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REVIEW

Smart Wearable Technology
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# Wearable Technology in Healthcare: Opportunities, Challenges, and Future Directions

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**Abstract:** Wearable technology is rapidly transforming health care by providing unprecedented opportunities for continuous, real-time health monitoring, proactive disease management, and early detection of health issues. This review delves into the diverse landscape of wearable devices, including smartwatches, fitness trackers, medical-grade biosensors, and intelligent textiles, with a particular focus on their role in managing chronic conditions, enhancing remote patient monitoring, and improving preventative care strategies. Unlike existing literature, this paper emphasizes the integration of artificial intelligence (AI) and machine learning (ML) with wearable technologies, offering groundbreaking predictive capabilities for early diagnosis, personalized treatments, and dynamic health interventions. Additionally, the paper addresses critical challenges that hinder widespread adoption, such as data privacy concerns, sensor accuracy, and the integration of wearable data within established healthcare systems. By synthesizing the current state and future trends in the field, this review offers novel insights into the technological, regulatory, and ethical considerations that must be overcome for the successful incorporation of wearables into mainstream health care. The paper concludes by proposing future avenues for innovation, particularly in sensor advancement, energy efficiency, and system interoperability, which will not only improve healthcare delivery but also make it more accessible to underserved populations worldwide.

**Keywords:** wearable technology, health care, remote monitoring, data security, chronic conditions, artificial intelligence

## 1. Introduction

In the context of health care, wearable technology refers to several devices intended for attachment to the body to continually monitor and gather data connected with health. Among the numerous shapes these devices show are smartwatches, fitness trackers, health monitoring patches, and smart textiles [1]. The major objective of wearable technology is to provide continuous monitoring of health parameters such as heart rate, activity levels, blood pressure, glucose levels, and sleep patterns thereby providing a mechanism for real-time, tailored health care [2]. Wearable devices promote access and personalization in health care by including sensors, smartphone apps, and cloud platforms —which improve individualized health management outside of conventional clinical settings. Not only are regular fitness trackers among wearable healthcare gadgets but also medical-grade devices tracking certain health issues and crucial signal monitoring [3]. By means of early warnings on changes in health parameters, these devices assist individuals and medical professionals in identifying and managing chronic diseases, reducing risks related to acute disorders, and may stop the spread of disease [4]. Mostly in health care, wearable technology relates to the shift from reactive to proactive therapy. Moreover, wearables offer continual access to personal health data, promoting patient autonomy and inspiring active engagement in health management [5]. Wearable technology is rather crucial in contemporary healthcare systems. Wearables not only enable better personal health care but also significantly aid to transform the healthcare paradigm from conventional in-person consultations to a more distributed, data-centric, real-time approach [6]. This continuous observation serves to enable fast reactions that can help to prevent the aggravation of medical disorders and increases the responsiveness of health care to patient demands. Wearables also enable people to take more active part in monitoring their health, therefore alleviating stress on healthcare systems, and help to lower need for regular hospital visits [7]. Regular monitoring serves to enhance illness management and save long-term healthcare expenditures; hence, those with chronic diseases such as diabetes, heart disease, or hypertension would especially benefit from this [8].

Wearable healthcare technology has evolved fairly remarkably since its introduction. Wearable devices first surfaced largely in sports science for data collecting and fitness monitoring. Originally developed in the 1960s, bulky, wire devices mostly employed by sportsmen to evaluate cardiovascular performance were the first heart rate monitors [9]. Originally developed in the 1970s and 1980s, portable electrocardiograms (ECGs) became absolutely essential for medical diagnosis, especially in cardiology [10]. Originally intended for medical staff, these earliest wearable

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devices were limited to clinical or sports environments. The turning point came in the 1990s when personal computers first appeared and electronic components started to shrink, therefore allowing the development of more reasonably priced compact wearable gadgets [11, 12]. Clever healthcare-specific wearables such as portable glucose monitors and blood pressure cuffs have emerged from the growing necessity for ongoing patient monitoring—especially for individuals with chronic diseases. Early in the 2000s, wearable devices started to add wireless capabilities, enabling doctors and patients to remotely monitor health data and hence establish the basis for contemporary wearable technology [13, 14]. Wearable technology underwent significant transformation early in the 2010s, most famously illustrated by the consumer market introduction of products like the Fitbit and the Apple Watch. These smartwatches and fitness trackers outperformed conventional fitness monitors in their advanced sensors detecting heart rate, step count, and sleep habits [15, 16]. They also discussed the idea of personal health records under strict inspection and maybe instantaneous sharing with medical specialists. These advances democratized health monitoring and hence defined it as a shared idea since wearable health technologies became more broadly accessible [17]. Wearables helped to allow them by means of real-time data collecting and transmission made feasible by the combination of smartphones and cloud-based apps, therefore enabling continuous monitoring and offering excellent insights into individual health trends [18].

Right now, wearable technology has evolved much beyond basic tracking of fitness. Devices nowadays track various health variables, including ECGs, blood oxygen saturation ($SpO_2$), and stress levels. Some sophisticated wearables monitor arrhythmias, check glucose levels in diabetics, and track sleep apnea [19, 20]. Wearables also increasingly study the data they gather using artificial intelligence (AI) and machine learning (ML) technology, therefore providing predictive insights and possible alerts on health risks before they become a serious worry [21]. Wearable healthcare technology is looking bright with predicted increases in sensor technology, battery life, and wireless connectivity likely to boost the usefulness and usability of wearables. Wearables today serve not just for personal health monitoring but also for integration with clinical therapy in hospitals [22, 23]. Medical experts are including wearable technologies more and more into patient care plans. Wearable glucose monitors enable diabetics control their condition by means of real-time blood sugar readings. Wearables measuring ECG data and heart rate can inform medical staff members should a patient develop indications of arrhythmia or other cardiovascular disorders, therefore permitting quick intervention [24, 25]. From a reactive strategy to a more proactive, personalized, data-driven method, wearable technology has the ability to transform healthcare delivery [26, 27]. Wearable relevance in contemporary healthcare systems is several. Initially, they save the need for clinic visits by providing a straightforward and non-invasive method of monitoring patients' health over long periods. Wearables provide real-time data for patients with chronic diseases that allow doctors to monitor vital signs continuously, enabling prompt treatments and problem prevention [28]. Wearables tracking progress and reminding patients to take their drugs aid to increase medication adherence. By lowering the demand for frequent hospital visits, wearables also help patients save time and money, therefore lessening the load on healthcare systems. The capacity of wearables to help preventative therapy is one of their primary benefits [29, 30].

Wearable data enable both individuals and clinicians to track health trends and spot prospective problems before symptoms emerge. Wearable sensors recording physical activity can motivate individuals to welcome better lives, therefore reducing their risk of ailments including obesity, diabetes, and heart disease [31, 32]. Wearable gadgets measuring sleep patterns can similarly enable early intervention and enhance overall health outcome as well as aid diagnose sleep problems. Emphasizing the potential and difficulties wearable technology brings as well as its future paths, this study tries to investigate its developing position in health care [33, 34]. Wearables enable people to take control of their health and provide continuous monitoring, therefore changing health care [35, 36]. Still, with regard to data privacy and security, device accuracy, and integration with current healthcare systems, there are numerous difficulties ahead, just as with any emerging technology. These challenges will be covered in this study coupled with how wearable technology might enhance patient care, simplify clinical procedures, and enable improved future health outcomes [37, 38]. Wearable technology presents a proactive, patient-centered, data-driven, paradigm of therapy that is transforming health care. Thanks to ongoing technological progress, wearables enable to revolutionize the delivery of health care and help to enhance patient outcomes everywhere [39, 40].

Recent wearable technology innovations have improved user experience through haptic feedback systems. The Funabot-Sleeve, a wearable device with McKibben's artificial muscles, may produce a variety of haptic experiences. The Funabot-Sleeve simulates "Embraced", "Pinched", and "Twisted" feelings by changing air pressure patterns, providing more personalized and complex input. This research is crucial to enhancing tactile connection between users and wearable technologies for rehabilitation and prostheses [41, 42]. The Funabot-Suit, a bio-inspired suit powered by McKibben muscles, pushes the limits of soft robotics in wearable technology to improve mobility and user engagement. These advances demonstrate McKibben's artificial muscles' potential to provide more adaptive, responsive, and pleasant wearable devices, solving healthcare and user experience design concerns [42]. This paper attempts to clarify the existing state of wearable healthcare technologies, their advantages, their difficulties, and the interesting prospects for their adoption into contemporary healthcare systems.

## 2. Methodology

In this study, wearable technologies in health care are examined for their applications, potential, problems, and effects on chronic illness management, remote monitoring, and preventative care. The papers in this review were chosen for their relevance to wearable healthcare technology and healthcare outcomes. The research in this publication used RCTs, cohort studies, cross-sectional studies, and observational studies. Specific wearable technologies were evaluated in clinical settings using RCTs, notably those examining health outcomes including illness management and recovery rates. Cohort and cross-sectional studies were chosen to understand wearable technology applications and real-world effects. Long-term usability, patient adherence, and real-world efficacy of wearable devices were also assessed in observational studies. These papers were rigorously assessed for strengths, weaknesses, and conclusion robustness.

Sample sizes varied greatly in the examined research. Major studies with sample sizes exceeding 500 individuals were prioritized for their generalizability. Smaller sample sizes were common in investigations of chronic illnesses or specialized wearable technologies. These tiny researches were relevant to the area, but their findings were interpreted cautiously due to smaller sample numbers, which may compromise external validity. This review used peer-reviewed journal papers, clinical trials, and other high-quality healthcare wearable technology studies. These papers were chosen for their methodological rigor, healthcare relevance, and data robustness. Our data analysis focusses on wearable technologies including fitness trackers, smartwatches, biosensors, and smart textiles, which have healthcare applications from chronic illness management to preventative care.

The study acknowledged many data source constraints. The accuracy of wearable device sensor data is a major problem. These devices give real-time health data, but device fit, skin temperature, and mobility can affect measurement accuracy. Movement can affect heart rate data, and glucose tracking devices' accuracy depends on calibration and sensor technology. These restrictions were addressed when analyzing wearable device findings. Included research study designs are another disadvantage. Some observational research used self-reported data, which adds memory and selection biases. Some wearable devices, notably lifestyle and fitness ones, did not have randomized controlled trials, the gold standard for therapeutic proof. Thus, observational and cross-sectional research was evaluated bearing their limitations in mind.

Study sample sizes varied, which was a problem. Small sample size studies, especially those addressing specific chronic illnesses or wearable gadgets, may not generalize to wider populations. Clinical studies with fewer participants may lack statistical power to identify meaningful results. The limitations of these investigations were highlighted, and the results were given cautiously.

This evaluation also addressed wearable data privacy and security. Wearable gadgets capture sensitive health data, making data breaches and unauthorized access a major concern. Most research verified data gathering conformed with privacy requirements; however, this remains a concern in healthcare wearable device uptake. This evaluation included only peer-reviewed research from 2010 to 2024 to guarantee thoroughness. Studies that lacked methodological transparency, peer review, or healthcare outcomes data from wearable devices were eliminated. This method focused the review on high-quality, relevant research with important field contributions. Qualitatively synthesizing wearable device data revealed trends, possibilities, and problems in chronic illness management, preventative health care, and remote monitoring. Wearable devices were also evaluated for their ability to reduce hospital visits and improve treatment adherence using quantitative data.

## 3. Types of Wearable Devices in Health care

The healthcare sector boasts a number of wearable technologies, each with unique applications, advantages, and disadvantages. Although wearable patches and biosensors provide continuous vital sign and chronic illness monitoring, fitness trackers and smartwatches are the most widely utilized devices for general health surveillance [43]. Intelligent textiles and clothes enhance health monitoring by integrating sensors inside the fabric, therefore enabling discreet, continuous surveillance across the day. Implanted and ingestible devices finally provide the most complete method of health monitoring for patients with chronic diseases or major health concerns, therefore allowing constant surveillance and action [44, 45]. The fate of wearable healthcare devices will depend on ongoing technological progress with improvements in sensor precision, downsizing, and wireless communication raising their efficacy and user-friendliness. As they are more and more part of the healthcare system, these gadgets have the capacity to improve disease control, raise patient outcomes, and cut healthcare expenditures [46, 47]. Growing relevance of wearable technologies in health care is altering the monitoring and management of health. These devices enable real-time, continual monitoring of various health markers since they are meant for wear or connection to the body. Simple fitness trackers to sophisticated biosensors and implanted technology are among the wearables healthcare products under development [48, 49].

### 3.1. Fitness trackers and smartwatches

Fitness trackers and smartwatches are clearly the most widely utilized type of wearable health equipment. These devices track markers of general health and fitness like steps taken, heart rate, calorie burnt, and quality of sleep [50, 51]. Usually worn on the wrist, fitness trackers—like those made by Fitbit and Garmin—are chosen by persons wanting to either maintain or raise their degree of physical activity, most notably the Apple Watch and Samsung Galaxy Watch, smartwatches abound in health monitoring, fitness tracking, communication, and advanced capabilities including ECG readings and $SpO_2$ monitoring [52, 53]. Smartwatches and fitness monitors find great application in many different settings. These tools give everyone a practical approach to monitor daily physical activity, check heart rate, and design personalized workout plans [54, 55]. Clinically, they track the progress of persons with chronic diseases such as diabetes, hypertension, or cardiovascular disease, so giving real-time information to clinicians to enhance their decisions [56]. Moreover, smartwatches can notify the user to seek medical attention and identify early stages of cardiovascular disorders including atrial fibrillation (AFib). These gadgets can offer a more whole picture of a patient's health and enable remote patient monitoring (RPM) by means of connectivity with cloud-based systems and cell phones [57].

### 3.2. Biosensors and wearable patches

Biosensors are basic parts of wearable healthcare equipment since they provide constant vital sign monitoring and real-time health data. Many physiological parameters including blood glucose levels, heart rate, respiration rate, and hydration level are being tracked using wearable patches paired with biosensors [58]. Since they permit discreet placement on the skin, these little, lightweight adhesive patches fit for long-term health monitoring. The glucose monitoring patches diabetic individuals use to non-invasively check blood sugar levels, therefore saving the need for finger-pricking one great example of this technology [59]. Biosensor patches provide more accurate data over a long time and considerable benefits for continuous monitoring unlike conventional, intermittent medical testing [60]. For diabetics, a biosensor patch that continuously checks glucose levels can allow them to keep their condition and lower risky blood sugar variations [61]. These patches could also be used to monitor $SpO_2$ and pulse rate for people with cardiovascular disorders, therefore identifying any anomalies that would demand prompt response [62]. Their continuous data enable doctors to evaluate the success of treatments and modify drugs as needed. The evolution of these devices—including the incorporation of sophisticated sensors and wireless communication networks—is expected to increase the accuracy and efficiency of biosensors in health care [63].

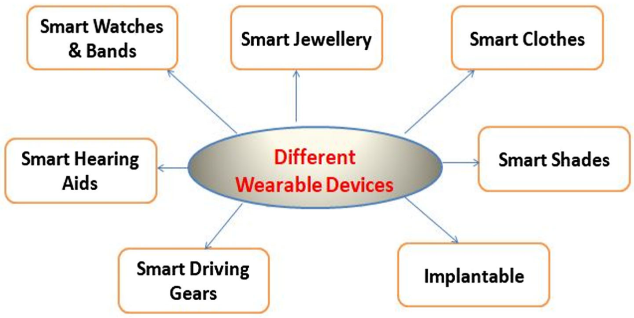
### 3.3. Smart clothing and textiles

Smart materials and clothes help to define one advanced domain in wearable healthcare technologies. These garments have sensors incorporated into them to track several health aspects, including posture, muscular activity, heart rate, and breathing rate [64]. Smart garments consist of shirts, pants, and socks with embedded sensors able to track physical activity, muscle strain, and early indicators of pressure ulcers or deep vein thrombosis in immobilized people [65]. By permitting all-day wear without clear pain, smart textiles largely aid with continuous health monitoring without depending on outside devices. For example, smart shirts connected with ECG sensors can track heart activity; socks with pressure sensors can identify anomalous foot pressure, which is especially beneficial for diabetic patients prone to foot ulcers [66, 67]. Moreover, clothing that monitor body temperature and sweat composition can offer crucial information on a person's hydration status and thermal regulation, therefore offering essential data in cases including heatstroke or dehydration [68]. By being inserted into conventional clothing, smart textiles are seen as a novel strategy for health monitoring that substitute for heavy-duty tools. These smart fabrics could be indispensable in tailored health care in the future since they adapt to the needs of the wearer by offering real-time data that could enable better lifestyle decisions, disease prevention, and overall well-being enhancement [69, 70].

## 3.4. Implantable and ingestible devices

Among the most sophisticated forms of wearable technology available in health care are implanted and ingestible devices, which provide enhanced monitoring and treatment capabilities. Surgically implantable devices including pacemakers, neurostimulators, and biosensors tracking health parameters or providing treatment [71, 72]. These devices benefit from always monitoring internal variables, such as cardiac rhythm or cerebral activity, absent outside sensors [73]. While implantable pacemakers regulate heartbeats in patients with arrhythmias, neurostimulators alleviate chronic pain or address neurological illnesses such as Parkinson's disease. Some implantable biosensors especially useful for those with chronic conditions like diabetes or COPD may identify specific biomarkers in the body, like glucose or oxygen levels [74, 75]. Healthcare experts can monitor real time and act by means of remote transmission of the data from various implantable devices. Thought of as either focused treatments or monitoring gastrointestinal tract disorders, ingestible devices—tiny, capsule-shaped tools—can be Devices like the PillCam enable one to observe the gastrointestinal tract and assist in the diagnosis of anomalies including inflammation or cancers [75]. By providing a non-invasive substitute for conventional endoscopy, they increase patient comfort and hence help to lower hospital visit demand. Technologies, both ingestible and implanted, show great advancement in the management and monitoring of chronic conditions [31]. Although they are more invasive than wearable devices, their advantages in offering accurate, continuous data and tailored treatment are crucial, especially for those with major health issues needing continuous monitoring [15, 19]. Figure 1 [76–78] illustrates the various categories of wearable smart devices, which are designed to be worn on the body for purposes ranging from health tracking to enhancing everyday activities. The diagram centralizes "Different Wearable Devices" and branches out into several categories. These include Smart Watches & Bands, which offer features such as fitness tracking, notifications, and communication. Smart Jewellery merges style and functionality, often integrating features like health monitoring and connectivity. Smart Clothes refer to clothing embedded with technology for functions such as temperature regulation or health tracking. Smart Shades represent eyewear equipped with technology like augmented reality or sensors for enhanced interaction. Smart hearing aids improve hearing, incorporating functions like noise cancelation and

**Figure 1**
**Wearable smart devices**




health monitoring. Smart Driving Gears are wearable devices tailored for the driving experience, offering features such as safety enhancements and performance tracking. Lastly, implantable devices refer to technology that is inserted into the body for continuous health monitoring or other specialized functions. This diagram demonstrates the growing diversity and integration of wearable technology into everyday life.

Table 1 [79, 80] outlines various types of wearable and implantable devices, each with distinct features, advantages, and challenges. Fitness Trackers and Smartwatches, such as Fitbit and Apple Watch, track general health markers like steps, heart rate, and sleep quality. These devices are widely available, non-invasive, and easy to use, making them particularly useful for fitness and chronic disease management. However, they are limited in that they primarily provide surface-level health tracking and may not offer medical-grade data. Biosensors and Wearable Patches, such as glucose monitoring patches, provide continuous monitoring of vital signs like glucose levels, heart rate, and oxygen. These devices allow for real-time, non-invasive health monitoring, offering valuable data for ongoing health management. The challenges include the need for precise calibration, the discomfort from long-term wear, and the potential for skin irritation or other issues. Smart Clothing and Textiles incorporate embedded sensors to monitor health metrics like heart rate, muscle activity, posture, and stress. Examples include smart shirts and socks. These devices allow for continuous, discreet monitoring and are comfortable for long-term wear. However, they are still in the early stages of development, with limited use cases, design challenges, and potential comfort concerns that need to be addressed for broader adoption. Finally, implantable and ingestible devices, such as pacemakers or the PillCam, offer in-depth monitoring of internal health parameters, making them suitable for patients with chronic conditions that require constant monitoring. While they provide more detailed health data, these devices are invasive, requiring medical intervention for installation, and come with high costs, making them less accessible for some individuals. Overall, Table 1 provides a comprehensive overview of these devices, highlighting their unique advantages in health monitoring alongside the challenges they face in terms of usability, comfort, and cost.

## 4. Opportunities in Health care

Wearable technologies have generated various potential uses in health care especially in the management of chronic diseases, RPM, mental health, preventative care, and clinical research [3]. These gadgets give real-time data to healthcare providers who could

**Table 1**
**Types of wearable devices in health care**

| S. No. | Device type | Description | Advantages | Challenges |
|---|---|---|---|---|
| 1 | Fitness Trackers and Smartwatches | Track general health markers like steps, heart rate, and sleep quality. Examples: Fitbit and Apple Watch. | Widely available, non-invasive, and easy to use. Useful for fitness and chronic disease management. | Limited to surface-level health tracking. May not provide medical-grade data. |
| 2 | Biosensors and Wearable Patches | Continuous monitoring of vital signs like glucose levels, heart rate, and oxygen. Example: glucose monitoring patches. | Offers continuous, real-time data collection. Provides non-invasive health monitoring. | Requires accurate calibration and long-term wear. Potential for discomfort. |
| 3 | Smart Clothing and Textiles | Clothing with embedded sensors to track health metrics like heart rate, muscle activity, posture, and stress. Example: smart shirts, socks. | Allows continuous, discreet monitoring. Comfortable and wearable for long periods. | Still in early stages, with limited use cases. Design issues and comfort concerns. |
| 4 | Implantable and Ingestible Devices | Devices implanted or ingested to monitor internal health parameters. Example: pacemakers, PillCam. | Provides in-depth monitoring of internal health parameters. Suitable for patients with chronic diseases requiring constant monitoring. | Invasive, requires medical intervention for installation, high cost. |

enhance treatment and outcomes and let users actively participate in their health management [17]. As technology advances in transforming health care, wearables will become more and more crucial since they provide early diagnosis, tailored treatments, and better quality of life for people all over [2, 20]. Over the past 10 years, wearable technologies have greatly enhanced their value in the healthcare sector providing excellent prospects in domains such as chronic illness management, RPM, mental health, preventive health care, and clinical research [53].

## 4.1. Chronic disease management

Management of chronic diseases is one of the most crucial uses for wearable devices. By means of continuous monitoring of key health indicators, these devices provide real-time data that can considerably improve the management of diseases such as diabetes, cardiovascular diseases, and respiratory issues [19, 31].

*4.1.1. Diabetes (continuous glucose monitoring (CGM))*

Wearable glucose monitors such as the Abbott Freestyle Libre and the Dexcom G6 represent a significant advance in diabetes control. These devices track glucose levels continuously by means of sensors buried under the skin. They give patients and clinicians real-time data, therefore preventing harmful blood glucose variations [81]. These devices considerably lower the dangers related to hyperglycemia and hypoglycemia since they provide rapid modifications to medicine or lifestyle [77]. By using CGM, one can improve overall glucose management and thereby help to avoid long-term consequences of diabetes like renal failure, visual impairment, and cardiac problems. By means of rapid response, the real-time alarms generated by these devices could possibly avoid hospitalizations [82].

*4.1.2. Cardiovascular diseases (ECG, blood pressure monitoring)*

Wearable devices have greatly affected the control of cardiovascular disease. Nowadays, wearables like the Apple Watch include inbuilt ECG features that let users evaluate their heart rhythm and spot signs of AFib, a usually undetectable condition that could cause stroke and other effects [83, 84]. Continuous blood pressure monitoring is made possible by wearable blood pressure monitors—like those produced by Omron [85]. Real-time blood pressure monitoring using these devices provides early warnings for hypertension, a major risk factor for kidney damage, stroke, and cardiovascular disease. Constant monitoring helps doctors to spot and treat cardiovascular diseases quickly, hence improving patient prognoses [86].

*4.1.3. Respiratory conditions (oxygen saturation, spirometry)*

Among wearable devices meant for respiratory diseases, portable spirometers and oxygen saturation monitors are among the ones that offer continuous measurement of pulmonary performance. Oxygen saturation monitors—which some people with chronic respiratory diseases like asthma or COPD occasionally use—feature pulse oximeters [87]. Measuring the oxygen saturation in blood, these instruments give doctors and individuals important data. Furthermore, wearable spirometers can assess pulmonary performance using various respiratory parameters and airflow, therefore enabling early detection of lung damage in patients with diseases such as asthma or COPD [88].

## 4.2. RPM and telemedicine

Wearable technology has revolutionized RPM, therefore enabling patients—especially those in rural locations or with mobility issues—more comfortable and accessible treatment. RPM has various benefits for both patients and healthcare providers for ongoing patient surveillance outside of clinical environments [89, 90].

*4.2.1. Real-time data collection for remote consultations*

Wearable devices let medical staff members remotely monitor patients by means of constant, real-time data collecting. Wearable data—heart rate, ECG, blood pressure, glucose levels—can be sent right away to medical professionals, therefore facilitating more informed decisions free from the need for in-person discussions [91, 92]. Patients with chronic diseases notably benefit from this since it allows constant monitoring and treatment approach change without requiring frequent visits to medical facilities. Sometimes remote consultations using wearable data can help to avoid unnecessary hospital admissions or emergency room visits [93]. Figure 2 [70, 94] displays a diagram of routine smart devices commonly used in medical sciences, highlighting various technologies worn or used on the body for continuous health monitoring and therapy. These devices include wearable spirometers, which help in tracking respiratory function; glucose monitors for monitoring blood sugar levels; and BP, $O_2$ saturation & pulse monitoring sensors that track vital signs like blood pressure, oxygen levels, and pulse. Additionally, temperature & activity trackers are used for monitoring body temperature and physical activity. The diagram also includes range & motion sensors to track movement and physical function, along with pacemakers & implanted defibrillator devices, which are used for heart conditions. ECG patches & Holter devices monitor heart activity continuously, while insulin pumps deliver insulin for diabetic patients. Smart gloves are featured for tracking hand movements or aiding in therapy, and TENS therapy Devices are used for pain management through electrical nerve stimulation. This figure provides a comprehensive overview of the routine smart devices that play a crucial role in modern medical care, offering continuous and real-time monitoring or treatment for various health conditions.

*4.2.2. Post-surgical and rehabilitation monitoring*

Wearables have shown considerable utility in post-surgical care and rehabilitation. Wearable devices tracking activity levels, heart rate, and muscle repair can offer critical data on patient recovery from surgery or physical therapy [95]. Wearable technology tracking range of motion, muscular strain, and step count enables physiotherapists to make real-time changes to rehabilitation plans, therefore enhancing the efficacy of recovery. Moreover, the possibility for remote recovery monitoring enables patients to stay at home, therefore alleviating the strain on medical facilities and lowering the danger of hospital-acquired infections [96].

## 4.3. Mental health and well-being

Mental health diseases are often underdiagnosed or treated badly mostly due to insufficient surveillance and the stigma around the search of mental health care. Wearable gadgets generate significant data since they allow patients and medical practitioners continuous mental health monitoring [97].

*4.3.1. Stress and anxiety monitoring*

Certain wearable technologies—such as the Muse headband and the Spire Stone—can measure stress levels by recording physiological variables including heart rate variability (HRV) and breathing patterns [98]. These devices give real-time input, so users can pinpoint times when they feel more stressed or nervous and apply mindfulness or deep breathing. These gadgets enable persons with anxiety disorders or excessive stress levels to properly control their emotions; hence, they offer therapies at the moment of need. Moreover, data acquired by these devices can be shared with mental health experts to direct therapy sessions [99].

*4.3.2. Sleep tracking and disorder diagnosis*

Like the Oura ring or Fitbit, wearable devices meant for sleep tracking can provide insightful analysis of sleep patterns including length, quality, and disruptions. These sensors monitor throughout sleep movement, heart rate, and oxygen saturation [78, 100]. Wearable devices give patients with sleep disorders including insomnia, sleep apnea, or restless leg syndrome a non-invasive way to have their patterns tracked and anomalies found. Early identification of sleep apnea can help to enable quick diagnosis and treatment, perhaps preventing major problems including diabetes and cardiovascular disease [19].

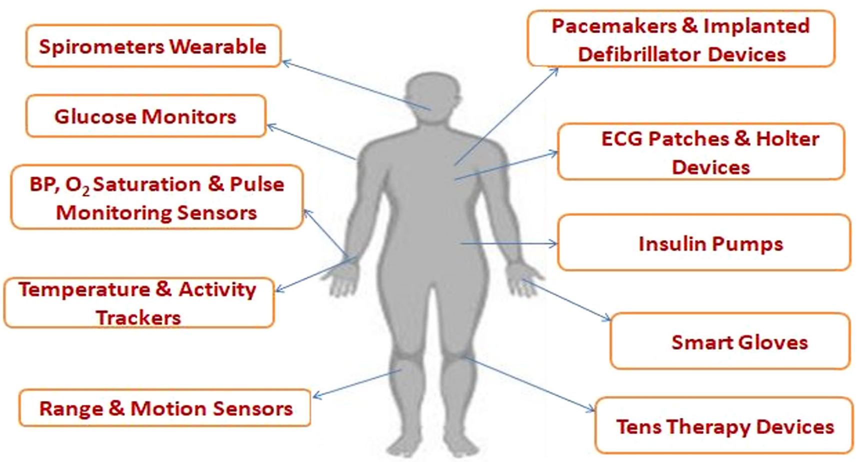
## 4.4. Preventive health care and fitness

Since they encourage physical exercise and good living, wearables are rather crucial in preventive health care [101].

*4.4.1. Promoting physical activity and healthy lifestyles*

Wearable devices—including fitness trackers and smartwatches —motivational aids let users log steps taken, calories burned, and active minutes, therefore enabling participation in physical exercise

**Figure 2**
**Routine smart devices, we deal with in medical sciences**



[101]. Wearables give feedback and daily goals that inspire people to be active and choose better living. Public health can be much affected by more physical exercise since it lowers the risk of several diseases like diabetes, heart disease, and obesity. These instruments help consumers to keep an eye on other facets of their life, including nutrition, water, and sleep, thereby supporting a whole strategy of health management [102, 103].

#### *4.4.2. Early detection of health risks*

Wearable technology clearly has advantages in terms of early on, generally premonition for health problem spotting. Usually, these are before symptoms manifest themselves. Through continuous monitoring, wearables can detect changes in several important markers that would point to the beginning of a medical illness [94]. Wearables recording HRV can identify early indicators of cardiovascular problems; devices checking glucose levels can notify patients with prediabetes to initiate lifestyle adjustments before type 2 diabetes occurs. Early detection serves to enable prompt response, hence lowering the load of chronic diseases and enhancing long-term health outcomes [76, 104].

### 4.5. Clinical research and trials

Wearables are transforming clinical research and trials, enhancing their efficiency and accessibility [105].

Figure 3 [8, 91, 97] outlines the challenges faced in the application of smart wearable devices in the developing world. One major challenge is storage limitations, where many devices have limited storage capacity, making it difficult to store large amounts of data, which is especially problematic in areas with limited access to cloud-based services. Data availability & reliability is another challenge, as reliable data for health monitoring and other functions may not be consistently available, reducing the effectiveness of wearable devices. Model selection & reliability also pose difficulties, as it can be challenging to select durable and reliable devices that can perform well under the specific conditions found in developing regions. The issue of development alternatives refers to the lack of local development options for affordable and context-specific wearable technology, which may limit the availability of devices suited to the needs of the region. Security & privacy concerns are significant, as wearable devices often collect sensitive health and personal data, and the digital security infrastructure in many developing countries may not be robust enough to ensure the protection of this data. Utility & user acceptance highlight the importance of ensuring that wearable devices are useful and align with the cultural and practical needs of users in developing areas, as low acceptance could hinder adoption. Lastly, power backup limitations refer to the challenges of maintaining device operation in areas with inconsistent or limited access to reliable power sources, which can make it difficult to use wearable technology effectively. These challenges illustrate the various barriers that need to be addressed to make smart wearable devices more accessible and functional in the developing world.

#### *4.5.1. Wearables for data collection in research studies*

Clinical research is using wearables more and more to gather real-time data, therefore enhancing the scope and accuracy of research initiatives. Regular data collecting from more people enables researchers to more completely evaluate effects and trends in health [105]. Wearables improve the accessibility and convenience of clinical trial involvement by lowering the requirement for participants to attend research sites. From this, more varied study populations and more noteworthy research results could ensue [106].

#### *4.5.2. Enhancing patient engagement in clinical trials*

Wearables offer a unique chance to increase patient participation in clinical research. Wearables maintain participant motivation and involvement during the study by providing real-time tracking of health data and insights regarding development [107]. Moreover, wearables improve data accuracy and reduce the possibility of human mistake since data are personally acquired and sent to researchers. This can help to lower timescales, speed up the creation of new treatments, and ease the clinical trial procedure [108]. Table 2 [7, 25, 49, 100] highlights the various areas where wearable devices are having a significant impact on health care. In chronic disease management, wearables allow for continuous monitoring of key health parameters such as glucose levels, heart rate, and blood pressure. This constant tracking enables more personalized care, ultimately improving patient outcomes by providing data that can be used to adjust treatment plans as needed. In RPM, wearables enable healthcare professionals to monitor patients' health outside of clinical settings, ensuring that timely interventions can be made. This reduces the need for in-person visits, saving valuable time and healthcare resources, especially in remote areas. For mental health and well-being, wearables help track physiological markers like HRV and sleep patterns, which provide insights into an individual's emotional state. These data allow for better management of stress, anxiety, and sleep disorders, contributing to improved mental health care. In preventive health care, wearable devices encourage physical activity and track fitness goals, offering real-time feedback that promotes healthier lifestyles and

**Figure 3**
**Challenges of application on smart wearable devices in the developing world**

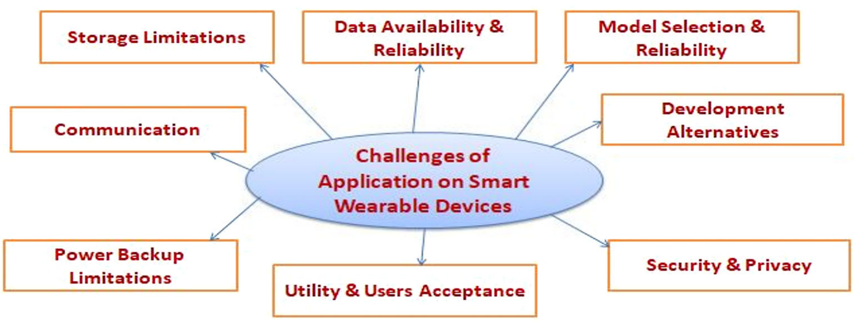


**Table 2**
**Opportunities in health care**

| S. No. | Area | Description | Impact |
|---|---|---|---|
| 1 | Chronic Disease Management | Wearables enable continuous monitoring of health parameters like glucose levels, heart rate, and blood pressure, which improves chronic disease management. | Improves patient outcomes by offering personalized care. |
| 2 | Remote Patient Monitoring | Remote patient monitoring allows healthcare professionals to monitor patients' health outside of clinical settings, ensuring timely interventions. | Reduces the need for in-person visits, saving time and healthcare resources. |
| 3 | Mental Health and Well-being | Wearables help monitor mental health by tracking physiological variables such as heart rate variability and sleep patterns, providing insights into emotional states. | Enables better management of stress, anxiety, and sleep disorders. |
| 4 | Preventive Health care | Wearable devices encourage physical activity, track fitness goals, and offer real-time feedback, thereby promoting healthier lifestyles and preventing diseases. | Helps prevent chronic diseases such as diabetes and heart disease. |
| 5 | Clinical Research and Trials | Wearables improve the efficiency of clinical trials by providing continuous real-time data collection, enhancing patient participation and engagement. | Enhances data accuracy and broadens participation in clinical studies. |

helps prevent diseases such as diabetes and heart disease. Lastly, in clinical research and trials, wearables enhance the efficiency of clinical trials by providing continuous, real-time data. This improves the accuracy of the collected data and broadens participation in clinical studies, leading to more comprehensive research outcomes.

## 5. Challenges in Wearable Technology

Wearable technology offers both fantastic possibilities and certain difficulties in the field of medicine. Though they have the potential to transform preventative treatment, remote monitoring, and management of chronic diseases, technical, privacy, acceptance, and legal problems limit wearable devices from being extensively employed [109]. Dealing with these obstacles requires advancements in device precision, energy economy, data security, user engagement, and legal processes. By means of overcoming these challenges, wearable technology will be able to achieve its promise to improve health outcomes as well as to increase global healthcare system efficiency and accessibility [110]. Wearable technology offers significant possibilities to change the way medical treatments are provided and administered. Several health factors are monitored and evaluated using medical-grade wearables, smartwatches, and fitness trackers, therefore generating real-time data that can help enhance health outcomes [111]. Still, wearable medical gadgets present certain difficulties, just as with any new technology. These limitations include regulatory obstacles, technical issues, data protection issues, and user acceptance challenges. We will probe these issues in great detail since knowledge of the constraints and possibilities of wearable technology in health care depends on them [112].

### 5.1. Technical challenges

*5.1.1. Accuracy and reliability of sensor data*

Main technical difficulty in ensuring the accuracy and quality of the data wearable devices in healthcare collecting is using sensors. Wearable devices monitor many physiological variables including heart rate, glucose levels, and blood pressure [113]. Still, many sensors lack the accuracy observed in clinical environments. For example, even though smartwatches such as the Apple Watch can offer heart rate measurements, the accuracy of these data may vary based on sensor quality and user behavior like the tightness of the device fit. Moreover, affecting sensor readings are several medical disorders or variables including skin pigment, temperature, and movement that produce inconsistent data, impairing professional decision-making [45, 67]. Manufacturers are striving to increase the sensitivity and calibration of sensors in order to meet this challenge; yet, this calls for overcoming technical constraints including battery lifespan and sensor downsizing, which can be expensive and difficult. If they are to be effectively employed in healthcare facilities, devices meant for daily use must fulfill medical-grade criteria for accuracy, hence a challenging demand for consumer-oriented wearables [58, 104].

*5.1.2. Battery life and energy efficiency*

For wearable devices, the lifetime of batteries offers a major technical challenge. Continuous monitoring of health data requires constant power consumption, which can quickly run out especially when devices are compiling significant volumes of data. Most wearable devices are meant to be used constantly; hence, they need extended battery life to stay useful for consumers [40, 111]. Many fitness trackers and medical wearables have only one or two days of battery life before they need to be recharged, therefore limiting their effectiveness for continuous, long-term health monitoring. To solve this problem, low-power sensors must advance and energy efficiency must improve. Still improving battery life while maintaining gadget functionality and sensor efficiency is a constant difficulty. The ideal wearable gadget needs to show enough energy economy to enable continuous monitoring without regular recharging, which calls for changes in hardware and software design [32, 92].

### 5.2. Data privacy and security

*5.2.1. Risks of data breaches and unauthorized access*

Sensitive health information produced by wearable devices could be vulnerable to security issues. Data breaches and illegal access to personal health information (PHI) become ever more important issues as these devices become more linked with the internet [70, 106]. Not only does health data—which includes thorough information about a person's medical history, exercise habits, and physiological parameters—matter to healthcare professionals but also to hackers and unapproved third parties. For example, wearable devices sending data to cloud-based services have the risk of being hacked, therefore violating possible privacy rights [21, 98]. These devices' portability and simplicity make them easy target for theft or illegal use. Limiting risks and protecting consumers' private health information depend on applying strict authentication procedures, safe cloud storage, and data encryption [60, 76].

*5.2.2. Compliance with regulations (e.g., Health Insurance Portability and Accountability Act (HIPAA), General Data Protection Regulation (GDPR))*

Wearable devices in the healthcare sector have to meet specific data security standards such as the GDPR in Europe and the HIPAA in the United States. Collected, kept, and disseminated under specific guidelines is PHI [72, 73]. Maintaining user confidence and avoiding legal issues depends on health-related data acquired by wearable devices respecting regulations. Ensuring that designers of wearable technology adhere to these intricate guidelines is a difficulty. Health data gathering technologies ought to provide privacy and security top importance so that consumers retain control over their information and that it is just accessible to authorized individuals. This is important, making sure policies for data sharing are unambiguous, that data storage and transmission follow encryption standards, and that users may renounce access to their data when necessary [50, 53].

## 5.3. User adoption and usability

*5.3.1. Comfort and design of wearable devices*

Wearable healthcare gadgets' usability and comfort as well as their functionality define their efficiency. Wearables have to be lightweight, covert, and engineered for long use if we are to enable effective constant monitoring. Still, many wearable gadgets could be inconvenient or uncomfortable—especially if used for extended periods of time [20, 105]. Extended use may produce skin irritation or discomfort, thereby lowering adherence and user pleasure. Wearable manufacturers must focus on ergonomics so that their products are comfortable and esthetically beautiful. This will enable their great adoption. Customizing choices and creative design can aid to raise consumers' regular usage of these devices' probability. Manufacturers also have to take skin sensitivity, waterproofing, and perspiration resistance into account to make sure the gadgets are suitable for daily use [83, 90].

*5.3.2. User adherence and engagement*

The effectiveness of wearable devices depends on frequent user application. Still, maintaining constant curiosity and following these technologies' use presents major difficulties. Wearable gadgets may seem to many users as an additional need instead than a necessary part of their daily routine. This could cause less use, especially for devices that need regular interaction or recharging [8, 51]. Manufacturers and healthcare providers have to create wearables that provide specific, useful insights that motivate consumers to keep their usage in order to solve this conundrum [85, 108]. This could cover offering customized health recommendations, gamified exercise goals, or connection with other health management systems. Wearables should also provide consumers with real-time input on their health indicators, hence improving the interactability and usability of the gadget in daily life. This can improve user compliance and inspire ongoing interaction with wearable technology [2, 89].

## 5.4. Regulatory and ethical issues

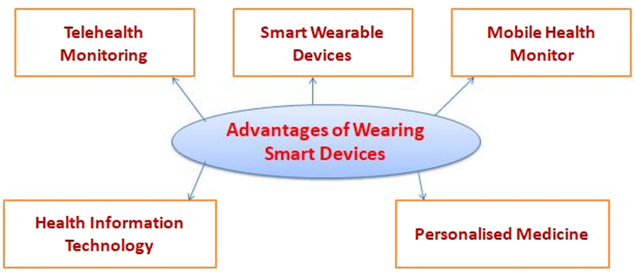
*5.4.1. Approval processes for medical-grade wearables*

Wearable gadgets meant for clinical usage or classified as medical devices have to go through strict approval procedures set by agencies including the European Medicines Agency or the U.S. Food and Drug Administration. Medical-grade wearables have a long and costly approval process that forces manufacturers to demonstrate the safety and effectiveness of their devices [30, 31]. This usually means clinical research, assessments, and copious of documentation. Wearable makers have a difficult balance between the desire for extensive testing and approval and the need for quick invention [11, 13]. Many consumer-oriented wearables that collect health data are not regulated by the same strict guidelines, but they will be under more scrutiny and regulation when these devices move to medical-grade uses. Wearables should be adopted in healthcare environments without unnecessary delays by optimizing the approval procedure while maintaining safety and efficacy criteria [10, 77].

*5.4.2. Ethical concerns regarding data ownership and usage*

Wearables raise many ethical questions about data use and ownership. Whose data—that of the manufacturer, the user, or the healthcare provider—that these gadgets capture? How can people make sure their medical records are used for their benefit instead of profit or other goals? When wearable data is shared with third parties, such insurance companies or businesses, it raises ethical questions. Health data of users could be used for discriminating policies in fields including employment and insurance [17, 95]. Thus, clear and open data-sharing rules have to be developed, and consumers should keep control over the use and distribution of their information. Furthermore, it is absolutely necessary to ensure that wearable technology honors people's liberty and privacy. Establishing ethical standards and best practices can help to ensure the responsible use of wearable technologies, therefore protecting consumers' rights and dignity [4, 25]. Figure 4 [43, 102, 114] illustrates the advantages of wearing smart devices in the healthcare system. The diagram shows several key areas where these devices provide significant benefits. Telehealth monitoring refers to the ability to monitor a patient's health remotely, allowing healthcare providers to track vital signs and intervene as needed without requiring in-person visits. Smart wearable devices play a central role in this by offering continuous health tracking, which is valuable for both disease management and preventive care. Mobile health monitors extend this concept

**Figure 4**
**Advantages of wearing smart devices in healthcare system**



by enabling health monitoring through smartphones, making it accessible and convenient for users to track their health metrics anywhere. Figure no. 04 also highlights the importance of health information technology in managing and analyzing the data collected by wearable devices. By integrating smart devices with health information systems, healthcare providers can create more efficient and personalized care plans. Finally, personalized medicine is another key advantage, as wearables allow for the collection of real-time data, enabling treatment and care to be tailored to an individual's specific health needs, leading to more precise and effective medical interventions. These advantages show how wearable devices are transforming health care by improving monitoring, communication, and personalization of care.

## 6. Future Directions

Driven by developments in AI, ML, biosensors, and smart implants, wearable technology in health care has a pretty promising future. These technologies will enable tailored treatments, increase access to health care for impoverished individuals, and improve preventative care and management of chronic diseases [36, 47]. Development of technology will be able to grow by means of multidisciplinary cooperation, thereby improving the accessibility, cost, and efficiency of health care all around. Wearable technology will become essential in directing the path of customized, real-time, patient-centered therapy as it gets more and more included in healthcare systems [7, 15].

## 6.1. Integration with AI and ML

Wearable technology for health care has made a major step towards integration of AI and ML. These instruments are transforming the study of healthcare data and offering hitherto unthinkable forecasting capabilities [115].

### *6.1.1. Predictive analytics for early disease detection*

Wearable technology combined with AI makes real-time monitoring of health metrics—including physical activity levels, oxygen saturation, and heart rate—feasible [115]. Predictive analytics lets ML systems look at data trends to find early signs of diseases such as neurological problems, diabetes, and heart attacks. Early detection of these trends allows wearables to provide actionable insights that support quick medical intervention, hence perhaps preventing major repercussions or early death [114]. Wearables driven by AI are being developed to detect AFib, alert consumers to seek medical help before a major incident, such as stroke, and identify aberrant heart rhythms. Wearable AI systems can track glucose levels in diabetic patients and predict likely swings, therefore suggesting appropriate changes in lifestyle or medication. These wearables can lower hospital visits and increase better patient outcomes by helping to detect diseases [116].

### *6.1.2. Personalized treatment recommendations*

Apart from the diagnosis of diseases, AI and ML could provide customized treatment recommendations. By use of longitudinal data analysis, ML techniques may personalize healthcare interventions for specific patients, hence improving the efficacy and efficiency of treatment [117]. Wearable technologies tracking stress, physical exercise, and sleep quality can generate customized health programs encouraging good behavior. Real-time data allows these systems to be constantly improved, hence increasing patient involvement and helping to reach long-term health goals. AI-driven solutions can help medical professionals create customized treatment plans fit for a certain patient's requirement. Rather than depending on set procedures, healthcare professionals can create extremely tailored treatment plans using data from wearables that use the patient's unique biological indications, lifestyle, and medical history [118].

## 6.2. Advanced biosensors and multi-functional devices

### *6.2.1. Non-invasive biomarker detection (e.g., sweat, saliva)*

The discovery of non-invasive biomarkers made feasible by biosensory development marks a significant progress in wearable technology for health care. Devices under development are supposed to identify biomarkers by perspiration, saliva, or breath so users may track significant health signs without having to go through painful blood draws [119]. Wearable devices in active development can track perspiration for markers connected to metabolic problems, stress, or dehydration. Such devices would help people track their health in real time and act preventively to control expected issues [120]. Wearable sweat sensors might also be used to measure electrolyte, glucose, or lactate concentrations, thereby helping athletes to monitor hydration and performance or enabling diabetes sufferers to reach appropriate glucose management. Saliva-based sensors under development are meant to detect hormones and other molecules pointing to the beginning of diseases including infections, inflammatory diseases, or cancers. Constant home health monitoring made possible by these advances would help to perhaps limit the spread of unseen diseases [15, 30].

### *6.2.2. Multi-parameter monitoring in a single device*

A future trend is the development of wearable gadgets with many functions able to monitor several parameters with one tool. These wearables might have sensors to track heart rate, $SpO_2$, glucose levels, stress, body temperature, and ambient factors including air quality [9, 74]. These wearables would provide thorough health tracking for consumers and provide healthcare professionals with a more complete view of a patient's condition by combining several monitoring features into one gadget. This would simplify the healthcare system, lessen the need for many devices, and improve patient care efficacy [61, 66].

## 6.3. Expansion into underserved populations

### *6.3.1. Wearables for low-resource and remote settings*

Spread into impoverished areas is a big future goal for wearable healthcare technology. Sometimes, rural and disadvantaged communities have limited access to health care, which makes ongoing health monitoring more difficult. Affordable, user-friendly wearable technologies running in contexts with limited resources might significantly increase healthcare access [18, 119]. Far-off locations without medical personnel might deploy portable, cheaply cost wearables tracking vital signs including temperature, oxygen saturation, and heart rate. These gadgets support RPM and interventions by forwarding real-time data to medical staff. These wearables could be crucial in areas with limited healthcare access since they provide preventative treatment that is not otherwise feasible [53, 107].

### *6.3.2. Affordable and accessible wearable solutions*

Wearable healthcare gadgets are expected to be more used in underprivileged areas as their cost is dropping and their availability improves. Especially in underdeveloped countries, the development of affordable solutions will help more people to gain from continuous health monitoring [54, 69]. By providing real-time input on lifestyle choices, medications, and other health-related factors, these gadgets could help chronic diseases not deteriorate. Wearables reduce barriers to healthcare access, therefore improving health outcomes and promoting justice in world health [20, 120].

### 6.4. Interdisciplinary collaboration

*6.4.1. Partnerships between tech companies, healthcare providers, and researchers*

Appropriately exploiting the possibilities of wearable technologies depends on multidisciplinary cooperation. Working together among researchers, healthcare companies, and technology companies will help to hasten the development and application of wearable devices meeting both technical and clinical criteria [4, 89]. Although healthcare companies provide knowledge on patient care, clinical applications, and regulatory requirements, technology companies offer proficiency in engineering, software development, and data analytics. Investigating the scientific basis of wearable health technologies and their ability to improve outcomes is mostly dependent on researchers. This cooperation ensures that wearable devices are therapeutically relevant as well as technologically advanced. Working together, these companies could create wearables with great utility and user-centric design that help to greatly improve health [29, 38].

*6.4.2. Development of standardized protocols for wearable data*

Standardized criteria for wearable data are becoming more important as wearables are being included in healthcare settings. Standard processes for data collecting, processing, and interpretation will ensure the safe and successful use of wearables in health care. Establishing these criteria calls for cooperation among producers, healthcare organizations, and regulatory bodies to develop generally accepted procedures for data precision, confidentiality, and reporting [11, 12].

### 6.5. Emerging trends

*6.5.1. Smart implants and ingestible sensors*

Among the most innovative developments in wearable technologies are some intelligent implants and ingestible sensors. Many health problems are being addressed with intelligent implants including pacemakers and neurostimulators; the future points to the creation of even more complex technology [16, 50]. These implants might constantly check patients' health, find anomalies, and independently change treatment, therefore reducing the need for regular hospital visits. RPM is expected to benefit much from ingestible sensors, small, swallowable devices able to track interior health signals. These devices give real-time data on a patient's health from within the body, thereby monitoring digestion, medication compliance, or even the functioning of internal organs [112].

*6.5.2. Wearables for aging populations and elderly care*

The generation of elderly people makes an expanding cohort that will greatly benefit from wearable technology. Designed for the elderly, devices can track vital signs, identify falls, control drug compliance, and alert emergency services or caregivers [121]. Wearables will help the elderly preserve their liberty while allowing continuous monitoring since they often suffer from chronic diseases or age-related health degradation. Wearables tracking cognitive health also help to spot early signs of diseases like Alzheimer's or dementia, so enabling quick intervention [122, 123].

## 7. Conclusion

Wearable technology presents a means of transforming health care as well as substantial advantages in personalized therapy, preventive care, and management of chronic diseases. Wearables give healthcare professionals valuable data for informed decision-making since they enable individuals to actively participate in their health by means of continuous monitoring of important health criteria. These gadgets can eventually cut healthcare costs by helping to detect ailments early on, encourage healthier living, and lastly enhance health outcomes by means of betterment of life. Still, there are major difficulties especially with sensor accuracy, data confidentiality, battery life, user acceptance, and regulatory endorsement. The resolution of these issues will determine the great acceptance and efficient integration of wearables into healthcare systems. Moreover, ensuring that wearable technology is accessible to poor populations and retainable will help to reach equal healthcare advantages worldwide. Wearable health technologies provide quite promising future directions. Although biosensors will produce non-invasive monitoring and multi-parameter evaluation as they improve, AI and ML will allow predictive analytics and tailored treatment recommendations. Advancing new technologies and addressing present issues will depend mostly on government, medical practitioner, researcher, and technological company cooperation. To maximize their opportunities, all players have to cooperate to ensure that wearable technology is accurate, safe, user-friendly, and readily available. Solving these issues will help us to realize the complete promise of wearable technologies and provide a more accessible, tailored, and effective healthcare system for everybody. Figure 5 [50, 67, 74] summarizes the potential achievements when using wearable healthcare devices. The diagram starts with wearable healthcare devices at the top, which form the foundation for improving various aspects of health care. These devices contribute to personalized therapy, where care is tailored to the individual based on real-time health data collected

**Figure 5**
**Summary—what can be achieved using wearable healthcare devices**

from the wearables. This personalized approach leads to preventive care, as the continuous monitoring of health metrics helps to identify potential risks early and take preventative measures before conditions worsen. From preventive care, the next step is data-driven decision-making, where healthcare providers can use the data gathered by wearable devices to make more informed decisions about treatment and care plans. This leads to the final outcome, which is the management of chronic diseases. By leveraging wearable health devices, chronic conditions can be better managed through continuous monitoring, early detection of changes, and timely interventions. Overall, the diagram demonstrates how wearable healthcare devices play a pivotal role in personalizing care, preventing diseases, and managing long-term health conditions.

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## Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

## Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

## Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

## Author Contribution Statement

**Zulfkar Qadrie:** Conceptualization, Software, Formal analysis, Investigation, Resources, Writing – review & editing, Visualization, Supervision. **Humaira Ashraf:** Software, Formal analysis, Resources, Visualization. **Mudasir Maqbool:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision. **Saeema Farooq:** Validation, Data curation, Project administration.

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