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Article

Harnessing Wearable Devices for Enhanced Long-Term Care: Opportunities, Challenges, and Future Directions

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Abstract: The incorporation of wearable devices within long-term care represents a groundbreaking advancement in healthcare. These devices, leveraging sensor and intelligent technologies, possess the potential to revolutionize the supervision and handling of chronic illnesses, enriching the lives of individuals reliant on extended care. One of the primary considerations revolves around the question of whether recent technological advancements have made it feasible to deliver healthcare remotely to the elderly population. This paper conducts an exhaustive examination of wearable devices in the long-term care context, spotlighting their wide-ranging applications. It encompasses devices tailored for monitoring vital signs, mobility, medication adherence, cognitive health, and other critical facets of long-term care. Through an in-depth exploration of their capabilities and limitations, it illuminates their capacity to ease the strain on healthcare systems and enhance patient well-being. Moreover, this paper investigates the hurdles related to wearable device adoption in long-term care, addressing concerns like data security, user acceptance, and interoperability. By tackling these challenges, it endeavors to chart a path for the seamless integration of wearable technologies. Drawing insights from current research and industry trends, it identifies emerging prospects such as personalized care plans, remote monitoring, and data-driven healthcare interventions, fostering collaboration among healthcare stakeholders. By harnessing the full potential of wearable technologies, the quality of life of individuals in long-term care can be improved and also, it can contribute to achieve more efficient and sustainable healthcare systems.

Keywords: wearable devices; long-term care; healthcare monitoring; chronic illness management; remote monitoring; patient-centric care; healthcare technology

1. Introduction

The well-being of individuals is a primary concern across all demographic sectors, and wearables have emerged as a valuable tool in monitoring and managing health. These gadgets, which range in price from smartwatches to fitness trackers, provide real-time data on a range of health measures, encouraging proactive health management and assisting in early intervention [1]. Regardless of their social background, people may take better care of their health by incorporating wearables into their daily lives. Wearable technology adoption therefore advances the shared objective of improving health and well-being among many communities. Additionally, projections suggest that by 2050, the global population of older adults will soar to around 1.5 billion individuals [2]. This demographic shift signifies a

substantial economic influence on both public and personal finances across societal sectors. Particularly noteworthy is the escalating economic expenditure on healthcare for older adults, which exerts a pronounced effect on developing nations. Notably, the rise in chronic ailments has become more prevalent in recent years, predominantly attributed to the expanding elderly population [3]. Among the most prevalent diseases within this demographic segment are cardiovascular diseases, diabetes, cancer, and dementia [4].

Projections show that the wearable medical device market will develop significantly, reaching a huge value of US$ 59.12 billion in 2022. According to projections, the market value is expected to reach US$ 428.92 billion by 2030 [5], growing at a compound annual growth rate of 28.6% from 2023 to 2030. In this field, gadgets like smartwatches and activity trackers are essential since they are made with the express purpose of tracking and gathering data in real time on people's general health and fitness. According to 2023 research by mHealth Intelligence, a significant percentage of Americans—roughly 40%—engage with healthcare-related applications, and 35% use wearable healthcare devices, highlighting the expanding use of such technology [6].

The rise of novel healthcare equipment has been facilitated by the growing need for people to take an active role in managing their health and by the progress made in wearable technology. This growth includes biosensors, hearing aids, and goods like Fitbits in addition to more traditional gadgets like fitness trackers. Moreover, a major factor driving wearable medical device sales is the frequency of chronic diseases and disorders linked to lifestyle choices. Remarkably, a sizable proportion of patients voice support for the incorporation of wearable device data into medical procedures, offering insightful information that helps medical practitioners properly diagnose and treat patients' conditions [6,7].

In the forthcoming years, the wearable medical device market is poised for substantial growth, driven by factors such as the increasing prevalence of chronic ailments and the willingness of patients to incorporate wearable technology into their healthcare routines. This growth trajectory is further bolstered by the continuous evolution of wearable devices, expanding beyond basic fitness tracking to encompass a diverse range of healthcare applications. As stakeholders continue to innovate and collaborate, wearable medical devices are expected to play an increasingly integral role in shaping the future of healthcare delivery and patient wellness management.

Figure 1 gives the indicative market coverage of the wearable devices divided into health and fitness, BFSI, gaming and entertainment, fashion, travel, education, and logistics & warehouse [8]. The wearable technology market experienced substantial growth in 2022, with the health and fitness segment emerging as a dominant force [9]. This trend is fueled by a global shift towards prioritizing health and wellness, as individuals become increasingly aware of the importance of fitness in their lives. Wearable devices, ranging from fitness trackers to smartwatches, offer users real-time insights into their health metrics, empowering them to take proactive steps towards improving their well-being. With features like activity tracking, heart rate monitoring, and sleep analysis, these devices have become integral tools for individuals striving to lead healthier lifestyles [10].

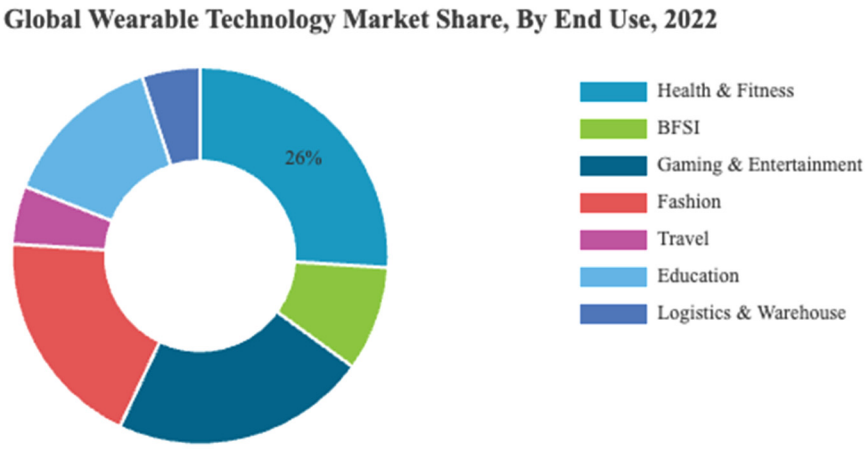

Figure 1. Global Wearable Technology Market Share by End Use, 2022 [8].

In addition to catering to individual health needs, wearable technology is revolutionizing healthcare delivery through remote monitoring capabilities [11]. This advancement allows healthcare providers to remotely monitor patients' health conditions and progress, reducing the need for frequent in-person visits to medical facilities. Particularly beneficial for those with chronic illnesses, remote monitoring offers

convenience, timely interventions, and personalized care plans, ultimately enhancing patient outcomes. As wearable technology continues to evolve and integrate seamlessly into everyday life, its impact on health and wellness is expected to grow exponentially, shaping the future of healthcare delivery and personal well-being [12].

The wearable devices market for long-term care has been growing rapidly in recent years and is expected to continue to grow in the coming years. The growth of this market can be attributed to several factors [13], including: (1) Increasing demand for remote patient monitoring and telemedicine services, particularly in the wake of the COVID-19 pandemic; (2) Advances in wearable technology, including the miniaturization of sensors and the development of new applications for wearables in healthcare; (3) Growing awareness of the benefits of wearable devices for long-term care, including improved patient outcomes, increased patient engagement, and reduced healthcare costs; (4) Increasing investment and support from governments and private sector organizations in the development of wearable technology for healthcare [13,14].

Furthermore, the google updates API also played the significant role for encouraging the for patient COVID-19 pandemic also encouraged the huge population to use the android applications which can collect the vaccination and tests results of the patients and helped to suggest the necessary actions based on their health data [15]. Overall, the wearable devices market for long-term care is expected to continue to grow as the demand for these devices increases and technology advances. Businesses looking to enter or expand in this market can take advantage of this growth potential and capitalize on the increasing demand for wearable devices in long-term care. Here have been several successful use cases of wearable devices for long-term care that demonstrate the potential benefits of these devices for both patients and healthcare providers. Figure 2, provides an overview of the architecture for wearable systems. Some examples include:

- Remote patient monitoring: Wearable devices equipped with sensors and communication capabilities can allow healthcare providers to monitor patient health data remotely, such as vital signs, physical activity, and medication adherence. This can improve patient outcomes, reduce healthcare costs, and provide patients with more convenient and accessible care [16,17].
- Fall detection: Wearables that are equipped with a variety of sensors and sophisticated accelerometer technology can identify falls and provide notifications to healthcare practitioners in real time [18]. This proactive feature is an essential intervention mechanism that allows quick actions to stop accidents and improve patient safety in healthcare settings [19].
- Medication reminders: Personalized schedules are programmed into wearable medicine reminders, which alert users with alerts or messages at predetermined intervals [20]. These notifications, which are frequently programmable and connected to companion applications, provide feedback choices and integration with health data to assist users in adhering to their drug schedule. Wearables' user-friendly interfaces and connection characteristics help to enhance healthcare management by enabling remote monitoring, greater adherence, and timely drug ingestion [21].
- Chronic disease management: Wearable devices can provide continuous monitoring and tracking of health data for patients with chronic diseases, such as diabetes, heart disease, and respiratory conditions. This can improve disease management and prevent complications, leading to improved patient outcomes and reduced healthcare costs [20,22].

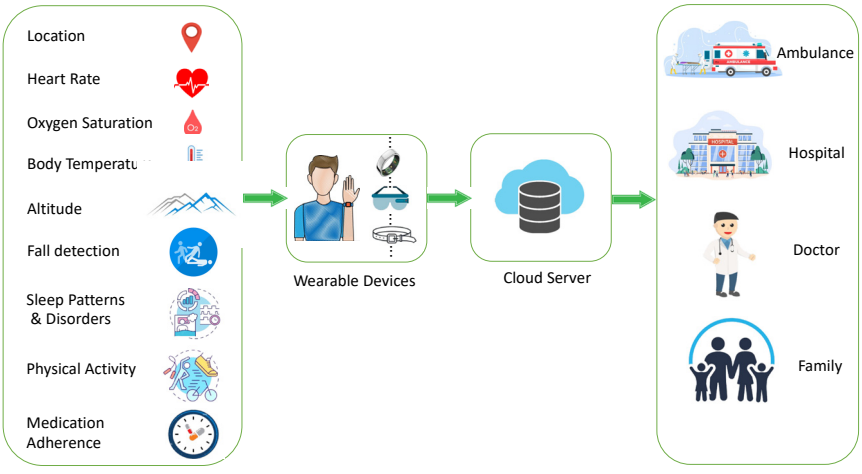

Figure 2. Overall Architecture of Wearable Technology.

Remote healthcare, combined with advanced wearable technology, can revolutionize the way healthcare is delivered. By enabling patients to obtain remote medical assistance, physicians to perform procedures remotely, and both to have access to vital health information, remote healthcare can improve access to care and increase efficiency. In addition, wearable devices, equipped with sensors and other technologies, can provide real-time health monitoring, enabling healthcare providers to identify potential health issues and respond quickly. This can be particularly beneficial for individuals with chronic conditions requiring frequent monitoring and support and those living in remote areas with limited healthcare services. As a result, remote healthcare and wearable technology have the potential to improve outcomes, reduce costs, and increase patient satisfaction. The reports from different sources like ReportsnReports [23], MarketsandMarkets [24], ResearchAndMarkets [25] also provided the current market projection of the wearable devices market for long-term care, including market size, growth. They also provide insights into key drivers, challenges, and trends affecting the market, as well as an analysis of market share and competitive landscape.

Traditional methods of training medical teams with new techniques and tools can be disrupted in the face of fast-moving medical threats, such as pandemics, natural disasters, and other emergencies [16]. In these situations, remote medicine can play a critical role in closing the gap and ensuring that medical teams have access to the latest information and training [26]. With remote medicine, healthcare providers can participate in training sessions and access educational resources from anywhere, without the need for travel or in-person interaction. This can help ensure that medical teams have the knowledge and skills they need to provide effective care, even in fast-moving and unpredictable circumstances. Remote medicine can also improve access to care by enabling healthcare providers to reach and treat patients who are unable to travel or are located in remote areas [27]. This can be particularly important in the context of fast-moving medical threats, where access to care can be limited.

The COVID-19 pandemic has made remote medicine more attractive and necessary in many ways. Many patients have become worried about seeking in-person medical care due to the risk of exposure to the virus and the need to avoid crowded medical centers [28]. At the same time, safety rules and guidelines have prevented physicians from physically approaching patients, making it difficult to provide effective care in a traditional setting. In response, remote medicine has become an increasingly important solution, providing patients with medical care and support while reducing their risk of exposure to the virus. Remote medicine has also allowed healthcare providers to continue delivering patient care, despite the pandemic's challenges [28]. This has been critical in ensuring that individuals with chronic conditions and other health needs continue to receive the care they require, even in the context of a global health crisis.

Wearable technology is becoming more and more popular for a number of reasons, such as the need to reduce healthcare costs, serve the needs of aging populations, and address the rising incidence of chronic illnesses. These technologies are attractive to both individuals and healthcare institutions because they have the potential to improve health outcomes, increase patient engagement, and reduce the cost of healthcare supply. With capabilities like medication adherence tracking, real-time vital sign monitoring, and seamless patient-provider communication, wearables provide people with an effective and proactive way to manage chronic diseases [27,28]. In addition, the widespread availability of remote medical services has generated increased curiosity about wearable technology due to its ability to provide vital information and insights that are essential for supporting remote care programs and improving health outcomes.

There are several reasons for the increase in demand for wearable technology, such as the urgent need to address the rising incidence of chronic illnesses, ageing populations, and healthcare expenses. These cutting-edge gadgets are appealing to both consumers and healthcare organizations because they provide a viable means of enhancing health outcomes, encouraging increased patient participation, and reducing the financial burden on healthcare systems [29]. Wearables enable people to manage chronic illnesses more efficiently and proactively by enabling real-time monitoring of vital signs, adherence to prescription regimens, and seamless communication between patients and healthcare professionals. Wearable technologies are becoming more and more popular as the area of remote medicine grows. This is because these devices provide important data and insights that may help support remote care efforts and improve overall health outcomes.

Numerous compelling causes, such as the pressing need to control healthcare costs, accommodate aging populations, and address the growing burden of chronic illnesses, are driving up demand for wearable devices. These innovative gadgets are an appealing choice for both consumers and healthcare facilities because of their enormous potential to improve patient involvement, health outcomes, and financial strain on healthcare delivery [30]. Wearables enable people to manage chronic illnesses with more efficiency and predictability by providing features like real-time vital sign monitoring, medication adherence tracking, and smooth communication between patients and healthcare professionals.

Furthermore, wearable devices have become more and more popular as remote medical services have grown, because they may provide vital information and insights that are essential for assisting with remote care initiatives and promoting better health outcomes.

The integration of AI, ML, and big data analytics in wearable technology has significantly enhanced the usefulness of sensor data in many ways. By processing and analyzing large amounts of data generated by wearable sensors, AI and ML algorithms can identify patterns and make predictions that were not previously possible [31]. This can help healthcare providers and individuals better understand their health status and make informed decisions about their care. For example, AI algorithms can be used to detect early signs of chronic conditions and alert patients and healthcare providers before the conditions become serious. By utilizing machine learning algorithms and big data analytics, wearable technology can make sense of complex data streams and provide actionable insights that can improve health outcomes, reduce costs, and increase patient engagement [32]. The power-efficient nature of AI and ML algorithms, combined with advances in cost-efficient and power-efficient electronics, has made wearable technology increasingly accessible to individuals and healthcare organizations [33,34].

Wearable technology has become an essential part of home care systems, providing a variety of functions to improve patient outcomes. These multipurpose gadgets, which are fitted with a variety of sensors, monitor vital indicators such as blood pressure, body temperature, and heart rate continuously, giving instantaneous information on a person's health. Beyond monitoring, wearables are excellent in medication management. They accurately ensure that patients take their medications as prescribed and diligently remind them to do so. Furthermore, in the case of an accident, their fall detection capabilities provide prompt warnings to emergency contacts or caregivers, promoting speedy response procedures. These gadgets are also excellent at monitoring activity and mobility, providing thorough insights into a person's physical well-being. Moreover, the smooth remote connection between patients and their caregivers or healthcare providers is made possible by their integration with speech and video features. Wearables that are enhanced with emergency buttons can quickly notify responders or selected contacts in an emergency. Furthermore, these devices are essential for controlling chronic disorders such as diabetes since they continually measure activity levels, check glucose levels, and provide regular injection reminders. All things considered, wearable technology is a valuable asset to the home care industry, combining various features to support chronic disease management, patient care, and safety [35].

This comprehensive article carefully examines the revolutionary role wearable technology has taken on in the healthcare industry. It highlights their diverse contributions by exploring the ways in which these devices facilitate the detection, tracking, and treatment of a range of health-related problems. The article emphasizes the importance of wearable technology and looks in-depth at how it may empower medical personnel by providing real-time insights into patients' vital signs, activity levels, and medication adherence. Wearable technology is equipped with advanced sensors and data analytics. Moreover, it offers a perceptive examination of the growing market demand for wearable technology, clarifying the elements propelling its uptake and its multifarious uses in healthcare environments. This scrutiny encompasses the devices' usability, interoperability, and their potential to revolutionize diagnostics, preventive care, chronic disease management for long-term care.

2. Literature Review

Wearable devices can play a significant role in managing chronic conditions by providing real-time monitoring and tracking of key health metrics, such as heart rate, sleep quality, activity levels, and medication adherence. Additionally, some wearables can be equipped with sensors that can detect early warning signs of chronic conditions, such as fluctuations in heart rate or blood pressure. Wearables can also be integrated with digital health platforms and linked to electronic health records (EHRs), enabling healthcare providers to access up-to-date patient information and monitor progress over time [36,37]. This information can be used to inform treatment decisions and adjust medications as needed. Wearables can also be used to motivate patients to adopt healthy behaviors, such as exercise and healthy eating, and to provide reminders for self-care activities, such as taking medications and monitoring blood sugar levels.

Several studies, such as those carried out by A. Dutta et al. [38], M. Farid et al. [39], M. S. Borycki et al. [40], K. S. Chiang et al. [41] and K. R. Mann. [42], explore deeply into the use of wearable technology in tracking chronic illnesses like diabetes, heart disease, and COPD. Together, they highlight the potential benefits of wearable technology in the management of chronic illnesses, pointing to lower healthcare costs, better patient outcomes, and more patient participation.

Furthermore, these research works agree on the obstacles that need to be overcome for implementation to be successful. For wearable technology to be seamlessly integrated into the

management of chronic diseases, a number of critical issues need to be addressed. These issues include data privacy, security concerns, and the pressing need for standardized procedures in data gathering and analysis. Their complementary results highlight the need of resolving these issues in order to fully realize the potential advantages that wearable technology may provide for the management of long-term medical disorders.

With a variety of features that help people follow their drug schedules, wearable technology has become an important tool in medication management. Wearables act as dependable companions by using notifications and reminders to help users remember to take their medications on time. Additionally, wearables with sensor integration may precisely identify when prescriptions have been taken, adding an additional degree of adherence guarantee. By lowering the possibility of missing or giving the wrong amount, this improves patient safety in addition to encouraging improved medication compliance [43].

Additionally, the ability of wearable devices to communicate with electronic health records (EHRs) improves the capacity of medical professionals to remotely check on patients' adherence to their prescribed medications. Timely actions, including modifying medication schedules or offering individualized instructional materials, are made possible by real-time feedback [44]. In addition to improving patient outcomes, this proactive approach gives people the confidence to make educated decisions about their health. Wearables provide a more customized and collaborative approach to drug management by bridging the gap between patients and healthcare professionals, which eventually improves treatment results.

Wearable technology offers comprehensive information into users' health and wellness beyond just managing medications. Wearable technology tracks a variety of physiological data points, including heart rate, activity level, and sleep habits, and then uses that data to deliver individualized feedback that encourages people to lead better lifestyles. This empowerment encourages people to prioritize their well-being beyond just taking their medications and promotes a proactive approach to self-care. In the end, wearable technology integration into healthcare systems signifies a paradigm change toward patient-centric care, in which technology enhances conventional medical procedures to improve patient outcomes and general quality of life.

J. N. Arslan et. al. [45], Y. Kim et. al. [46], L. Marengo et. al. [21] and J. M. et. al. [47] discussed the applications of wearable devices for reminding patients to take their medication and tracking medication adherence. The paper discusses the potential benefits of wearable devices for medication adherence, including improved patient outcomes, increased patient engagement, and reduced healthcare costs. The authors also highlighted the challenges that need to be addressed for effective implementation of wearable technology for medication adherence, including data privacy, data security, and the need for standardization of data collection and analysis methods.

The way people check their vital signs has been completely transformed by wearable technology, which includes anything from fitness trackers to smartwatches to specialist health monitoring equipment. These wearables, which come with sensors that can measure things like blood pressure, temperature, blood oxygen levels, and heart rate, provide users with real-time health metrics information. Wearable technology offers continuous monitoring by blending in seamlessly with regular activities, giving consumers a complete picture of their physical well-being. By analyzing physical activity levels, identifying small changes in health status, and sending out notifications for any health problems, this ongoing data gathering can help people take proactive steps to improve their health [43].

Wearable vital sign monitoring technologies show great potential for improving the quality of life for people with chronic diseases or those who are at risk for health issues. These wearables enable early identification of changes from normal health indicators and facilitate fast medical intervention when necessary by providing immediate and tailored health information. Furthermore, wearable technology's accessibility and ease of use encourage users to take an active role in self-care, giving them a sense of control over their health management. However, overcoming a number of obstacles is necessary to fully utilize wearable technology in vital sign monitoring.

Ensuring the accuracy and dependability of sensors, resolving privacy and security issues with regard to sensitive health data, and creating reliable algorithms for data interpretation are challenges related to wearable devices for vital sign monitoring. To overcome these challenges, engineers, medical experts, and legislators must work with collaboratively to develop complex data analysis algorithms, enforce strict sensor accuracy guidelines, and put strong data encryption mechanisms in place. Notwithstanding these obstacles, wearable technology is still developing at a rapid pace, which highlights its revolutionary potential to completely change the way healthcare is delivered and open the door to a more proactive, individualized, and data-driven approach to health monitoring and management.

A number of papers [48–52] explore the use of wearable technology for monitoring vital signs such as blood pressure, oxygen saturation, and heart rate. This includes smartwatches, sensors, and similar devices. Every research highlights the potential benefits associated with these technologies, including

better patient outcomes, more patient engagement, and decreased healthcare costs. They all accept the challenges that must be overcome in order to successfully use wearable technology in continuous vital sign monitoring, including issues with data privacy, security, and the requirement for standardized data gathering and processing procedures.

The work presented in [53] offers a comprehensive synopsis, including algorithms, assessment techniques, and common issues in this field. Similarly, a thorough examination is provided in [54], which focuses on different algorithms, feature extraction approaches, classification methods, and performance assessment measures. In addition to these evaluations, the work in [55] presents a complete system that makes use of wearable sensors such as gyroscopes and accelerometers to categorize a variety of activities in addition to detecting falls. Further exploring the use of wearable sensors in smart home settings. Moreover, the results in [56] highlights behavioral modeling for fall detection and clarifies the difficulties in implementing such systems. Together, these works cover a wide range of research topics, including system construction, algorithms, and difficulties in using wearable sensors for fall detection. As a result, they greatly advance this important field of study.

3. Challenges

Imolementation of any new technology seems to face some hurdles while it initiates its implementation in new phase. From the prospect of wearable devices implementation in healthcare setting, there needs to be addressed following challenges

1. Data Privacy and Security Concerns:

In terms of gathering health data, the widespread use of wearable technology is a double-edged sword that offers convenience but also raises privacy concerns [57]. Fitness trackers and medical-grade wearables are just a few examples of the gadgets that continuously monitor and collect private health data, making it necessary to take precautions against abuse or unauthorized access. Respecting legal frameworks such as HIPAA is essential to guaranteeing patient privacy and security, reducing the possibility of data breaches, and preserving public confidence in healthcare institutions [58].

Adherence to HIPAA standards is essential in preventing the unapproved sharing or misuse of health information gathered via wearable technology. Healthcare practitioners and technology businesses may maintain patient information confidentiality and integrity by following these criteria, which will help to create a safe environment for the use of wearable technology in healthcare settings [58]. In order to address the rising concerns about the possible hazards connected with wearable devices and, ultimately, increase user trust and confidence about the protection of their personal health information, robust security safeguards and privacy protocols are required.

2. Interoperability and Integration:

There are obstacles in integrating wearables into healthcare systems since there are many different platforms and technologies involved. In order to promote effective data exchange and deliver comprehensive patient care, wearables and current electronic health record (EHR) systems must be seamlessly interoperable. Without this kind of connection, medical professionals could find it difficult to access and use the important health data that wearable technology has to offer, which could restrict their capacity to make wise judgments and administer individualized care.

In order to effectively transmit data in the healthcare industry, it is imperative that efforts be made to ensure interoperability between wearables and EHR systems. Healthcare professionals may offer more thorough and individualized treatment by providing seamless integration, which gives them access to real-time health information from wearable devices within the context of patients' electronic health records [59,60]. In the end, interoperability benefits patients and healthcare practitioners alike by increasing the usefulness of wearable technology in clinical settings and encouraging improved accuracy and efficiency in data handling and analysis.

3. Reliability and Accuracy of Data:

The precision and dependability of data gathered by wearable technology are extremely important in the field of healthcare, especially when it comes to supporting clinical decision-making. These technologies give exact measurements and insights about patients' health status, which is what healthcare professionals need to make decisions regarding diagnosis, treatment, and continued care. Any errors or discrepancies in the information might be interpreted incorrectly, which could lead to the wrong medical treatments or the omission of important health conditions. Therefore, it is crucial to guarantee the precision and dependability of data produced by wearables in order to protect clinical decision-making processes and shield patients from unfavorable outcomes [61].

In order to reduce the possibility of misunderstandings and possible damage to patients, wearable technology must go through extensive testing and validation procedures to verify its dependability and accuracy. To make sure that the data produced by wearables are consistent, dependable, and indicative of patients' true health state, this entails evaluating elements including sensor accuracy, data consistency, and device functionality under varied circumstances. In addition, to identify and resolve any problems or inconsistencies that may develop over time, continuous monitoring and quality assurance procedures are required. Wearable technology may successfully enhance clinical decision-making processes by adhering to strict criteria for data integrity and dependability [62]. This will eventually improve patient outcomes and raise the bar for healthcare delivery as a whole.

4. User Adoption and Engagement:

Encouraging patients to interact with the generated data and promoting regular wearable gadget usage are significant challenges in the healthcare industry. However, putting tactics like creating user-friendly interfaces, giving thorough training, and delivering rewards for compliance into practice may greatly increase user adoption rates and promote sustained engagement [63]. Healthcare providers can enable patients to effectively interact with wearable devices and interpret the data they generate by designing user-friendly interfaces that are simple to navigate and understand. This will increase patients' willingness to incorporate these devices into their daily routines.

Promoting sustained engagement also requires providing patients with sufficient training and assistance on how to utilize wearable technology and comprehend the data they provide. Healthcare professionals may enable patients to actively participate in their own health and well-being by providing them with the information and abilities needed to use these devices. Long-term patient engagement with wearable technology and adherence to suggested health behaviors can also be encouraged by providing incentives like discounts or awards for persistent usage and adherence. Healthcare professionals may effectively overcome user adoption hurdles and encourage patients to engage with wearable technology over an extended period of time by combining these tactics [63,64].

5. Regulatory Compliance:

Strict regulatory requirements are in place for wearable medical devices to guarantee their dependability, safety, and effectiveness. Before these devices may be sold and utilized in clinical settings, they must comply with regulatory criteria, such as gaining clearance from organizations like the Food and Drug Administration (FDA) [65,66]. This is vital to ensure that these devices fulfill the appropriate quality and performance standards. For developers of wearable healthcare solutions, navigating the regulatory landscape may be a challenging and time-consuming process since it requires proving compliance with certain regulations and producing copious amounts of paperwork to bolster the device's efficacy and safety.

Wearable medical devices need to go through stringent testing and validation procedures in addition to regulatory compliance in order to verify its accuracy, dependability, and usefulness [67]. To evaluate the device's operation and confirm that it serves the stated medical purpose, these validation methods frequently entail doing performance testing and clinical trials. It might be difficult and time-consuming to navigate regulatory regulations and go through testing, but doing so is necessary to guarantee the quality and safety of wearable healthcare solutions and to give patients and healthcare professionals confidence in their dependability and efficacy.

6. Cost and Reimbursement:

Due to the high cost of the device and related healthcare services, wearable technology adoption within healthcare systems may encounter financial challenges, especially for those with low incomes. Establishing payment models that pay for wearable technology costs and show how these innovations are cost-effective in enhancing patient outcomes are essential to removing this obstacle. Healthcare providers may help patients afford wearable technology and ensure that everyone has access to it, regardless of financial situation, by implementing reimbursement methods like insurance coverage or government subsidies [68].

Moreover, demonstrating the cost-effectiveness of wearable technology in enhancing patient outcomes is essential for garnering support from healthcare stakeholders and decision-makers. Conducting research and analysis to quantify the economic benefits of wearable technology, such as reduced hospitalizations, improved disease management, and enhanced preventive care, can provide compelling evidence to justify investments in these innovations [69]. By showcasing the tangible benefits of wearable technology in terms of both health outcomes and cost savings, stakeholders can be incentivized to prioritize the integration and utilization of these technologies within healthcare systems, thereby facilitating their widespread adoption and uptake. An overview of challenges of wearable technology is provided at [70].

4. Opportunities

High-speed communication developments have completely changed the healthcare industry by making it possible to deploy remote technology like wearables for remote monitoring, video conferencing, and smart home health products widely [71]. These advancements lower the risk of infection and save time and money by enabling remote access to patient data, real-time contact with healthcare practitioners, and fewer in-person visits. They also open up more patient access to experts, improving accessibility to treatment overall and launching telemedicine into a new age [72].

Because cloud computing has made powerful computer resources more accessible, smaller medical institutions may now handle large amounts of medical data and create cutting-edge models without having to make significant infrastructure expenditures. Investments made in healthcare research by the government and insurance companies stimulate innovation and lead to the creation of cutting-edge sensors and remote medical infrastructure. These expenditures guarantee a progressive change in medical technology by considerably improving patient outcomes and lowering healthcare expenses.

In the meanwhile, cutting-edge machine learning algorithms simplify the delivery of healthcare by helping doctors make decisions, gaining insights from the analysis of massive amounts of medical data, and improving resource efficiency [73,74]. Connectivity advancements and sensor downsizing keep medical technology more accessible and affordable while also enabling more effective device communication and increasing access to healthcare, particularly in underprivileged areas. In the end, these developments offer better health results and more accessibility to healthcare for anyone [75].

Several factors pose as inhibitors to the widespread adoption and successful implementation of new medical technology. First, the substantial costs involved in both the development and deployment phases can act as a significant barrier, especially for smaller healthcare facilities. Additionally, the necessity for transparent and explainable machine learning algorithms in the medical realm is crucial to instill trust and ensure decisions align with patient welfare. Adjusting healthcare insurance models and infrastructure is vital to support access to these technologies. Stringent regulatory requirements, including compliance with HIPAA and other testing standards, contribute to time-consuming and costly processes. Protecting sensitive medical data, adhering to privacy regulations like HIPAA, remains a paramount concern [76,77]. Moreover, the challenge of parts obsolescence and lifecycle limitations in medical devices poses hurdles in maintenance and upgrades, driving up costs. Lastly, the complexity of processing vast amounts of medical data necessitates new technologies that can effectively handle these demands.

There are several chances to transform patient outcomes and healthcare delivery with wearable technology. Proactive treatment of chronic illnesses and early diagnosis of health difficulties are made possible by the ability for continuous monitoring of vital signs, activity levels, and other health data that these devices offer. Wearable technology allows healthcare practitioners to tailor treatment plans and treatments based on real-time data about patients' health condition. This improves patient outcomes and raises the standard of care.

The Internet of Things, or IoT, is a new technology paradigm that aims to improve device-to-device communication and make connections easier, even for ever-tinier gadgets. Instead of incorporating sensors into whole wearable devices, there is now more interest in directly connecting individual sensors to communication networks. This method allows physiological data to be collected in real time, necessitating the need for future sensors to be able to communicate large volumes of data on their own. The increasing need for sensors, especially in medical applications, makes it imperative to create more compact and high-performing batteries to power these independent sensors. In essence, the goal is to enable wireless communication for every sensor, which would lessen the need on intricate device integration and radically change the notion of wearables.

Nevertheless, there are obstacles to overcome in order to achieve wireless communication with such small devices, most notably energy consumption. Therefore, the development of stronger batteries that can sufficiently power each device is a must for the evolution of these standalone sensors. To further improve the performance of these isolated sensors, it is imperative to design smaller and more efficient semiconductors in order to optimize energy utilization. In order to fully achieve the promise of IoT-enabled sensor networks to revolutionize different industries, including healthcare, it is imperative that these limitations be overcome [78].

A major divergence from conventional wearable device design is the move towards directly attaching individual sensors to communication networks. Real-time data gathering and analysis are made possible by IoT technology, which focuses on isolated sensors with wireless communication capabilities [78]. Nonetheless, to guarantee the sustainability and efficiency of these sensor networks across a range of applications, tackling issues like energy consumption calls for coordinated efforts in battery and chip development.

On the other hand, improvements in memory size, processing speed, and sensor-to-application communication throughput will make it easier for technological paradigms like artificial intelligence

(AI), which has been progressively incorporated into wearable technology over the past several years, to be adopted. However, continuous work is being done to address the problem of improving the intelligence of each individual sensor so that it can self-adjust to the physiological state of the patient without requiring human interaction for calibration or configuration changes [74].

The goal of creating better biosensors that can measure biosignals from the human body in a more "invasive" manner is gaining interest. More exact measurements of several physiological variables, such blood glucose levels, are made possible by this method [79]. As previously said, the idea of developing ever smaller devices creates a wealth of opportunities for the use of sensors that are suitable for being inserted or implanted into different areas of the human body without posing any discomfort or restriction. Molecular device research has already begun, suggesting a move toward extremely sophisticated yet low-intrusive monitoring systems. Future developments in sensor technology, artificial intelligence, and biosensors promise to bring about advanced monitoring systems that are both precise and actionable in providing health insights, while also blending in seamlessly with people's daily lives.

However, wearable technology makes remote patient monitoring possible. This reduces the need for frequent hospital visits and lowers healthcare expenses by allowing medical personnel to remotely monitor patients' progress and take appropriate action. Furthermore, by offering features like fitness monitoring, medication reminders, and health coaching, wearable technology may encourage better lives and the prevention of disease [17]. This empowers people to take a more active part in managing their health. All things considered, the use of wearable technology to healthcare has the potential to revolutionize the field and make medical care more patient-centered, effective, and easily accessible.

5. Conclusions

The synthesis of learnings from a range of papers exploring wearable technology's application in long-term healthcare presents an enthralling picture of its revolutionary potential. In this context, wearable technology combined with telemedicine emerges as a disruptive force that makes it easier to monitor patients remotely and collect real-time health data. This integration improves the effectiveness of treatments and accuracy by bridging geographical gaps and creating a complete repository of health information. Navigating this upward trajectory is not without its challenges, though. The most important issues are privacy and security concerns around patient data, which demand strong structures and procedures to support broad implementation. In addition, there are many obstacles to overcome, including the need to secure universal support from stakeholders, establish consistent regulatory frameworks, invest in necessary infrastructures, validate data accuracy for well-informed clinical decisions, and ensure interoperability among various devices and systems. However, wearables present a strong value proposition for long-term care facilities. These devices indicate the ultimate level of continuous monitoring capabilities, early health anomaly identification, real-time data access for increased patient involvement, streamlined provider collaboration, decreased readmissions to hospitals, and the exciting potential for long-term cost savings. Wearable technologies have the potential to completely transform the way that extended healthcare is delivered.

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Author Contributions

S.P. wrote initial paper and performed the literature review, L.B.E. revised and write the conclusion, J.C.F. and R.B. supervised and performed the final revision. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest Statement

The authors declare no conflicts of interest.

Data Availability Statement

No data is provided.

References

1. Olmedo-Aguirre J, Biosensors JR-C-, 2022 undefined Remote healthcare for elderly people using wearables: A review. mdpi.comJO Olmedo-Aguirre, J Reyes-Campos, G Alor-Hernández, *Biosensors*, 12(2), 73.
2. Economic UND (2020). Social Affairs PD. *World Population Ageing 2020 Highlights: Living Arrangements of Older Persons*. United Nations. ST/ESA/SERA/451.
3. Prince MJ, Wu F, Guo Y, et al (2015) The burden of disease in older people and implications for health policy and practice. thelancet.comMJ Prince, F Wu, Y Guo, LMG Robledo, M O'Donnell, R Sullivan, S Yusuf. *The Lancet*, 385:549. https://doi.org/10.1016/S0140-6736(14)61347-7.
4. Rizzuto, D., F. Melis R.J., Angleman, S., et al. (2017). Effect of chronic diseases and multimorbidity on survival and functioning in elderly adults. Wiley Online LibraryD Rizzuto, RJF Melis, S Angleman, C Qiu, *A Marengoni Journal of the American Geriatrics Society*, 2017•Wiley Online Library 65:1056–1060. https://doi.org/10.1111/jgs.14868.
5. Wearable Medical Devices Market Size | Research Report [2030]. Available at: https://www.fortunebusinessinsights. com/industry-reports/wearable-medical-devices-market-101070. (Accessed on 15 November 2023).
6. Over a Third of Adults Use Health Apps, Wearables in 2023, Up From 2018. Available at: https://mhealthintelligence. com/news/over-a-third-of-adults-use-health-apps-wearables-in-2023-up-from-2018 (Accessed on 15 November 2023).
7. Most Patients Support Incorporating Wearable Device Data in Healthcare. Available at: https://mhealthintelligence.com/ news/most-patients-support-incorporating-wearable-device-data-in-healthcare (Accessed on 15 November 2023).
8. Wearable Technology Market Size, Share & Industry Growth, 2030. Available at: https://www.fortunebusinessinsights.com/ wearable-technology-market-106000 (Accessed on 15 November 2023).
9. Dehghani, M., Abubakar, A.M., Pashna, M. (2022). Market-driven management of start-ups: The case of wearable technology. *Applied Computing and Informatics* 18:45–60. https://doi.org/10.1016/J.ACI.2018.11.002/FULL/ HTML.
10. Xu, Y., Ou, Q., Cheng, Y., et al (2023) Comparative study of a wearable intelligent sleep monitor and polysomnography monitor for the diagnosis of obstructive sleep apnea. *Sleep and Breathing* 27:205–212. https://doi.org/10.1007/S11325-022-02599-X.
11. Kazanskiy, N., Khonina, S., Physical, M.B.-S. and AA, 2024 undefined *A Review on Flexible Wearables-Recent Developments in Non-Invasive Continuous Health Monitoring*. Elsevier.
12. Jiang S, Zhang T, Zhou Y, et al. *Wearable Ultrasound Bioelectronics for Healthcare Monitoring*. Elsevier
13. Escobar-Linero E, Muñoz-Saavedra L, Sensors FL-P-. 2023 undefined Wearable Health Devices for Diagnosis Support: Evolution and Future Tendencies *Sensors*, *23*(3), 1678.
14. Chen J, Li T, You H, et al. Behavioral interpretation of willingness to use wearable health devices in community residents: a cross-sectional study. *International Journal of Environmental Research and Public Health*, *20*(4), 3247.
15. Google Updates API for Patient Access to Personal COVID-19 Data. Available at: https://ehrintelligence.com/news/google-updates-api-for-patient-access-to-personal-covid-19-data (Accessed on 15 November 2023).
16. Malasinghe LP, Ramzan N, Dahal K (2019) Remote patient monitoring: a comprehensive study. J Ambient Intell Humaniz Comput 10:57–76. https://doi.org/10.1007/S12652-017-0598-X.
17. Shaik T, Tao | Xiaohui, Higgins N, et al (2023) Remote patient monitoring using artificial intelligence: Current state, applications, and challenges. Wiley Online Library 13:. https://doi.org/10.1002/widm.1485.
18. Yhdego H, Paolini C, Sciences MA-A, 2023 undefined Toward Real-Time, Robust Wearable Sensor Fall Detection Using Deep Learning Methods: A Feasibility Study. *Applied Sciences*, *13*(8), 4988.
19. Chang M, Wu Y, Niu H, et al Cross-Platform Gait Analysis and Fall Detection Wearable Device. mdpi.com
20. Atienza A, … LB-2023 II, 2023 undefined Towards Personalized Medication Management: A Novel Approach to Medication Reminder Using Wearable Sensors and IoT. ieeexplore.ieee.org.
21. Marengo LL, Barberato-Filho S (2023) Involvement of Human Volunteers in the Development and Evaluation of Wearable Devices Designed to Improve Medication Adherence: A Scoping Review. *Sensors* 2023, Vol 23, Page 3597 23:3597. https://doi.org/10.3390/S23073597.
22. Guo Y, Liu X, Peng S, et al. *A Review of Wearable and Unobtrusive Sensing Technologies for Chronic Disease Management*. Elsevier.
23. ReportsnReports (2021). Wearable Medical Devices Market by Product (Smartwatch, Smart Glasses, Fitness Tracker, Sleep Tracker, and Insulin Pump), Application (Remote Patient Monitoring, Fall Detection, Medication Reminders, and Chronic Disease Management), End User - Global Forecast to 2025.
24. MarketsandMarkets (2021) Wearable Medical Devices Market by Product (Diagnostic & Monitoring, Therapeu-tic), Application (Remote Patient Monitoring, Fitness & Wellness, Medical Training & Rehabilitation), Component (Sensors, Display), End User—Global Forecast to 2022. [Report]. Available at: https://www.marketsandmarkets.com/report-search-page.asp?rpt=wearable-medical-devices-market. (Accessed 11 September 2023).
25. Research and Markets (2021). Global Wearable Medical Devices Market By Product, By Application, By Region, Competition Forecast & Opportunities, 2012-2022. [Report]. Available at: https://www.researchandmarkets.com/reports/Global-Wearable-Medical-Devices-Market-By-Product-By-Application-By-Region-Competition-Forecast-Opportunities-2012-2022-Report.html. (Accessed on 13 September 2023).

26. Ghosh K, Nanda S, … RH-J of P, 2023 undefined (2023) Mindfulness Using a Wearable Brain Sensing Device for Health Care Professionals During a Pandemic: A Pilot Program. journals.sagepub.com 14:. https://doi.org/10.1177/21501319231162308.
27. Coutu F, Iorio O, Medicine BR-F in, 2023 undefined Remote patient monitoring strategies and wearable technology in chronic obstructive pulmonary disease. ncbi.nlm.nih.gov.
28. Leitner J., Behnke A., Chiang P.-H., et al. (2023) A new approach to digital health? Virtual COVID-19 care: A scoping review. journals.sagepub.com 27:. https://doi.org/10.1109/JBHI.2023.3239366.
29. ERKILIÇ C., Dergisi AY-Gİ ve İ., 2020 undefined (2020) Evaluation of the wearable technology market within the scope of digital health technologies. dergipark.org.tr 6:310–323. https://doi.org/10.30855/gjeb.2020.6.3.006.
30. Mirica K.A. (2024) Unlocking the Potential of Wearable Sensors in Healthcare and Beyond. ACS Sens 9:533–534. https://doi.org/10.1021/ACSSENSORS.4C00325.
31. Nahavandi D., Alizadehsani R., … AK-CM and, 2022 undefined Application of artificial intelligence in wearable devices: Opportunities and challenges. Elsevier.
32. Xie Y., Lu L., Gao F., et al (2018) Integration of artificial intelligence, blockchain, and wearable technology for chronic disease management: a new paradigm in smart healthcare. Springer 41:1123–1133. https://doi.org/10.1007/s11596-021-2485-0.
33. Miao F, Wu D, Liu Z, et al (2022) Wearable sensing, big data technology for cardiovascular healthcare: current status and future prospective. mednexus.org 136:1015–1025. https://doi.org/10.1097/CM9.0000000000002117.
34. Witte H., Blatter T.U., Nagabhushana P., et al. (2023) Statistical learning and big data applications. *Journal of Laboratory Medicine.* https://doi.org/10.1515/LABMED-2023-0037/HTML.
35. Lu T., Ji S., Jin W., et al Biocompatible and Long-Term Monitoring Strategies of Wearable, Ingestible and Implantable Biosensors: Reform the Next Generation Healthcare. mdpi.com.
36. Epstein C., Obstetric TM-J of, Neonatal G&, 2023 undefined Linking Ele.ctronic Health Records With Wearable Technology From the All of Us Research Program. Elsevier.
37. Assenza G., Fioravanti C., … SG-… on M for, 2020 undefined New perspectives on wearable devices and electronic health record systems. ieeexplore.ieee.org.
38. Dutta A., Patel R.B., Sorber M.J. (2020) Wearable Technology for Chronic Disease Management: A Systematic Review. *J. Med. Syst.*
39. Farid M., Hasan A. Wearable Technology and Chronic Disease Management: A Review. J Med Syst
40. Borycki M.S., Kaushal M.C., Jensen R.H. Wearable Devices for Chronic Disease Management: A Review of the Litera-ture. *J. Med. Internet Res.*
41. Chiang K.S., Chao M.F. Wearable Technology and Chronic Disease Management: The Future is Now. *J. Med. Syst.*
42. Mann K.R., Lee K.J. Wearable Technologies for Chronic Disease Management: A Review of the Literature.
43. Yu S., Chen Z,. … XW-J of ER and P, 2023 undefined (2023) The impact of wearable devices on physical activity for chronic disease patients: findings from the 2019 Health Information National Trends Survey. mdpi.com. https://doi.org/10.3390/ijerph20010887.
44. Ferguson C., Hickman L., Turkmani S., et al "Wearables only work on patients that wear them": Barriers and facilitators to the adoption of wearable cardiac monitoring technologies. Elsevier.
45. Arslan N., Pathak P.N., Gupta V.K. Medication Adherence and Wearable Devices: A Review. *J. Med. Syst.*
46. Y. Kim J.K. and J.K., Kim Y., Kim J., Kim J. Wearable Technology for Medication Adherence Monitoring: A Systematic Review. *J. Med. Syst.*
47. Babic J.M., Banavar S. Wearable Technology for Medication Adherence: A Systematic Review. *J. Med. Syst.*
48. Dutta A, Patel RB, Sorber MJ Wearable Vital Sign Monitoring Devices: A Systematic Review. *J. Med. Syst.*
49. Wang X., Liu L., Li Y. Wearable Devices for Continuous Vital Sign Monitoring: A Review of the Literature. *J. Med. Internet Res.*
50. Arslan J.N., Pathak P.N., Gupta V.K. Wearable Technology for Continuous Vital Sign Monitoring: A Systematic Review. *J. Med. Syst.*
51. Kim J.S., Kim J., Kim J. Wearable Devices for Vital Sign Monitoring: A Review of the Literature. *J. Med. Internet Res.*
52. Farid M, Hasan A Wearable Technology for Vital Sign Monitoring: A Review. *J. Med. Syst.*
53. Bet P, Castro P, informatics MP-I journal of medical, *2019 Undefined Fall Detection and Fall Risk Assessment in Older Person Using Wearable Sensors: A Systematic Review*. Elsevier.
54. Ojetola O, Gaura E, International JB-2011 S, 2011 undefined Fall detection with wearable sensors--safe (Smart Fall Detection). ieeexplore.ieee.org.
55. Maglogiannis I, … CI-IC, 2016 undefined (2018). Fall detection and activity identification using wearable and hand-held devices. content.iospress.com. https://doi.org/10.3233/ICA-150509.
56. Forbes G, Massie S, Craw S (2020). Fall prediction using behavioural modelling from sensor data in smart homes. Artif Intell Rev 53:1071–1091. https://doi.org/10.1007/S10462-019-09687-7.
57. Cilliers L (2020) Wearable devices in healthcare: Privacy and information security issues. Health Information Management Journal 49:150–156. https://doi.org/10.1177/1833358319851684.
58. Sui A, Sui W, Liu S, Rhodes R (2023) Ethical considerations for the use of consumer wearables in health research. Digit Health 9:. https://doi.org/10.1177/20552076231153740.
59. Baskar S, Shakeel P, … RK-C, 2020 undefined A dynamic and interoperable communication framework for controlling the operations of wearable sensors in smart healthcare applications. Elsevier.
60. Canali S, Schiaffonati V, Aliverti A (2022) Challenges and recommendations for wearable devices in digital health: Data quality, interoperability, health equity, fairness. PLOS Digital Health 1:e0000104. https://doi.org/10.1371/JOURNAL.PDIG.0000104.

61. Fuller D, Colwell E, Low J, et al. Reliability and validity of commercially available wearable devices for measuring steps, energy expenditure, and heart rate: Systematic review. mhealth.jmir.org.
62. Kobsar D, Charlton JM, Tse CTF, et al. (2020) Validity and reliability of wearable inertial sensors in healthy adult walking: A systematic review and meta-analysis. J Neuroeng Rehabil 17:. https://doi.org/10.1186/S12984-020-00685-3.
63. Nasser Al-Nuaimi M, Arpaci Bandirma Onyedi Eylül Üniversitesi I, Al-Sharafi MA, et al. (2023) Towards a wearable education: Understanding the determinants affecting students' adoption of wearable technologies using machine learning algorithms. Springer 28:2727–2746. https://doi.org/10.1007/s10639-022-11294-z.
64. Sergueeva K, Shaw N, of SL-CJ, 2020 undefined Understanding the barriers and factors associated with consumer adoption of wearable technology devices in managing personal health. Wiley Online Library.
65. Echenim K, Elluri L, Trust KJ, et al. Ensuring privacy policy compliance of wearables with iot regulations. ebiquity.umbc.edu.
66. Viceconti M, Tome M, Dartee W, et al (2022). On the use of wearable sensors as mobility biomarkers in the marketing authorization of new drugs: A regulatory perspective. Front Med (Lausanne) 9:. https://doi.org/10.3389/FMED.2022.996903/FULL.
67. A.V. Minbaleev, K.Y. Nikolskaia, V.M. Zhernova. 2020 undefined (2020). Legal Enforcement of Cybersecurity of Wearable Mobile Devices in Healthcare. atlantis-press.com.
68. Manninger M, Zweiker D, Svennberg E, et al. Current perspectives on wearable rhythm recordings for clinical decision-making: the wEHRAbles 2 survey. academic.oup.com. https://doi.org/10.1093/europace/euab064.
69. Leenen J, Leerentveld C, … J van D-J of medical, 2020 undefined Current evidence for continuous vital signs monitoring by wearable wireless devices in hospitalized adults: systematic review. jmir.org.
70. Nahavandi D, Alizadehsani R, … AK-CM and, 2022 undefined Application of artificial intelligence in wearable devices: Opportunities and challenges. Elsevier.
71. Rana M., 3006-4023 JS-G science (JAIGS) I, 2024 undefined AI in Healthcare: Transforming Patient Care through Predictive Analytics and Decision Support Systems. ojs.boulibrary.com. https://doi.org/10.1109/IC3TSN.2017.82844537.
72. Stoltzfus M, Kaur A, Chawla A, et al (2023) The role of telemedicine in healthcare: an overview and update. Egypt J Intern Med 35:. https://doi.org/10.1186/S43162-023-00234-Z.
73. Wiens J, diseases ES-C infectious, 2018 undefined Machine learning for healthcare: on the verge of a major shift in healthcare epidemiology. academic.oup.com.
74. Unlocked AA-I in M, 2022 undefined Using machine learning for healthcare challenges and opportunities. Elsevier.
75. Ahmad MA, Eckert C, Teredesai A (2018) Interpretable Machine Learning in Healthcare. 559–560. https://doi.org/10.1145/3233547.3233667.
76. Mbonihankuye S, computing AN-… and mobile, 2019 undefined Healthcare data security technology: HIPAA compliance. hindawi.com.
77. Puneeth RP, Parthasarathy G (2023) Survey on Security and Interoperability of Electronic Health Record Sharing Using Blockchain Technology. *Acta Informatica Pragensia* 12:160–178. https://doi.org/10.18267/j.aip.187.
78. Kashani, M., Madanipour, M., … MN-J of N and, *2021 Undefined A Systematic Review of IoT in Healthcare: Applications, Techniques, and Trends*. Elsevier.
79. Kim, E., Joe, C., Mitchell, R., et al. Biosensors for healthcare: Current and future perspectives. Cell.