Literature Review

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AN EXAMINATION OF THE IMPLEMENTATION OF INTERNET OF THINGS IN HEALTHCARE UTILISING SMARTWATCHES

Kajian Implementasi Internet of Things dalam Pelayanan Kesehatan Memanfaatkan Jam Tangan Pintar

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Abstract

Background: Smartwatches can use sensors to collect and send data to medical teams and family members through the platform of the Internet of things (IoT). The data are first analysed on the platform and the final results are used by the medical team.
Aims: This paper reviews and categorises studies conducted in the field of the Internet of things based on smartwatches.
Methods: The covered papers have been published over 13 years from 2010 to 2022. The search yielded 227 papers out of which 43 papers were reviewed after screening. The search keywords were "wearables, internet of things, smartwatches, smartbracelet, healthcare, and disease". The search covered databases including PubMed, ScienceDirect, and IEEE.
Results: Smartwatches are used in three fields of healthcare, including palliative care, speech therapy, diagnosis, disease prevention, rehabilitation, and health improvement.
Conclusion: Smartwatches are not free of drawbacks, and have not received the attention they deserve in the healthcare field. Given the potential of smartwatches, they can be useful in the health sector.

Keywords: Disease, IOT, Smartwatch, Wearable

Abstrak

Latar Belakang: *Jam tangan pintar dapat menggunakan sensor untuk mengumpulkan dan mengirim data ke tim medis dan anggota keluarga melalui platform* Internet of Things (IoT). *Data pertama kali dianalisis di platform dan hasil akhirnya digunakan oleh tim medis.*
Tujuan: *Makalah ini mengulas dan mengkategorikan penelitian yang dilakukan di bidang Internet of Things berbasis jam tangan pintar.*
Metode: *Makalah tercakup telah diterbitkan selama 13 tahun dari 2010 hingga 2022. Pencarian menghasilkan 227 makalah dimana 43 makalah direview setelah penyaringan. Kata kunci pencariannya adalah "wearables, internet of things, jam tangan pintar, gelang pintar, kesehatan, dan penyakit". Pencarian mencakup database* termasuk PubMed, ScienceDirect, dan IEEE.
Hasil: *Jam tangan pintar digunakan dalam tiga bidang perawatan kesehatan, termasuk perawatan paliatif, terapi wicara, diagnosis, pencegahan penyakit, rehabilitasi, dan peningkatan kesehatan.*
Kesimpulan: *Jam tangan pintar juga memiliki kekurangan dan belum mendapatkan perhatian yang layak di bidang kesehatan. Mengingat potensi jam tangan pintar, dapat bermanfaat di bidang kesehatan.*

***Kata kunci**: Penyakit, IOT, Jam Tangan Pintar, Dapat Dipakai*

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Introduction

The healthcare sector is experiencing profound transformations driven by rapid technological advancements, particularly through the Internet of Things (IoT). Smartwatches, as sophisticated IoT devices, have demonstrated substantial potential in revolutionizing healthcare delivery. These devices enable continuous monitoring of daily activities, provide comprehensive data analysis, and facilitate seamless communication between patients, caregivers, physicians, and family members, thus offering invaluable insights into patients' health and behavioural patterns.

The adoption of smartwatches in healthcare is propelled by their compact size, affordability, and user-friendly nature. These devices present a cost-effective, efficient, and accurate alternative to traditional data collection methods, which are often more expensive, time-consuming, and susceptible to human error (Dubey *et al*., 2015). By ensuring rapid and continuous data collection, smartwatches significantly enhance the quality and efficiency of healthcare services.

One of the most impactful applications of smartwatches is in elderly care. The global trend of an aging population presents significant challenges for health and supportive systems (Bobin *et al*., 2019). Smartwatches address these challenges by offering continuous health monitoring, thereby supporting the elderly in managing their health more effectively. Research indicates that these devices help elderly patients adhere to medication schedules and monitor vital health parameters, ultimately enhancing their overall well-being (Levine *et al*., 2019).

In the management of severe diseases such as cancer, smartwatches have shown remarkable benefits. They facilitate home-based pain management, encourage physical activity post-chemotherapy, and help mitigate related disabilities (Seidman *et al*., 2021). For nervous system disorders such as Parkinson's disease, smartwatches provide precise data on movement and tremors, aiding in early diagnosis and effective management (LeBaron *et al*., 2020).

Smartwatches are also crucial in monitoring dementia patients. These devices can track the location and physical activity of patients, significantly reducing risks associated with memory loss and disorientation (Lee *et al*., 2019; Kamdar and Wu, 2016). Additionally, photoplethysmography (PPG) sensors in smartwatches provide highly accurate assessments of blood circulation, essential during cardiac arrest situations. Studies have demonstrated the superiority of smartwatches over traditional methods in these critical conditions (Edelman *et al*., 2018).

Furthermore, smartwatches can detect atrial flutter, a condition linked to strokes, by monitoring heartbeat rates. This early detection capability is crucial for timely medical intervention and stroke prevention (Reeder and David, 2016). For pregnant women, monitoring heartbeat rates ensures the health and safety of both the mother and the fetus, a function effectively performed by smartwatches (Dreher *et al*., 2019).

Despite these significant advantages, the widespread adoption of smartwatches in healthcare faces several challenges. Technical issues, patient adherence, and privacy concerns are major barriers. Patients might forget to wear the device, face synchronisation problems, or experience discomfort due to the materials used, all of which can impede the effectiveness of smartwatches in healthcare applications.

The objective of this paper is to provide a comprehensive overview of the diverse applications of smartwatches in the healthcare sector. It aims to identify the most effective areas for their deployment and highlight sectors where their potential remains untapped. Additionally, this paper seeks to address the barriers to the widespread adoption of smartwatches in healthcare and propose solutions to overcome these challenges, thereby enhancing their integration into mainstream healthcare practices.

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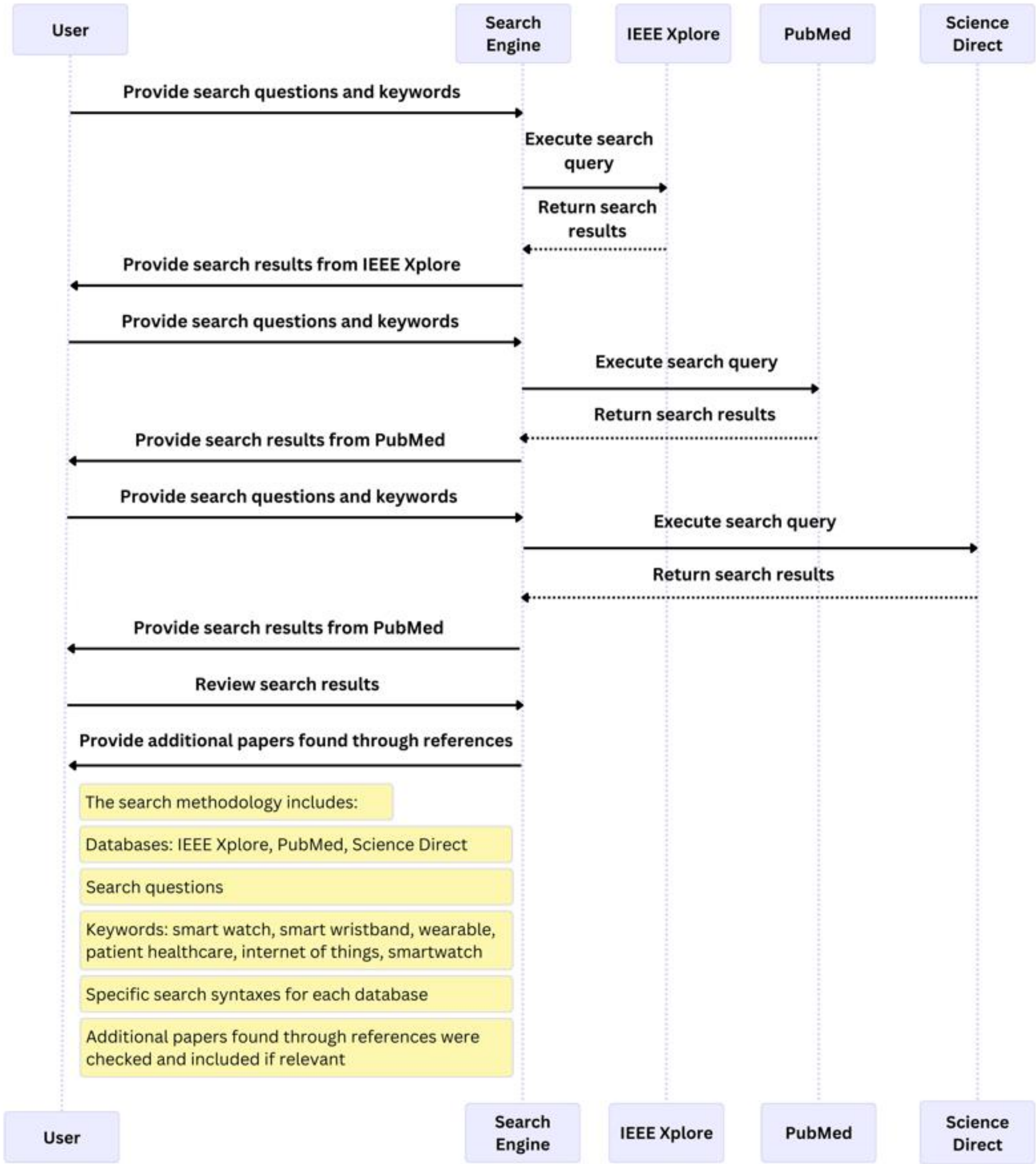

Figure1. Flowchart of the Literature Search Process and Methodology

Method

The databases included in this study were IEEE Xplore, PubMed, and Science Direct (Figure 1). The search was based on two questions: (1) What studies have been conducted on IoT and smartwatches and bracelets in the healthcare field? (2) How are smartwatches and bracelets utilised in the disease field? Using these two questions, a set of keywords (smartwatch, smartwristband, wearable, patient healthcare, internet of things, smartwatch) were used to search the databases. The reason for choosing the keyword “smart wristband” was that many use the term and smartwatch interchangeably.

The syntaxes used in the search were as follows:

PubMed

- “internet of things” [Title/Abstract] AND “smartwatch” [Title/Abstract] AND (2010:2022[pdat])
- “internet of things” [Title/Abstract] AND “wearable” [Title/Abstract] AND “smartwatch” [Title/Abstract] AND (2010:2022[pdat])

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- "internet of things" [Title/Abstract] AND "healthcare" [Title/Abstract] AND (2010:2022[pdat])
- "wearables" [Title/Abstract] AND "smartwatch" [Title/Abstract] AND (2010:2022[pdat])
- ("wristband" [Title/Abstract] AND "healthcare" [Title/Abstract]) AND (2010:2022[pdat])
- ("Patient" [Title/Abstract] AND "internet of things" [Title/Abstract] AND "smartwatch" [Title/Abstract]) AND (2010:2022[pdat])
- ("smartwatch" [Title/Abstract] AND "Patient" [Title/Abstract] AND (2010:2022[pdat])

Science Direct
- "Patient" AND "smartwatch"

IEEE Xplore
- ("Abstract": smartwatch) AND ("Abstract" : healthcare) AND ("Abstract" : internet of things)
- ("Abstract" : smartwatch) AND (Abstract" : healthcare)

Extra papers were found through references, checked, and added to selected papers if pertinent to the subject of study.

To systematically review the implementation of Internet of Things (IoT) in healthcare utilising smartwatches, we conducted a comprehensive literature search across three major databases: IEEE Xplore, PubMed, and ScienceDirect. The search spanned publications from 2010 to 2022 and focused on identifying relevant studies that addressed our two primary research questions. We employed a set of specific keywords to retrieve relevant articles. These keywords included "smartwatch," "smartwristband," "wearable," "patient," "healthcare," "Internet of Things," and "smartwatch." The search yielded an initial total of 227 papers.

To ensure the relevance and quality of the studies reviewed, we applied specific inclusion criteria. These criteria were: papers published in peer-reviewed journals, studies specifically focused on the application of IoT in healthcare using smartwatches, articles written in English, and papers providing empirical data on the use of smartwatches in various healthcare applications, including health improvement, disease prevention and diagnosis, rehabilitation, palliative care, and speech therapy. Conversely, to refine our selection and exclude less relevant studies, we established exclusion criteria. These included duplicates of previously included studies, papers focusing on IoT in healthcare without specific reference to smartwatches or smartwristbands, review articles or meta-analyses that did not present original empirical data, studies primarily addressing the technical aspects of IoT devices without direct application to healthcare, and papers lacking clear data or outcomes relevant to our research questions.

The initial screening involved reviewing the titles and abstracts of the 227 retrieved papers to assess their relevance based on the inclusion and exclusion criteria. This screening process resulted in the exclusion of 184 papers, primarily due to their lack of specific focus on smartwatches in healthcare, duplication, or insufficient empirical data. After applying the inclusion and exclusion criteria, 43 papers remained for detailed review. These papers were thoroughly analysed to extract relevant information on the various applications of smartwatches in healthcare. The analysis focused on how smartwatches are utilised in health improvement, disease prevention and diagnosis, rehabilitation, palliative care, and speech therapy.

Result and Discussion

The selected studies demonstrated that smartwatches have been used in multiple healthcare fields, including health improvement, disease prevention and diagnosis, rehabilitation, palliative care, and speech therapy. Despite their potential, the adoption of smartwatches in healthcare faces several challenges, such as patient adherence, technical issues, and privacy concerns. These challenges and potential solutions are discussed in detail in the following sections. By addressing these issues, the integration of smartwatches into mainstream healthcare practices can be significantly enhanced, ultimately

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improving patient outcomes and healthcare delivery efficiency.

The reviews showed that smartwatches have been used in various healthcare fields, including health improvement, disease prevention and diagnosis, rehabilitation, palliative care, and speech therapy. Table 1 provides a clear and concise overview of the findings from the 43 studies reviewed, highlighting the various applications of smartwatches in healthcare, the benefits observed, and the drawbacks identified in each study.

Obstacles in way of using smartwatches were as follows: In some cases, the patient does not adhere to the protocol in the long term and fails to use the watch optimally, resulting in unsatisfactory outcomes. Additionally, elements of the gadget, such as the magnets, can cause complications for the user. Smartwatches are used in various fields, including healthcare, with a variety of applications. However, some areas of healthcare have failed to fully utilise the benefits of the gadget. The following sections elaborate on the applications of smartwatches in different fields of healthcare.

Table1: Usage and Drawbacks of Smartwatches in Healthcare

Study	Application	Benefits	Drawbacks
Ahanathapillai *et al*. (2015)	Activity monitoring	Improved activity tracking for patients	User adherence issues
Alam *et al*. (2019)	Dementia-related agitation prediction	Early detection of agitation	Technical complexity
Arunkumar & Bhaskar (2020)	Heart rate estimation during exercise	Accurate heart rate monitoring	Potential interference with other devices
Asher *et al*. (2021)	Stroke patient monitoring	Enhanced monitoring of motor signs	Magnetic interference with implantable devices
Bobin *et al*. (2019)	Upper limb monitoring for stroke patients	Improved rehabilitation outcomes	Cost of devices
Chalmers *et al*. (2021)	Stress detection	Real-time stress monitoring	Battery life limitations
Chaudhry *et al*. (2020)	Sleep monitoring	Better sleep quality data	Data synchronization issues
Dimitrov (2016)	Eating behavior monitoring	Prevention of obesity-related diseases	User discomfort
Dreher *et al*. (2019)	Monitoring chemotherapy patients	Enhanced patient adherence to treatment	Privacy concerns
Dubey *et al*. (2015)	Voice and speech treatment for Parkinson's	Improved speech therapy	Device comfort issues
Edelman *et al*. (2018)	Blood glucose monitoring	Non-invasive monitoring	Calibration challenges
Golbus *et al*. (2021)	Home blood pressure monitoring	Improved disease management	Data security issues

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Study	Application	Benefits	Drawbacks
Grym *et al*. (2019)	Pregnancy monitoring	Continuous health tracking	Skin irritation from device materials
Haghi *et al*. (2017)	General health monitoring	Comprehensive health data	Technical expertise required
Junaid *et al*. (2022)	Remote healthcare management	Reduced healthcare costs	Connectivity issues
Kamdar & Wu (2016)	Mental health monitoring	Better mental health management	User compliance challenges
Khemtonglang *et al*. (2022)	Alcohol monitoring	Real-time alcohol level detection	User privacy concerns
Kobel *et al*. (2022)	Cardiac health monitoring for children	Improved cardiac care	Device sensitivity issues
Koshy *et al*. (2018)	Heart rate assessment in arrhythmias	Accurate arrhythmia detection	Magnetic interference
LeBaron *et al*. (2020)	Cancer pain management	Better pain management at home	Device discomfort
Lee *et al*. (2019)	Cardiac arrest monitoring	Accurate pulse checks	Data synchronization problems
Levine *et al*. (2019)	Immunosuppressive medication adherence	Improved adherence	User adherence challenges
Li *et al*. (2023)	Allergic rhinitis symptom control	Better symptom management	User discomfort
Muhsen *et al*. (2021)	Oncology monitoring	Enhanced cancer care	Data management issues
Olmedo-Aguirre *et al*. (2022)	Elderly remote healthcare	Improved elderly care	Connectivity issues
Paranjape *et al*. (2020)	Personalized healthcare	Enhanced health management	Data privacy concerns
Qian *et al*. (2020)	Cardiac arrhythmia prevention	Early detection of arrhythmias	Device sensitivity issues
Raja *et al*. (2019)	Parkinson's disease diagnosis	Early diagnosis of Parkinson's	Device accuracy concerns
Ray *et al*. (2019)	Dementia patient tracking	Improved patient safety	Technical complexity
Reeder & David (2016)	General wellness monitoring	Comprehensive health data	Battery life limitations
Seidman *et al*. (2021)	Pacemaker monitoring	Improved pacemaker management	Magnetic interference
Shawen *et al*. (2020)	Parkinson's symptom detection	Accurate symptom tracking	Data accuracy issues
Stradolini *et al*. (2018)	Anesthetic monitoring	Enhanced anesthetic management	Technical expertise required
Thompson *et al*. (2017)	Physical activity monitoring in cancer patients	Better physical activity data	User adherence issues

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Health improvement

A set of physiological and environment stimuli-based sensors can be useful for diseases such as asthma that can be intensified by specific factors. The data collected by smartwatches and monitoring patient's condition based on the data can improve the symptoms and avoid intensification of the symptoms, which results in health improvement in the patients (Muhsen *et al.*, 2021). Measuring environmental stimuli can also be helpful for health improvement in individuals with special diseases and sensitivity to temperature, dust, and light.

Signal processing techniques to detect chewing and swallowing using the internal microphone in smartwatches is a way to monitor eating behaviors. People prefer wearing a gadget that can monitor and analyse their eating behaviour (Dimitrov, 2016). Monitoring and measuring eating behaviour are useful for health improvement and also preventing a variety of diseases such as stroke, diabetes, and cardiac diseases that are rooted in obesity. Some diabetes diseases are developed because of bad eating habits and it is possible to use data collected by IoT platforms based on smartwatches to prevent such diseases. It is possible to detect eating patterns using smartwatches and this feature can be used to avoid diseases that need nutrition control.

In addition to heartbeat, the breath counting feature of smartwatches provides useful data even in sleep that can be helpful for health improvement. One of the outputs of these gadgets is determining the sleep phase using a special algorithm that gives useful data to the user (Chaudhry *et al.*, 2020). Taking into account that the quality of sleep affects one's cognitive performance, quality of life, and many diseases (e.g., stroke) are due to low quality sleep, smartwatches are inexpensive tools to examine quality of sleep. Electroencephalogram equipment used at hospitals to measure the quality of sleep is expensive and uneasy to use.

Smartwatches are useful gadgets to improve health and prevent intensification of diseases in older adults. The gadget has a good potential to provide care and support to this age group. One of the uses of the gadget is to remind the users of the exact time of taking medicines. In addition, older adults mostly live alone and because of a variety of disabilities in doing their daily jobs, they need to be monitored remotely. Smartwatches are an easy way to do this and improve health in older adults not only in terms of medication but also in terms of mental and spiritual health. This age group needs to feel that someone is taking care of them, which is good for their mental health. With a good spirit, older adults will benefit more from their medication.

Monitoring anesthetic drugs using smartwatches is another way that smartwatches facilitate monitoring and controlling patient's condition for physicians. In the case of parameters exceeding the safe limit, the physician can take corrective measures even remotely by giving the required orders and advice (Junaid *et al.*, 2022). In some cases, drugs must be tested in early testing stages and this might include recruiting individuals from remote areas to test the drugs. Smartwatches are helpful gadgets for the purpose of remote monitoring and decrease the expenses. In some cases, a patient life alone and there is no one to monitor taking medications by the patients. In such scenarios, smartwatches enable medical staff to monitor the patient remotely.

Smartwatches are useful tools to improve adherence to medications and disease control. An experiment on allergic rhinitis patients showed that the group with a smartwatch had a higher adherence to medication compared to the group without a smartwatch (Paranjape, Schinkel and Nanayakkara, 2020). To have efficient health management, individuals need to adhere to their medication plan and with a smartwatch, physicians can receive the data and have a more accurate analysis of the patient's status. Without a smartwatch, patients usually face problems in managing their disease. Smartwatches are very handy in the case of acute diseases like cancer or transplant operations in which the success of medications highly depends on timings. By giving alarms, smartwatches prevent intensification of the patient's

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condition, while physicians can remotely monitor improvement of the patient's condition.

Disease prevention and diagnosis

Studies have shown that smartwatches can be used as a tool to monitor and measure physiological parameters such as heartbeat, changes in heartbeat, oxygen saturation, and blood pressure. These parameters are important to have an accurate diagnosis of diseases. In cases of individuals suspected of chronic diseases, having access to these parameters improves the chance of early diagnosing health risks (Ray, Dash and De, 2019). Measuring these parameters is also useful in the case of pulmonary and cardiovascular diseases. PPG technology used in smartwatches can monitor heartbeat rate, detect atrial fibrillation, and prevent stroke caused by cardiac arrhythmia (Qian *et al.*, 2020). Atrial fibrillation usually has no specific symptoms and it mostly happens in older adults seeking medication for other complications. Having early information on atrial fibrillation can prevent acute diseases; and using daily based data, medical team members can follow-up the situation easily and take measures or even give advice remotely if necessary.

Estimates based on the peak vibration frequency reported by smartwatches can be used to diagnose Parkinson's disease. In the early stages, patients with Parkinson's disease demonstrate a specific shake that can be used for early diagnosis. With early diagnosis, physicians can take more specialised measures. A study on these patients used smartwatches and analogue accelerometers simultaneously and reported that the readings by the smartwatches were acceptable (Raja *et al.*, 2019). This feature can be used for mental and nervous diseases that cause spontaneous shakes. When diagnosed in the early stages of the disease, physicians can prevent intensification of the disease.

Using IoT based smartwatches can lead to a higher quality of life and personalised healthcare and diagnosis. One of the diseases that needs a higher level of healthcare is cancer. Smartwatches are a good way to monitor biometric parameters, which are needed in treating cancer (Chalmers *et al.*, 2021). There is a feature in Apple Watch known as iECG, which is FDA approved. This technology can be used by children with congenital cardiac disease (Chaudhry *et al.*, 2020). Having better monitoring of these children even helps the parents to have a happier life. Through remote monitoring, physicians can focus on cardiac activity of the patient and have better disease management.

The reported case of using ECG technology of smartwatches to diagnose cardiac disease highlighted the benefits of using these gadgets for diagnosing cardiac diseases. This technology prevents many strokes, myocardial infarctions, and other cardiac diseases every day and has saved many lives. In addition, it prevents heavy medical costs in case of late diagnosis (Shawen *et al.*, 2020).

Smartwatches can measure daily physical activities including footsteps count. This feature can be used by older adults who need to have a minimum level of physical activity every day and take the necessary measures if they fail to have a minimum level of physical activity (Alam *et al.*, 2019). In some cases, older adults live alone and using smartwatches by these individuals can save them from myocardial infarction. For instance, the smartwatch can alert the physician that the individual has not moved for four hours during the hours of the day that they are supposed to be physically active. In this scenario, the physician can call and check the client. If the same behaviour is seen for many consecutive days, the physician might interpret the situation as a depression condition.

In general, smartwatches can be used for preventing and diagnosing diseases through measuring physiological and biometric parameters.

Rehabilitation and speech therapy

Using traditional methods of recording patient's data on a board next to their bed is no longer an efficient way. With smartwatches, the patient's information is easily accessible to medical team members

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without human errors. Data collected from smartwatches can be saved and used for post-disease care or remote follow-ups. Patients with Parkinson's disease suffer from voice and speech disorders and need speech therapy practices at home. Using a smartwatch compatible with IoT, caregivers can monitor the patient's practices remotely and assess the progress using the old data and the new data collected by the gadget (Golbus *et al.*, 2021). Sensors and microphones in smartwatches not only help Parkinson's disease patients with speech problems but also are useful for children and individuals with speech problems who need to keep practice at home. With this feature, the parents do not need to be concerned if their child does the practices correctly as the gadget records the voices and sends them to the therapist. In addition, the data will remain available on the IoT platform for further analysis, which can be used for speech therapy purposes and tracking behavioral patterns of patients.

The sensors on smartwatches provide valuable data for stroke patients who need rehabilitation. Using the movement information, rehabilitators can examine the motor signs of the patient (Asher *et al.*, 2021). In addition, the movement information collected by the gadget can give a better perspective to modify practices or add/remove specific movements. Information about blood pressure collected by smartwatches can help rehabilitators to prevent further strokes due to high blood pressure by warning the patients, prescribing medicine, or immediately referring the patient to a specialist.

Palliative care

Blood sugar measurement using CGM devices is a painful process for those who have to measure their blood sugar every day. New approaches of isCGm and rtCGM based on smartwatches give us valuable information about glucose level and glucose change trend in the future (Thompson *et al.*, 2017). Such information can be useful for diabetic individuals and also individuals who want to check their blood sugar. Blood sugar control is very essential to avoid diabetic infection or, even worse, amputation. By communicating online with their diabetic patients via the IoT platform based on smartwatches, nutritionists can monitor their clients' diet remotely. For diabetic elderly, a way of remote examination with no need to visit a physician is a great advantage.

The systems used for managing and monitoring cancer patients are equipped with an accelerometer, a heartbeat display, and an application for real-time environment monitoring. The data collected by smartwatches became integrated using the IoT platform to examine cancer pain. The system is suitable for monitoring and alleviating cancer pain at home (Koshy *et al.*, 2018). Cancer patients' families have many concerns mostly regarding how to react to the patient's pain and how to manage it. With a system that enables remote monitoring, assessment, and treatment, these families and of course the patient surely feel less pressure. With less worries about the pain, the family members can concentrate more on the nutritional matters and help the patient to keep their spirits up.

Figure 2. Application of smartwatches in health sector (rehabilitation, speech therapy, health improvement, palliative care, diagnosis and prevention) (Author Image)

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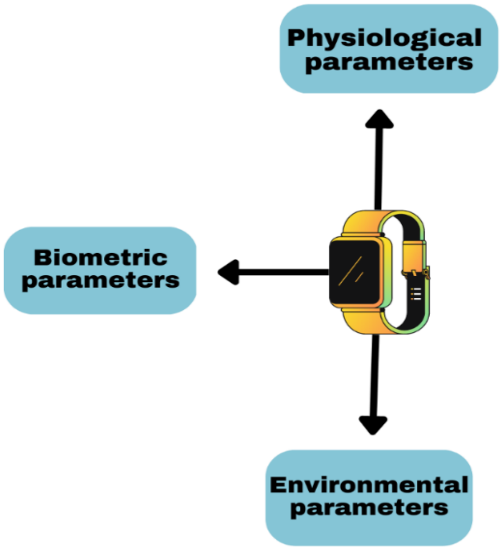

Figure 3. Measurable parameters by smartwatches (physiological parameters, biometric parameters, environmental parameters) (Author Image)

Drawbacks and problems of smartwatches

As noted, one of the problems of using smartwatches is that patients are not committed to using smartwatches as expected. Feeling committed to using the gadget is essential to achieve the expected results so that in some cases lack of this commitment deprives the patients from the expected benefits (Arunkumar and Bhaskar, 2020). Factors like privacy, forgetting, and synchronising can degrade commitment in patients to use smartwatches. In some cases, the patient forgets to wear the watch after leaving it to be charged; this disrupts synchronisation of the data.

Elements of smartwatches like magnets cause magnetic intervention with the devices already implanted in the user's body, which can be harmful (Stradolini *et al.*, 2018; Khemtonglang *et al.*, 2022). In addition, some parts of the gadget may cause skin problems because of the materials used in them (Grym *et al.*, 2019). Using biodegradable materials that are compatible with human skin not only adds to the benefits of using these gadgets but also increases the appeal for the users.

This study provides a comprehensive review of the existing literature on the implementation of IoT in healthcare through the use of smartwatches, highlighting the breadth of applications and benefits these devices offer. One of the major strengths of the study is its systematic approach to literature review, covering a wide range of databases and selecting studies based on stringent inclusion and exclusion criteria, ensuring the relevance and quality of the reviewed papers. Additionally, the study spans over a significant period (2010-2022), offering a thorough overview of the technological advancements and their implications in the healthcare sector. However, the study also has limitations, including potential publication bias as only peer-reviewed articles were considered, which might exclude relevant findings from other sources. Furthermore, the rapidly evolving nature of IoT and wearable technology means that some of the findings may quickly become outdated, necessitating continuous updates to capture the latest developments and trends in the field.

Conclusion

Using smartwatches is a noninvasive tool for healthcare purposes (Li *et al.*, 2023), which can be used in diverse fields of healthcare. However, their application in the fields that need caution, like car accidents caused by alcohol, is not as common. These issues can better be handled using smartwatches and the valuable data collected by these gadgets (Kobel *et al.*, 2022). Another application of smartwatches is to assess individuals in terms of ethnicity, race, age, and gender, which can be useful for physicians and other healthcare practitioners (Glöckner *et al.*, 2022).

Therefore, treatment is one of the applications of smartwatches that has not received the attention it merits in the healthcare sector. Given the high potential of the gadget, its application for treatment can become a reality in the future.

Abbreviations

IOT: Internet of Things, FDA: Food and Drug Administration, ECG:

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electrocardiogram, PPG: photo-plethysmo-graphy, CGM: continuous glucose monitor.

Declarations

Ethics Approval and Consent Participant

Not applicable.

Conflict of Interest

The authors declare that there is no conflict of interestin this study.

Availability of Data and Materials

Data and materials can be provided upon request.

Authors' Contribution

The first draft of the manuscript was written by FSB and MA. SS, FG, and MS reviewed it. All authors approved the manuscript.

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