment plan to prevent the development of cardiovascular diseases.

3.2 Diabetes Management

There is also the use of wearable devices in the management of diabetes. One of such is the continuous glucose monitors (CGMs), which are devices worn by the patient to monitor the glucose levels at regular intervals. It gives the patients with diabetes real-time results on the glucose levels to enable them to change their diet, activity, and even medication intake (12,13). As a result, CGMs offer a way of identifying hyperglycemia or hypoglycemia at early stages, thus allowing for intervention before complications occur.

Besides CGMs, other data that can be gathered with wearable technology are activity and sleep, which are also relevant to diabetes. For instance, fitness trackers can be worn around the diabetic neck or ordered onto the achieve wrist recommended to levels monitor of the physical amount of activity and frequency enhance of the exercise, the effectiveness of which may insulin be therapy useful to (14). Also, sleep patterns can help us understand how the quality of sleep influences blood glucose levels so that patients can make changes to their sleep schedules to help with diabetes.

Wearable technology adoption has seen a significant increase over the past decade, driven by advancements in digital health monitoring. According to Statista, global shipments of wearable devices rose from 28.8 million units in 2014 to over 533.6 million units in 2021, with projections reaching 559.7 million by 2024. Additionally, recent studies indicate that 44.5% of U.S. adults now own a wearable device, reflecting a growing integration of such technologies into everyday health management (15–17)

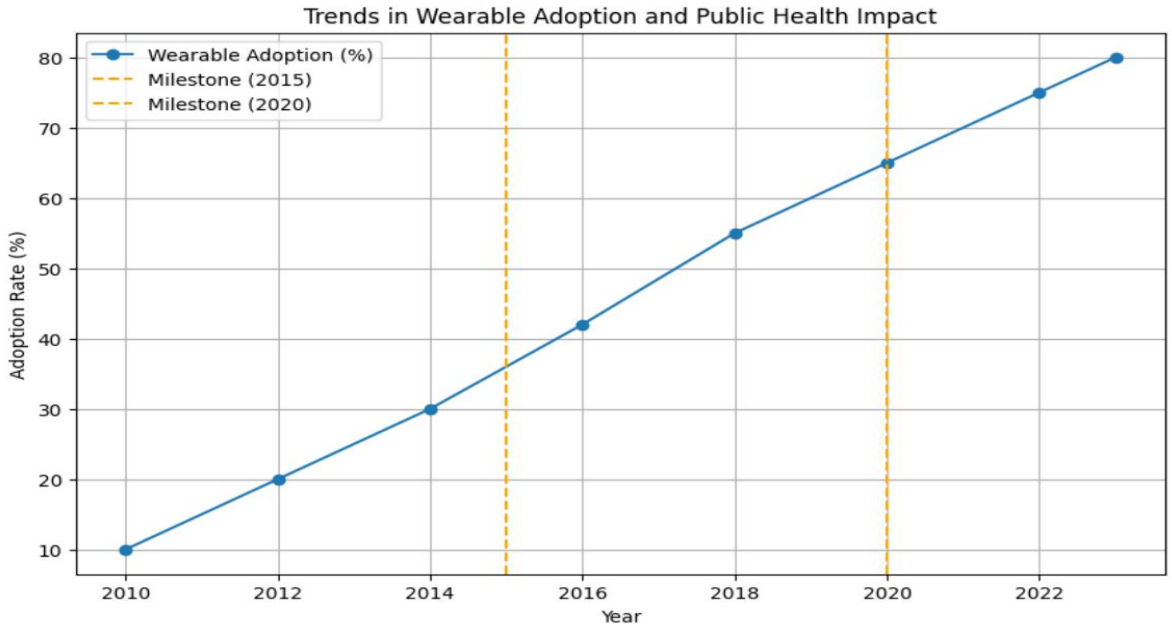

Figure 1: Line graph showing Trends in Wearable Adoption and Public Health Impact. The graph illustrates the percentage growth of wearable technology adoption from 2010 to 2024, with critical public health milestones (e.g., COVID-19 pandemic response)

3.3 Monitoring Chronic Conditions

Besides the control of cardiovascular disease and diabetes, smartwatches can be used in the management of other chronic diseases, including respiratory diseases, neurological diseases, and cancer. For instance, smartwatches with respiratory sensors can help in tracking the lung function of patients suffering from COPD or asthma by identifying the symptoms of exacerbations thus enabling early management. Likewise, devices that are capable of tracking movements can help in the management of neurological diseases, including Parkinson's disease, by giving important information to fine-tune treatment plans (18).

The use of wearable technology is also being considered as a way of cancer detection. For instance, scientists are working on creating wearable biosensors that are capable of identifying particular biomarkers related to cancer (19). Thus, the monitoring of these biomarkers in a continuous manner is that wearable devices may be capable of identifying cancer at a stage when it is more easily treatable. Although the present work is preliminary, this is an interesting area for the future development of wearable technology in the field of preventive public health.

4. Challenges in Implementing Wearable Technology in Public Health

Although wearable technology presents numerous opportunities for improving preventive public health, there are certain issues that need to be solved in order to achieve these advantages. The following issues have to be considered in order to properly implement the use of wearable technology while ensuring that its advantages are effectively harnessed.

4.1 Data Privacy and Security

The major barrier to wearable technology is the issue of data privacy and security. These devices are known to gather a lot of information regarding the health of an individual, for instance, heart glucose rate, levels of blood, and even sleep patterns, among others. This paper also highlights the importance of ensuring that such data is stored, transmitted, and used in a manner that is compliant with data protection laws so that the public loses confidence in wearable technology (20).

In response to this challenge, wearable technology developers have had to incorporate strong security features like encryption, data storage, and access control to ensure that user information is safe from theft and hacking. Also, there must be some set rules and regulations regarding wearable health data to control the use and sharing of the data and to give persons control over their data as well as to ensure that the data is used appropriately.

4.2 Accuracy and Reliability

Two of the most important characteristics of wearable devices are the accuracy and the reliability of the devices in detecting diseases in their initial stages. Although many of the wearable devices have been proven to be accurate, there is a difference in the quality of data that is collected by various devices. This variability can impact the effectiveness of wearable technology in clinical settings, particularly if inaccurate data leads to inappropriate treatment approaches (21).

To overcome this challenge, wearable technology developers need to enhance the accuracy and reliability of their devices with the help of proper testing and validation. In addition, healthcare professionals need to be capable of correctly analyzing the data obtained from the wearable devices and incorporating this data into the clinical practice in a manner that would improve the health of the patient (22). This includes the appreciation of the pros and cons of using wearable devices and the integration of the devices with other tools used in assessing the health of an individual.

4.3 The Digital Divide

The digital divide, which refers to the gap between individuals who have access to digital technologies and those who do not, is another significant challenge in the implementation of wearable technology in public health. Wearable devices can be expensive, making them inaccessible to certain populations, particularly those in low-resource settings. Additionally, individuals with limited digital literacy may struggle to use wearable devices effectively, limiting their ability to benefit from this technology (23).

To address this challenge, efforts must be made to ensure equitable access to wearable technology. This includes developing low-cost wearable devices, providing subsidies or financial assistance for individuals who cannot afford these devices, and offering training programs to improve digital literacy. Additionally, public health initiatives should focus on reducing disparities

in access to wearable technology, particularly in underserved communities, to ensure that the benefits of this technology are available to all individuals (24).

5. Strategies for Enhancing the Use of Wearable Technology in Public Health

To overcome the challenges associated with wearable technology and fully realize its potential in preventive public health, several strategies can be implemented. These strategies involve a combination of technological advancements, regulatory frameworks, and public health initiatives aimed at improving access to wearable technology and ensuring its effective use.

5.1 Technological Advancements

Investing in technological advancements is essential for improving the accuracy, reliability, and accessibility of wearable devices. This includes the development of more advanced sensors, the use of artificial intelligence (AI) for data analysis, and the integration of wearable devices with other health monitoring systems (25). Additionally, efforts should be made to develop low-cost wearable devices that are accessible to individuals in low-resource settings, as well as devices that are user-friendly and easy to operate.

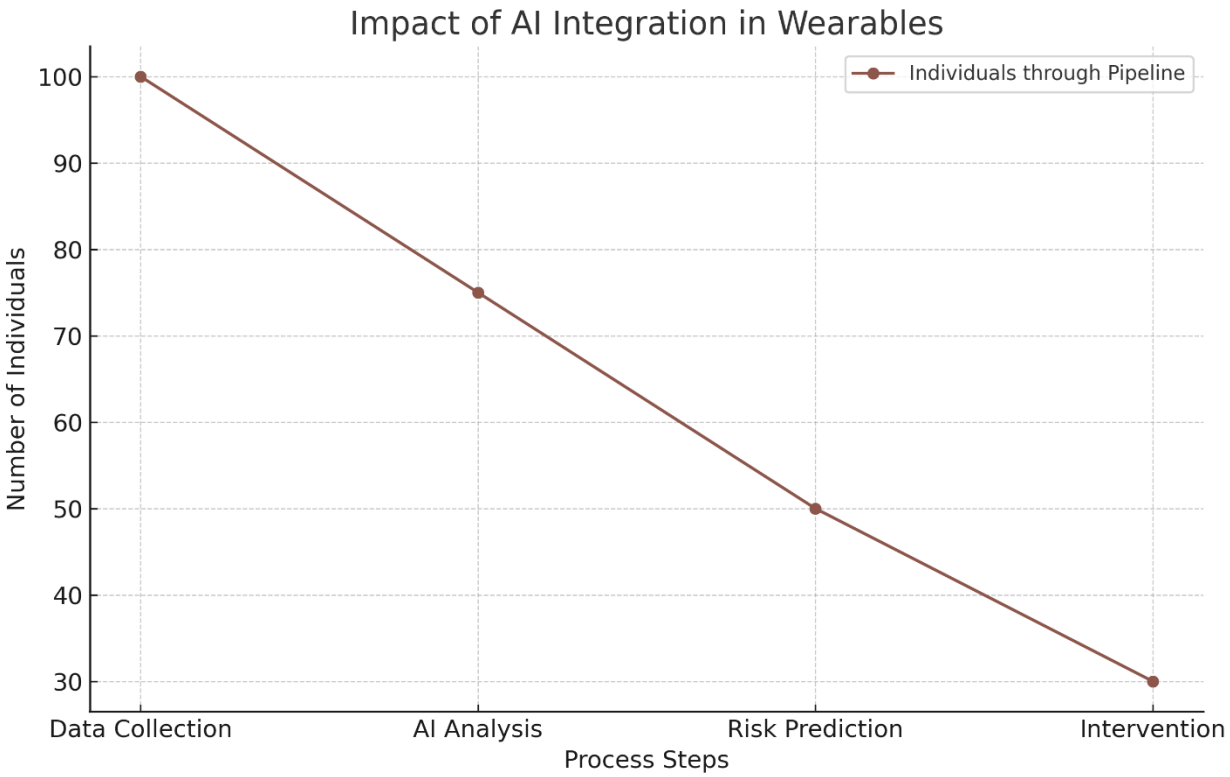

Figure 2: Impact of AI Integration in Wearables. This graph visualizes the process of wearable technology enhanced by AI, tracking the number of individuals involved at each stage: data collection, AI analysis, risk prediction, and intervention. The decline in numbers across stages reflects the refinement process, where AI filters and prioritizes individuals at higher health risks, ensuring targeted and efficient public health responses.

5.2 Regulatory Frameworks

Establishing robust regulatory frameworks is essential for ensuring the safe and ethical use of wearable technology in public health. These frameworks should provide clear guidelines for data privacy, security, and the use of wearable health data, ensuring that individuals have control over their data and that it is used responsibly (26). Additionally, regulatory frameworks should address the accuracy and reliability of wearable devices, ensuring that they meet certain standards before they are used in clinical settings.

5.3 Public Health Initiatives

Public health initiatives play a critical role in promoting the use of wearable technology and ensuring that its benefits are accessible to all individuals. These initiatives should focus on reducing disparities in access to wearable technology, particularly in underserved communities, by providing financial assistance, training programs, and outreach efforts. Additionally, public

health campaigns can raise awareness about the benefits of wearable technology and encourage individuals to use these devices as part of their preventive health strategies (27).

6. Beyond Individual Monitoring: Community and Ecosystem-Level Impacts of Wearable Technology

Wearable technology has come to play a very crucial role in personal health management and improvements and has also become essential in the monitoring of community health and the formation of health ecosystems. However, with the advancement of these devices, the data collection, processing, and transmission feature is revolutionizing the health systems making it possible to make health systems more effective by providing real-time and comprehensive data on the health of the population.

In the public health domain, wearable technology makes it possible to implement health interventions in real-time. For instance, in the course of the COVID-19 pandemic, smartwatches were used to identify and report symptoms like increased heart rate and low oxygen saturation. The data collected from these wearables when integrated helped the public health officials to identify the hotspots of the outbreak and manage the resource allocation and containment measures (28). These examples show that how wearables can be used as an effective tool to identify and contain infectious disease outbreaks, thus minimizing delay and saving lives. Apart from these, wearable technology also helps in the management of chronic diseases at the community level. These include devices that monitor blood pressure, glucose levels and physical activity that generate data that is stored in large databases which show the rate and ways of occurrence of chronic diseases including diabetes and hypertension. This can be used by the public health officials to come up with measures such as targeted fitness activities or dietary changes thus addressing the particular needs of the community in question.

Urban planning is another area where wearable data is driving change. Cities worldwide are leveraging wearable-derived insights to design healthier environments. there is a possibility of using wearable sensors that record physical activity and air quality to make policies that minimize pollution and increase people's physical activity in cities such as Amsterdam and Copenhagen. Through understanding of trends in mobility and exposure, policymakers can formulate policies that will enhance the well-being of citizens. Wearable technology has become an important part of the healthcare ecosystem and is enhancing access to care in many parts of the world, especially

in remote and underserved regions. In the areas with scarce structures of healthcare facilities, the wearable devices offer important information for the control and assessment of the patient's condition. For instance, in rural India, the community health workers wearing the sensors have been able to track the maternal health and identify complications like preeclampsia in women which would have otherwise been detected late and could not have been treated on time (29,30). Such examples show how the use of wearables can be effective in minimizing inequalities in access to health care services.

AI is a key component that helps in enhancing the effectiveness of wearable technology. The processed data from the wearables is analyzed using artificial intelligence to generate insights that can be acted upon and predictions on risks and recommendations on interventions. For instance, wearables that are equipped with AI algorithms have been used in the disaster-prone areas to track the stress level and other physiological changes in people who are at high risk, which has led to the implementation of mental health support programs that are relevant to the needs of the community. This is because AI is also capable of predicting; it also assists in managing chronic diseases by recognizing the warning signs and improving the efficiency of resource utilization.

Wearables are also enhancing public health surveillance. By aggregating anonymized data from millions of users, public health authorities gain valuable insights into epidemiological trends. During heatwaves, for instance, wearable devices can track temperature-induced physiological changes across populations, informing heat advisory systems and resource distribution strategies. Similarly, wearables have been used in wildfire-prone areas to monitor respiratory health, helping mitigate the impact of poor air quality on vulnerable groups. While the benefits are significant, challenges persist. Interoperability remains a critical barrier. With numerous manufacturers and platforms producing wearables, data standardization is essential to ensure seamless integration into healthcare systems. Collaborative efforts between technology providers and public health agencies are needed to develop unified frameworks that allow data sharing without compromising accuracy or privacy.

Another issue that is becoming a concern is the ecological footprint of wearable technology. The short product life cycles and the generation of electronic waste are the current drawbacks of these innovations. In order to address this, researchers are working on developing biodegradable sensors and modular concepts that can enhance the usefulness device. of For the instance, in the

wearables' domain, flexible and smart patches that use organic materials are being tested for health monitoring in disasters and other situations, which are claimed to dissolve after their intended use. In this way, the developments of the wearables are coherent with the green goals, thus contributing to the achievement of a proper equilibrium between advancement and eco-efficiency (31,32).

There is a huge potential for wearable technology to enhance the issue of providing health affordable equity. wearables The initiatives which regions with limited resources can help make advanced health monitoring accessible to everyone. programs that include the distribution of wearables together with the digital literacy training that has been implemented parts in of Africa and Asia have also been effective in empowering people to manage their health. expansion With of the such programs across the world, wearables can be a powerful tool towards reducing health inequalities and attaining the goal of health coverage for all.

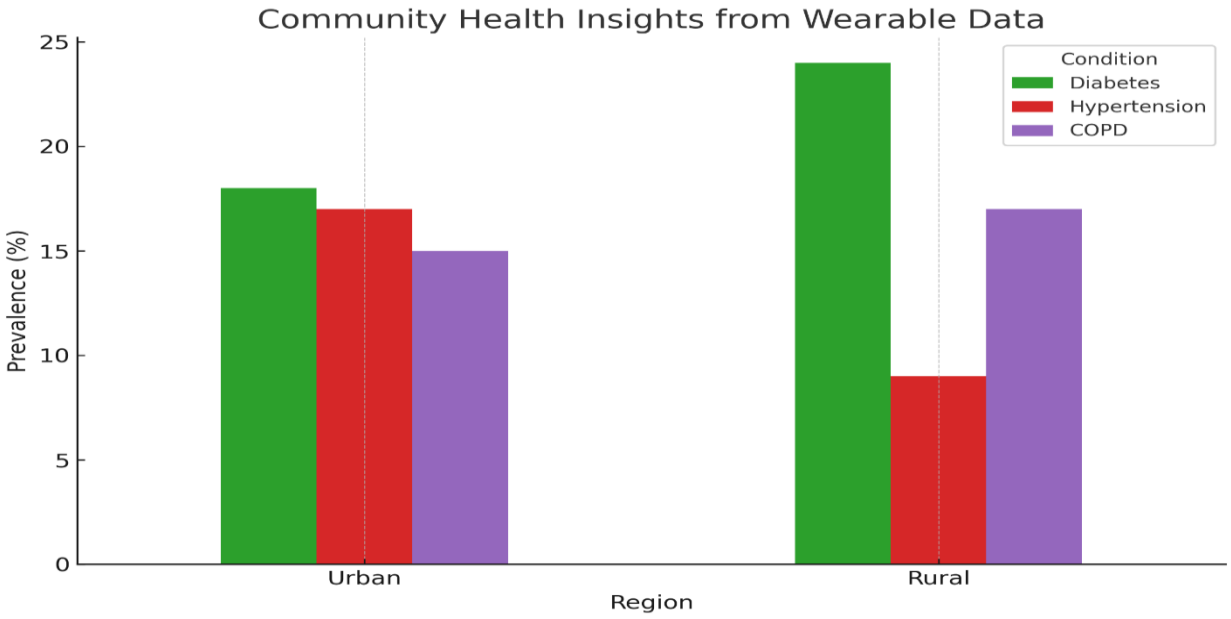

Figure 3: Bar graph showing Community Health Insights from Wearable Data. The bar graph compares the prevalence (%) of chronic conditions (diabetes, hypertension, and COPD) in urban and rural regions based on simulated wearable data. Urban areas show higher hypertension prevalence, while rural regions have elevated rates of diabetes and COPD. These insights underscore the importance of tailoring health interventions to specific community needs using data from wearable technology.

7. Discussion

Wearable technology is one of the most promising solutions in the field of preventive public health as it can help identify diseases in the initial stages, track health progress, and enhance health impacts. Through the collection of real-time data on various physiological parameters, wearable

devices can be used to identify conditions, including cardiovascular diseases, diabetes (33). This functionality enables early treatment, thus lowering the chances of complications and making public health measures more efficient.

However, issues thereof are data privacy barriers and security, the adoption inconsistency of wearable technology accuracy in and public reliability health of such devices, as well as the digital divide. This has to be dealt with so that wearable technology can be properly incorporated into public health measures and so that the opportunities that it presents are available to everyone (34).

It is, therefore, important to continue to invest in the development of technology as this will help to enhance the effectiveness of wearable devices through the enhancement of the sensors used, the application of artificial intelligence in data interpretation, and the linking of the wearable devices with other health monitoring devices. Also, there is a need to create affordable wearable devices that can be worn by people in areas with limited resources, as well as devices that are simple to wear and use.

It is also important to have proper regulations in place to ensure that wearable technology is used safely and appropriately in the public health sector. Such frameworks should outline the guidelines for data privacy, security, and the use of wearable health data and thus establish the rules governing the use of data (35). Also, the legal frameworks should state the conditions under which the wearable devices are to be used in the clinical setting and the quality guarantee of the devices.

Thus, public health programs are very important in supporting the use to mitigate the against wearable inequities technology in and the guaranteeing availability the of advantages wearable of technology its and applications seek for to every address patient. in these areas issues should that of endeavor require accessibility more attention through financial support, training, and promotion. Also, public health campaigns can help inform people about the advantages of wearable technology and thus create awareness of the need to embrace these devices in their personal preventive care plans.

8. Conclusion

Wearable devices are a modern solution for the enhancement of preventive public health since they allow for the timely identification of diseases and constant patient monitoring. There are,

however, certain drawbacks to the use of wearable technology including the issue of data privacy, data accuracy, and the issue of the digital divide. Thus, such challenges can be solved with the help of technological progress, specific well-defined measures, and legal in requirements, the and field of public health. As for the challenges, if properly solved, wearable technology has a great potential to become an important tool in public health as it will help to increase the efficiency of disease prevention and management.

Declarations

Ethical approval

Not applicable

Consent for publication

Not Applicable.

Availability of data and materials

Not Applicable

Competing interests

The authors declare that they have no competing interests.

Funding

This study did not receive any funds from the public or any donor agency.

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Acknowledgments

The author extends sincere gratitude to all the researchers who published their research and did hard work on their work. Without their contribution, this manuscript may not be possible.

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