

Digital Health Technologies in Chronic Disease Management: A Global Perspective

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ABSTRACT

In this systematic review, we delve into the transformative role of digital health technologies in chronic disease management worldwide. The methodology used in this review involves utilizing a comprehensive literature search from databases including PubMed, ResearchGate, and Google Scholar, we analyze and synthesize a broad spectrum of studies to assess the impact and evolution of these technologies. This review highlights how wearable devices, mobile applications, remote monitoring systems, and artificial intelligence are revolutionizing patient care, healthcare delivery, and public health strategies. We examine their influence on patient outcomes, with a particular focus on personalized medicine, real-time monitoring, and data-driven interventions. The review also explores the challenges of technology adoption, regulatory landscapes, and the potential to bridge healthcare disparities. Our methodical approach to collating and examining diverse literature provides a panoramic view of how digital health technologies are reshaping chronic disease management, offering tailored treatment options, and transforming healthcare systems for enhanced patient-centric care and improved health outcomes globally.

KEYWORD: digital; disease, healthcare; management; USA

INTRODUCTION

Chronic diseases are defined as health conditions that last one year or more and require ongoing medical attention or limit activities of daily living or both (Alghamdi, Aldosari, and Alsaed, 2021). Chronic diseases such as heart disease, cancer, and diabetes are the leading causes of death and disability in the United States (Gropper, 2023). They are also leading drivers of the nation's \$4.1 trillion in annual health care costs (Beyer, and Namin, 2023). Many chronic diseases are caused by a short list of risk behaviors: tobacco use and exposure to secondhand smoke, poor nutrition, physical inactivity, and excessive alcohol use (Zhang et al., 2023). Chronic diseases can be managed through a comprehensive approach that includes medication, lifestyle changes, and regular medical check-ups. Digital health technologies have the potential

to revolutionize healthcare delivery, particularly in the management of chronic diseases (Klonoff et al., 2023). Some of the key areas where digital health technologies can be used in chronic disease management include remote consultations, remote monitoring, and tele-education (Lokmic-Tomkins et al., 2023). Digital health tools, including digital therapeutics, wearables, remote patient monitoring, coaching and education, among others, can assist with condition-specific factors (Fürstenau, Gersch, and Schreiter, 2023, Phan, Mitragotri, and Zhao, 2023). Telehealth interventions, such as text messaging, web-based content and applications, and interactive content, can also be used to improve chronic disease management (Skiba et al., 2023, Evans et al., 2023).

In the US, only 32% have no or one chronic condition, 32% have two to three chronic conditions, 23% have four to five, and 14% have six or more (Bauer, 2014). The most common chronic illnesses in the US are heart disease, cancer, stroke, chronic lower respiratory disorders (like chronic obstructive pulmonary disease), and Alzheimer's disease, despite differing studies (Dahlhamer et al., 2018). Chronic conditions cost the US economy more than \$4 trillion a year in healthcare expenses, not to mention the disability and low quality of life they cause (Dieleman et al., 2020).

The escalating prevalence of chronic diseases poses a formidable global health challenge, necessitating innovative approaches to enhance disease management and improve patient outcomes. In this context, the advent of digital health technologies has emerged as a transformative force, offering unprecedented opportunities to revolutionize chronic disease management on a global scale. From cardiovascular conditions and diabetes to respiratory disorders and mental health, the integration of digital solutions has reshaped the landscape of healthcare delivery, providing a comprehensive and patient-centric approach to address the complexities of chronic diseases.

Digital health technologies encompass a diverse array of tools and platforms, including wearable devices, mobile applications, remote monitoring systems, and artificial intelligence (Ullah et al., 2023). These technologies empower individuals in self-management, facilitate real-time monitoring of health parameters, and enable data-driven decision-making by healthcare providers. This comprehensive review explores the multifaceted role of digital health technologies in chronic disease management, providing insights into their global impact on patient care, healthcare systems, and public health initiatives.

Digital health technologies enable the delivery of personalized healthcare interventions, considering individual health profiles, preferences, and response patterns (Khine, 2023). This shift towards tailored strategies has the potential to optimize treatment outcomes and enhance patient engagement. The integration of real-time monitoring systems facilitates continuous data collection, offering a dynamic understanding of disease progression and treatment efficacy. Data analytics further leverages this wealth of information, providing actionable insights for both patients and healthcare providers. Digital tools empower individuals to actively participate in their health management through self-monitoring, lifestyle interventions, and real-time feedback (Choukou et al., 2023). This patient-centric approach fosters a sense of autonomy and responsibility in chronic disease management. The global perspective encompasses an examination of the challenges associated with the widespread adoption of digital health technologies. Regulatory considerations, interoperability issues, and disparities in technology access are explored, providing insights into the complexities of implementation on a global scale.

The review addresses how digital health technologies have the potential to mitigate healthcare disparities by enhancing access to chronic disease management resources, especially in underserved and remote populations.

As the world navigates the evolving landscape of healthcare, this review aims to contribute a comprehensive understanding of the current state and future potential of digital health technologies in chronic disease management. By exploring global perspectives, adoption challenges, and the transformative impact of these

technologies, this review seeks to inform healthcare professionals, policymakers, and researchers about the dynamic role digital health plays in shaping the future of chronic disease care on a global scale.

2.0 Digital Health Technologies in Chronic Disease Management

Digital health technologies have the potential to revolutionize healthcare delivery, particularly in the management of chronic diseases. Some of the key areas where digital health technologies can be used in chronic disease management include remote consultations, remote monitoring, and tele-education (Ndayishimiye, Lopes, and Middleton, 2023). Digital health tools, including digital therapeutics, wearables, remote patient monitoring, coaching and education, among others, can assist with condition-specific factors. These elements include activity trackers, medication reminders, recording A1c levels, blood pressure or other vitals — so that the right information is easily accessible and not drawn from memory during infrequent doctor visits. Telehealth interventions, such as text messaging, web-based content and applications, and interactive content, can also be used to improve chronic disease management.

2.1 Chronic Disease Management

Chronic disease management is a comprehensive approach to managing the symptoms of a long-term disease, allowing patients to enjoy life (Yu et al., 2023). The goal of chronic disease management is to slow down the progression of the disease and help control the symptoms (Huyen et al., 2023). Chronic diseases are health conditions that stay with a patient long-term and don't heal or go away. They can last for several years or for a lifetime. There are many chronic diseases that millions of people have, including cardiovascular disease, diabetes, osteoporosis, arthritis, multiple sclerosis, lupus, asthma, Crohn's disease, ulcerative colitis, and hypothyroidism/hyperthyroidism (Jena and Sharan, 2023).

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2.1.1 Overview of the Global Burden of Chronic Diseases: Chronic diseases, commonly referred to as noncommunicable diseases (NCDs), are characterized by a protracted course and a confluence of behavioral, physiological, environmental, and genetic factors.

Table 1. Prevalence and patterns of Selected Chronic conditions in the USA (1999 – 2010) (Bauer et al.,2014)

	1999-2000	2005-06	2009-10
Diabetes*	9.0%	10.4%	11.5%
High cholesterol*	25.0%	27.0%	26.7%
Hypertension*	30.0%	30.5%	30.0%
Obesity*	30.5%	34.4%	35.7%
Current cigarette smoker†	23.1%	20.8%	19.3%
Did not meet physical activity guidelines‡	54.7%	No data	49.1%
Binge drinking§	14.9%¶	15.4%	15.8%**

Table 1 documents the prevalence and patterns of selected chronic conditions and risk factors between 1999 and 2010. These data are regularly reported in several CDC publications, such as Health, United States, which includes data from the NHIS, NHANES, and other sources (Bauer et al., 2014).

According to study by Hoffman, Rice, and Sung (1996) entitled “Persons with chronic conditions: their prevalence and costs” they discovered that most people who suffer from chronic illnesses are not old or crippled. All ages are impacted by chronic conditions. People with chronic conditions have substantially high costs because they require more care at any age. They discovered that ninety million Americans suffered from one or more chronic conditions in 1987; 39 million of them had multiple chronic conditions. More than 45% of Americans who are not institutionalized have one or more chronic conditions, and the direct medical expenses associated with these conditions make up three quarters of US health care spending.

Diabetes, malignancies, chronic respiratory conditions including asthma and chronic obstructive pulmonary disease, and cardiovascular disorders like heart attacks and strokes are the primary categories of noncommunicable diseases (NCDs) (Dwivedi, and Dwivedi, 2023). People with low- and middle-income countries are disproportionately affected by NCDs; in these countries, 31.4 million NCD deaths worldwide take place (Malarvizhi, Subramaniam, and Jayashree, 2023, Bhattacharya, Heidler, and Varshney, 2023).

NCDs impact people in all age ranges, in all countries and areas. Although these illnesses are frequently linked to older age groups, data indicates that 17 million deaths from NCDs happen before the age of 70 (Acharya, Mukhtar, and Richter, 2023). It is estimated that 86% of these premature deaths take place in low- and middle-income nations (Frick et al., 2023, Acharya, 2023). The risk factors that lead to non-communicable diseases (NCDs) can affect children, adults, and the elderly. These risks include unhealthy diets, physical inactivity, exposure to tobacco smoke, problematic alcohol consumption, and air pollution (Ioniță-Mîndrican et al., 2022).

Up until 2030, the WHO predicts increases in chronic disease-related illnesses and deaths in low- and middle-income nations (Meghji et al., 2021, Adeyi, Smith, and Robles, 2007). The rising average age of the population and the shifting epidemiologic profile of the population are the two main trends contributing to the rising prevalence of chronic disease in developing nations (Adeyi, Smith, and Robles, 2007).

Figure 1 illustrates that the mortality increase resulting from an aging population will not be outweighed by anticipated improvements in age-specific death rates from chronic diseases in developing nations.

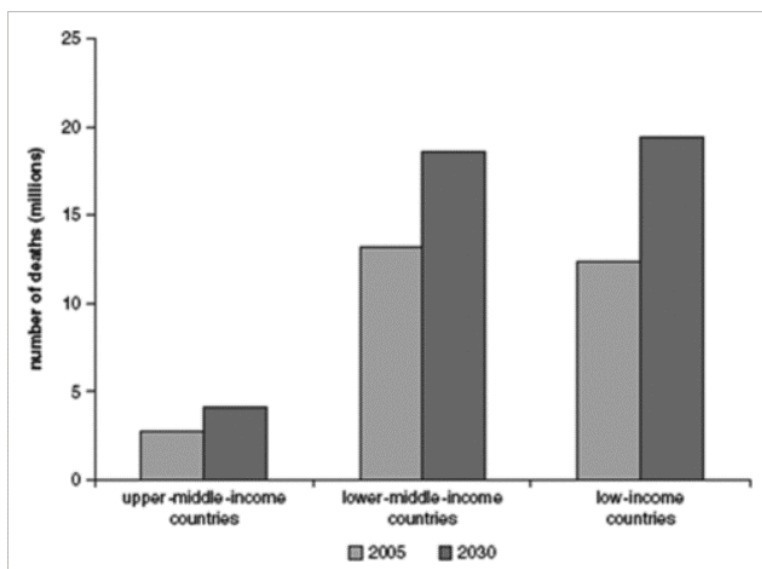


Figure 1. Projected deaths due to noncommunicable diseases by country income level, 2005 and 2030. Reprinted with permission from the World Bank (Adeyi, Smith, and Robles, 2007)

Chronic diseases are the largest cause of death in the world, accounting for 41 million deaths annually, which is equivalent to 74% of all deaths globally (Bauer et al., 2014). The leading chronic diseases include cardiovascular disease, cancer, chronic respiratory disease, and diabetes, which caused 29 million deaths worldwide in 2002 (Anderson, and Durstine, 2019). The Global Burden of Disease (GBD) study provides a comprehensive picture of mortality and disability across countries, time, age, and sex. It quantifies health loss from hundreds of diseases, injuries, and risk factors, so that health systems can be improved and disparities eliminated (GBD, 2019). The GBD study has gained international recognition on the Strategic Approach and Sound Management of Chemicals and Waste Beyond 2020. Digital health technologies have the potential to revolutionize healthcare delivery, particularly in the management of chronic diseases. Some of the key areas where digital health technologies can be used in chronic disease management include remote consultations, remote monitoring, and tele-education.

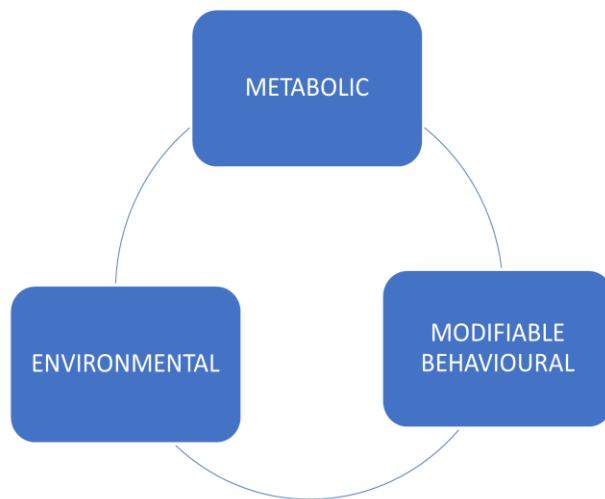


Figure 2. Risk Factors of Chronic Disease (NCDs)

The key risk factors of chronic disease is shown in the figure 2. They are mainly metabolic risk factors, environmental risk factors, and modifiable behavioural risk factors. The probability of NCDs is increased by adjustable behaviors like smoking, lack of exercise, eating an unhealthy diet, and drinking alcohol excessively. Almost 8 million deaths worldwide are related to tobacco use (including those caused by secondhand smoke exposure). Excessive consumption of salt and potassium has been linked to 1.8 million deaths per year (Ботякова, 2023). Cancer and other NCDs account for over fifty percent of the 3 million alcohol-related deaths that occur each year. Lack of exercise is a contributing factor in 830,000 deaths per year (Moradell et al., 2023).

Four major metabolic alterations raise the risk of noncommunicable diseases (NCDs) and are influenced by metabolic risk factors: elevated blood pressure, obesity or overweight, hyperglycemia (high blood glucose), and hyperlipidemia (high blood fat levels). Raised blood pressure leads the metabolic risk factors in terms of attributable deaths globally, accounting for 19% of deaths worldwide (Daiber, Hahad, and Münzel, 2023). Increased blood glucose, overweight, and weight gain follow.

NCDs are a result of various risk factors associated with the environment. The greatest among these is air pollution, which is responsible for 6.7 million deaths worldwide, of which 5.7 million are attributable to NCDs, such as lung cancer, ischemic heart disease, stroke, and chronic obstructive pulmonary disease (Liu

et al., 2023, Polezer et al., 2023, Singal, Kanwal, and Llovet, 2023).

Minimizing the risk factors connected to NCDs is a key strategy for managing these illnesses (Larkin et al., 2023). Governments and various stakeholders can lower the generally modifiable risk factors at a reasonable cost. In order to inform policy and set priorities, it is critical to track the development, trends, and risk associated with NCDs. A multifaceted approach is needed to mitigate the impact of NCDs on people and society. This involves collaboration between various sectors, including health, finance, education, transportation, agriculture, and planning, in order to lower the risks associated with NCDs and advance measures aimed at their prevention and control.

It is essential to make investments in improved NCD management. In addition to identifying, diagnosing, and treating NCDs, management of these illnesses entails giving those in need of palliative care access to it. To improve early detection and prompt treatment, primary health care can provide high impact essential NCD interventions. Research indicates that these interventions are very cost-effective because they can prevent patients from needing more costly care if given early. It is unlikely that nations with insufficient health care coverage will offer crucial NCD interventions to all citizens. Achieving the SDG target on NCDs requires NCD management interventions.

2.2 Digital Health Technologies

Digital health technologies use computing platforms, connectivity, software, and sensors for health care and related uses. These technologies span a wide range of uses, from applications in general wellness to applications as a medical product (Stasevych, and Zvarych, 2023). They include technologies intended for use as a medical product, in a medical product, as companion diagnostics, or as an adjunct to other medical products (devices, drugs, and biologics). Digital health tools have the vast potential to improve our ability to accurately diagnose and treat disease and to enhance the delivery of health care for the individual. Digital health offers real opportunities to improve medical outcomes and enhance efficiency. These technologies can empower consumers to make better-informed decisions about their own health and provide new options for facilitating prevention, early diagnosis of life-threatening diseases, and management of chronic conditions outside of traditional health care settings. Providers and other stakeholders are using digital health technologies in their efforts to reduce inefficiencies, improve access, reduce costs, increase quality, and make medicine more personalized for patients.

2.2.1 Significance of Digital Health Technologies in Chronic Disease Management

Digital health technologies have the vast potential to improve our ability to accurately diagnose and treat disease and to enhance the delivery of health care for the individual. Digital health offers real opportunities to improve medical outcomes and enhance efficiency. These technologies can empower consumers to make better-informed decisions about their own health and provide new options for facilitating prevention, early diagnosis of life-threatening diseases, and management of chronic conditions outside of traditional health care settings. Providers and other stakeholders are using digital health technologies in their efforts to reduce inefficiencies, improve access, reduce costs, increase quality, and make medicine more personalized for patients. Chronic disease management is a comprehensive approach to managing the symptoms of a long-term disease, allowing patients to enjoy life. The goal of chronic disease management is to slow down the progression of the disease and help control the symptoms. Chronic diseases are health conditions that stay with a patient long-term and don't heal or go away. They can last for several years or for a lifetime. Digital health tools have the vast potential to improve chronic disease management. Some of the key areas where digital health technologies can be used in chronic disease management include remote consultations, remote monitoring, and tele-education. Digital health tools, including digital therapeutics, wearables, remote patient monitoring, coaching and education, among others, can assist with condition-specific factors. Telehealth interventions, such as text messaging, web-based content and applications, and interactive content, can also

be used to improve chronic disease management.

2.3 Personalized Medicine and Tailored Interventions: Personalized medicine, also known as precision medicine, is a medical model that tailors treatment strategies to individual patients based on their unique genetic, molecular, and environmental characteristics. This approach contrasts with the traditional “one-size-fits-all” approach to healthcare, which often leads to suboptimal treatment outcomes and unnecessary side effects. Tailored interventions are specific treatment strategies designed based on the individual patient’s personalized medicine profile. These interventions can include Pharmacogenomics, Biomarker-driven therapy, Genomics-guided surgery, Behavioral medicine, Nutritional genomics. Utilizing genetic information to guide drug selection and dosage, minimizing adverse reactions and maximizing efficacy. Targeting specific biomarkers indicative of disease progression or treatment response to personalize therapeutic strategies. Tailoring dietary recommendations based on an individual’s genetic predisposition to certain diseases or conditions. Using genetic information to plan surgical procedures and improve outcomes. Employing personalized interventions to address specific behavioral and lifestyle factors contributing to disease risk or management.

Benefits of Personalized Medicine and Tailored Interventions are Improved treatment efficacy, Reduced side effects, Enhanced patient engagement, more cost-effective healthcare. Tailored interventions are more likely to be effective for individual patients, leading to improved disease outcomes and quality of life. Personalized medicine minimizes the risk of adverse reactions to medications and other interventions. Patients are more likely to be engaged in their care when they understand how it is tailored to their specific needs and preferences. Personalized medicine can lead to more efficient use of healthcare resources by avoiding unnecessary treatments and tests.

Challenges of Personalized Medicine and Tailored Interventions include Cost and accessibility, Data privacy and security, Ethical considerations, Limited evidence base. Implementing personalized medicine requires access to advanced technologies and expertise, which can be costly and inaccessible for some patients. Personalized medicine relies on the collection and analysis of large amounts of personal data, raising concerns about data privacy and security. The use of genetic information in healthcare raises ethical concerns around potential discrimination and social stigma. The evidence base for many personalized medicine interventions is still evolving, requiring further research and validation.

2.3.1 Future of Personalized Medicine and Tailored Interventions: Despite the challenges, personalized medicine has the potential to revolutionize healthcare by providing safer, more effective, and more personalized care. Advances in technology, such as artificial intelligence and big data analytics, are expected to accelerate the development and implementation of personalized medicine interventions. As the field continues to grow, it is important to address ethical concerns and ensure equitable access to these promising advancements.

Some specific examples of personalized medicine and tailored interventions are here presented. Using genetic information to determine the optimal dosage of a specific medication, such as warfarin, an anticoagulant. Tailoring chemotherapy regimens for cancer patients based on the genetic profile of their tumor. Developing personalized vaccines against infectious diseases based on an individual’s immune response. Recommending specific dietary interventions to individuals based on their genetic predisposition to type 2 diabetes. Providing behavioral counseling tailored to address an individual’s specific risk factors for mental health disorders.

Overall, personalized medicine and tailored interventions offer a promising approach to improving healthcare outcomes and reducing healthcare costs. As the field continues to advance, it has the potential to revolutionize the way we prevent, diagnose, and treat diseases.

2.4 Real-Time Monitoring and Data Analytics: Real-time monitoring and data analytics (RTMDA) have emerged as transformative tools in various fields, including healthcare, finance, manufacturing, and environmental monitoring. By providing continuous insights into complex systems and processes, RTMDA enables faster and more informed decision-making, leading to improved efficiency, safety, and overall performance.

Key Components of RTMDA include Data Collection, Data Processing, Data Visualization, Alerting and Notifications. Sensor networks, IoT devices, and other data acquisition technologies are used to collect real-time data from various sources. Stream processing frameworks and analytical tools are used to analyze and transform raw data into actionable insights. Real-time dashboards and other visualization tools are used to present data in a clear and understandable way. Automated alerts can be set up to notify users of critical events or potential issues.

Benefits of RTMDA include Enhanced decision-making, Improved efficiency, Increased safety, Enhanced customer experience, Boosted profitability. Real-time insights allow for faster and more informed decisions based on current data. RTMDA can help optimize processes, reduce waste, and improve resource utilization. Real-time monitoring can help identify and address potential safety hazards quickly and effectively. RTMDA can be used to personalize customer experiences and provide real-time support. RTMDA can lead to increased revenue and reduced costs by improving operational efficiency and effectiveness.

RTMDA finds application in various sector. Real-time monitoring of vital signs, patient activity, and medical equipment performance. Market analysis, fraud detection, and risk management. Predictive maintenance, quality control, and process optimization. Air quality, water quality, and weather forecasting. Traffic management, fleet optimization, and vehicle safety.

Despite the vast potential of RTMDA, some challenges exist. Real-time systems generate large volumes of data at high speeds, requiring efficient data processing and storage solutions. Protecting sensitive data from unauthorized access and ensuring privacy compliance is crucial. Integrating data from diverse sources can be complex and requires robust data management systems. Excessive alerts can lead to user fatigue and desensitization, reducing their effectiveness. Implementing and utilizing RTMDA effectively requires specialized skills and expertise.

The Future of RTMDA will be driven by technologies such as ML, edge computing among others. Machine learning, artificial intelligence, and other advanced analytics techniques will be used to extract deeper insights from real-time data. Processing data closer to the source will enable faster decision-making and reduce latency. RTMDA will be increasingly integrated with IoT devices and networks, expanding its reach and impact. Real-time data will be used to predict and prevent future events, leading to proactive management of systems and processes. RTMDA tools and technologies will become more user-friendly and affordable, making them accessible to a wider range of users and organizations.

Overall, RTMDA has the potential to revolutionize various sectors by providing real-time insights and enabling faster, more informed decision-making. As technology continues to evolve, RTMDA is expected to play an increasingly critical role in optimizing operations, improving efficiency, and driving innovation across industries.

2.5 Patient Empowerment and Self-Management: A Holistic Approach to Healthcare

Patient empowerment and self-management (PESM) represent a paradigm shift in healthcare, moving away from a solely provider-driven model towards a collaborative approach where patients actively participate in managing their own health. This shift recognizes the patient as the central figure in their healthcare journey,

fostering greater ownership and responsibility for their well-being.

Key components of PESM are here discussed. Providing patients with clear, accurate, and accessible information about their condition, treatment options, and self-management strategies. Equipping patients with the skills and tools necessary to manage their condition effectively, such as monitoring symptoms, adhering to treatment plans, and healthy lifestyle habits. Facilitating shared decision-making between patients and healthcare providers, allowing patients to make informed choices about their care. Addressing the emotional and social aspects of living with a chronic condition through peer support groups, mental health resources, and social service programs. Leveraging telehealth, mobile apps, and other digital tools to empower patients to remotely manage their health and connect with healthcare providers.

PESM can lead to better disease control, reduced complications, and overall improved health outcomes. Patients feel more empowered and engaged in their care, leading to increased satisfaction with their healthcare experience. PESM can help reduce healthcare costs by decreasing hospital admissions, emergency room visits, and unnecessary interventions. PESM empowers patients to live fulfilling lives despite their health challenges.

Examples of PESM interventions include Diabetes self-management education, Asthma action plans, Chronic pain management programs, Mental health self-help apps. Providing individuals with diabetes with the skills and knowledge to manage their blood sugar levels, diet, and exercise. Empowering individuals with asthma to recognize and manage their symptoms effectively. Helping individuals with chronic pain develop coping strategies and pain management techniques. Providing individuals with tools and resources to manage anxiety, depression, and other mental health conditions.

Challenges of PESM include Health literacy, Access to resources, Motivation and adherence. Ensuring that patients have the necessary knowledge and skills to understand their condition and manage their health effectively. Not all patients have equal access to healthcare providers, technology, and other resources necessary for self-management. Sustaining patient motivation and adherence to self-management plans can be challenging. PESM interventions need to be culturally sensitive and tailored to the needs and preferences of diverse populations.

Future of PESM will include Personalized medicine, Technology integration, Community-based interventions, Policy and system changes. PESM will be increasingly personalized based on individual patient needs and preferences. Advanced technologies like telehealth, wearables, and AI will play a more significant role in supporting self-management. PESM programs will be integrated into community settings to reach a wider range of patients. Healthcare systems need to adapt to support and encourage self-management strategies.

PESM is a crucial approach to improving patient outcomes, reducing healthcare costs, and empowering individuals to take control of their health. As technology advances and healthcare systems evolve, PESM is poised to become the standard of care, leading to a more patient-centered and sustainable healthcare model.

2.6 Global Adoption Challenges and Regulatory Considerations in Digital Health Technologies: The integration of digital health technologies holds immense promise for transforming healthcare globally. However, the widespread adoption of these technologies faces a myriad of challenges, including infrastructure limitations, socio-economic factors, and regulatory complexities. This review explores the key global adoption challenges and regulatory considerations that influence the successful implementation of digital health technologies on a worldwide scale. Despite the immense potential of emerging technologies like AI, machine learning, and genomics to revolutionize healthcare, their global adoption faces several challenges and raises significant regulatory concerns. Addressing these challenges and navigating the regulatory landscape effectively are crucial for ensuring the responsible and equitable access to these

transformative advancements.

Lack of reliable internet connectivity, limited access to advanced technology, and inadequate digital literacy can hinder widespread adoption, particularly in resource-limited settings. Concerns regarding data collection, storage, and sharing, coupled with potential breaches and misuse of sensitive patient information, require robust cybersecurity measures and ethical data governance frameworks. Algorithmic biases present in training data can lead to discriminatory outcomes and exacerbate existing health disparities. Addressing bias requires diverse datasets, transparent algorithms, and robust oversight mechanisms. Implementing and integrating emerging technologies can be expensive, and their value proposition may not be readily recognized by healthcare systems, hindering widespread adoption. Healthcare professionals need training and development opportunities to adapt to new technologies and integrate them effectively into their practice.

Regulatory Considerations are here proposed. Ensuring compliance with data protection regulations like GDPR and HIPAA requires robust data governance practices and transparent patient consent procedures. Establishing clear regulatory pathways for clinical trials involving emerging technologies is crucial for ensuring patient safety and ethical research practices. Developing regulations specific to AI in healthcare is necessary to address ethical considerations, mitigate potential harms, and promote responsible development and deployment. Lack of harmonization in regulatory frameworks across different countries can create barriers to global adoption and hinder innovation.

Strategies for Addressing Challenges and Considerations. Governments and healthcare organizations need to invest in expanding internet access, digital literacy programs, and robust data infrastructure to ensure equitable access. Implementing ethical data governance frameworks that prioritize patient privacy, security, and transparency is essential. Developing diverse datasets, implementing fairness audits, and actively mitigating biases in algorithms are crucial to addressing algorithmic bias. Demonstrating the value proposition of emerging technologies and exploring innovative economic models like pay-for-performance or value-based care can facilitate adoption. Providing healthcare professionals with training and support to acquire the necessary skills and knowledge to effectively utilize emerging technologies is crucial. Collaborating on developing harmonized regulatory frameworks across different countries can streamline global adoption and promote innovation.

Global adoption of emerging technologies in healthcare presents both tremendous opportunities and significant challenges. By addressing infrastructure and access limitations, prioritizing data privacy and security, ensuring algorithmic fairness, demonstrating value, and investing in workforce development, we can unlock the potential of these technologies to improve healthcare outcomes and accessibility worldwide. Collaboration among stakeholders, including policymakers, industry leaders, healthcare professionals, and patients, is key to navigating the regulatory landscape and ensuring responsible and equitable access to these transformative advancements.

2.7 Reducing Healthcare Disparities: Healthcare disparities remain a major obstacle to achieving optimal health outcomes for all individuals and communities. These disparities arise from complex social, economic, and environmental factors, leading to unequal access to quality healthcare, differential treatment experiences, and ultimately, poorer health outcomes for certain population groups. Addressing these disparities is essential to creating a more just and equitable healthcare system.

Key Drivers of Healthcare Disparities are here presented. These factors, such as poverty, lack of education, and limited access to healthy food and transportation, significantly contribute to health disparities. Systemic barriers embedded in healthcare systems and beyond can lead to discriminatory practices and unequal access to quality care for marginalized groups. Healthcare providers may lack cultural sensitivity and understanding of diverse patient populations, leading to miscommunication and suboptimal

care. Unconscious biases held by healthcare professionals can influence their clinical decisions and interactions with patients, negatively impacting care quality. **Limited access to health insurance and medical services.** Uninsured individuals and those living in underserved areas may face limited access to primary care, preventive services, and specialized treatments.

Some Strategies for Reducing Healthcare Disparities are here presented. Addressing social determinants of health. Investing in programs that address poverty, housing insecurity, food insecurity, and other social determinants can improve overall health and reduce disparities. **Combating structural racism and discrimination.** Implementing anti-discrimination policies, promoting diversity and inclusion within healthcare organizations, and addressing implicit bias are crucial steps. Training healthcare providers in cultural competency and providing language assistance can improve communication and build trust with diverse patient populations. Telehealth can expand access to care for underserved communities and remove geographic barriers. Partnering with community organizations and empowering patients to advocate for their health needs can drive positive change. Disaggregated data collection and analysis can identify disparities and inform targeted interventions. Advocating for policies that address the root causes of healthcare disparities and promote equity is crucial.

Examples of Successful Initiatives include the Patient-Centered Medical Home model. This model promotes coordinated care and personalized attention, leading to improved health outcomes for diverse populations. **Community health centers** provide culturally competent and affordable healthcare services to underserved communities. **Mobile health clinics** bring healthcare services directly to underserved communities, removing transportation barriers. **Health literacy programs** empower individuals with the knowledge and skills to navigate the healthcare system and advocate for their health needs.

Challenges and Future Directions centres around Funding and sustainability, Evaluation and impact assessment, Collaboration and partnerships. Securing sustainable funding for initiatives aimed at reducing healthcare disparities is critical. Rigorous evaluation of interventions is necessary to track progress and identify areas for improvement. Building strong collaborations among stakeholders, including policymakers, healthcare providers, community organizations, and patients, is essential for success. Addressing the social and economic factors that contribute to healthcare disparities requires long-term commitment and systemic change.

Reducing healthcare disparities requires a multifaceted approach that tackles the root causes of these inequalities. By implementing comprehensive strategies, promoting collaboration, and investing in long-term solutions, we can create a healthcare system that provides equitable access to quality care for all individuals and communities. Achieving healthcare equity is not just a moral imperative, but also a vital step towards a healthier and more just society.

3.0 Future Prospects and Innovations

Digital health technologies have the potential to revolutionize healthcare delivery, particularly in the management of chronic diseases. Some of the key areas where digital health technologies can be used in chronic disease management include remote consultations, remote monitoring, and tele-education. Digital health tools, including digital therapeutics, wearables, remote patient monitoring, coaching and education, among others, can assist with condition-specific factors. Telehealth interventions, such as text messaging, web-based content and applications, and interactive content, can also be used to improve chronic disease management.

In the future, digital health technologies are expected to become more sophisticated and personalized, with the use of artificial intelligence (AI) and machine learning (ML) algorithms (Agarwal et al., 2021). These technologies will enable healthcare providers to deliver more targeted and effective treatments, and will

allow patients to take a more active role in their own healthcare. Wearable devices and sensors will become more advanced, allowing for continuous monitoring of vital signs and other health indicators. The use of telemedicine is also expected to increase, with more patients opting for remote consultations and remote monitoring (Sreedhara et al., 2022).

Overall, the future of digital health technologies in chronic disease management is bright, with the potential to improve patient outcomes and reduce healthcare costs.

3.1 Technological Advancements and Emerging Trends

Technological advancements and emerging trends are rapidly transforming the healthcare landscape, offering exciting opportunities to improve patient care, enhance efficiency, and drive innovation.

AI is revolutionizing healthcare through applications in Diagnosis and prognosis, Drug discovery and development, Robot-assisted surgery, Administrative tasks. AI algorithms can analyze medical images and data to identify diseases, predict disease progression, and personalize treatment plans. AI can accelerate drug discovery by identifying promising drug candidates and optimizing clinical trials. AI-powered robots are being used for minimally invasive surgeries, leading to improved precision and reduced recovery times. AI can automate administrative tasks, freeing up healthcare professionals to focus on patient care.

By analyzing vast amounts of healthcare data, including electronic health records, genomic data, and wearable device data, we can gain deeper insights into disease patterns, patient responses to treatment, and healthcare trends. This can lead to improved population health management. Identifying at-risk individuals and implementing preventative measures. Tailoring treatment plans based on individual patient characteristics. Providing healthcare professionals with real-time insights to inform clinical decisions. Wearable devices and sensors are becoming increasingly sophisticated and integrated into healthcare, enabling; Remote monitoring of vital signs, Continuous data collection. This allows for early detection of potential health issues and timely intervention. Wearables can collect data on physical activity, sleep patterns, and other health metrics, providing valuable insights for patients and healthcare providers. Wearable data can be used to personalize fitness plans, nutrition recommendations, and other health interventions. Telehealth technologies like video conferencing and mobile apps are expanding access to healthcare, particularly for underserved communities and those with limited mobility. Telehealth can provide remote consultations and diagnoses. It can offer ongoing monitoring and management of chronic conditions. It increases access to mental health services. And reduce healthcare costs by avoiding unnecessary hospital visits.

Blockchain technology has the potential to revolutionize healthcare. Improving data security and privacy. Blockchain can securely store and manage patient data, reducing the risk of breaches and unauthorized access. Blockchain can enable seamless data exchange between different healthcare providers and institutions. Patients can have greater control over their health data and access it from anywhere.

The emerging trends are here presented. Personalized treatment plans based on individual genetic profiles. Software applications used to treat or manage medical conditions. Modifying genes to treat diseases. 3D printing of organs and other body parts for transplantation. Virtual reality and augmented reality applications for surgery training and patient education. These advancements and trends offer tremendous potential to improve healthcare outcomes, reduce costs, and create a more patient-centered healthcare system. However, it is important to address ethical considerations, ensure equitable access to these technologies, and invest in research to maximize their benefits while mitigating potential risks.

Overall, the future of healthcare is bright with technological advancements and emerging trends paving the way for a more efficient, personalized, and accessible healthcare system. As these technologies continue to

develop, we can expect to see even greater transformations in the way we diagnose, treat, and manage health.

3.2 Potential Impact on Global Health Systems: The potential impact of technological advancements and emerging trends on global health systems is multifaceted and far-reaching. While these advancements offer significant opportunities to improve healthcare delivery, access, and outcomes, there are also potential challenges and risks to consider.

Telehealth, mobile technology, and wearable devices can connect patients in remote areas with healthcare providers, overcoming geographical barriers and improving access to essential services. AI-powered tools can analyze medical images and data to aid in diagnosis, identify potential health risks, and personalize treatment plans, leading to better health outcomes. Automation of administrative tasks through AI and robotics can free up healthcare professionals' time and resources, improving efficiency and reducing costs. Wearable devices and patient portals can provide individuals with real-time data and insights into their health, promoting self-management and active participation in their healthcare. Big data analytics can provide valuable insights into disease patterns, resource allocation, and healthcare system performance, informing evidence-based policy decisions. Improved data collection and analysis through technological advancements can help identify and respond to public health threats more effectively.

Challenges and Risks are here presented. Unequal access to technology and digital literacy can exacerbate existing health disparities and leave marginalized communities behind. Concerns about data breaches and misuse of personal health information require robust cybersecurity measures and ethical data governance frameworks. AI algorithms are susceptible to biases present in training data, which can lead to discriminatory outcomes and perpetuate existing health disparities. Overdependence on technology can lead to dehumanization of care and neglect of the human connection crucial for patient well-being. Emerging technologies like gene editing raise complex ethical questions that need careful consideration and public discourse. Implementing and maintaining advanced technologies can be expensive, posing challenges for resource-limited settings.

To maximize the positive impacts of technological advancements while mitigating potential risks, a collaborative and proactive approach is vital. This includes investing in infrastructure and digital literacy. Ensuring equitable access to technology and internet connectivity is crucial for inclusive healthcare. Developing robust data governance frameworks. Protecting patient privacy and securing sensitive health information requires ethical guidelines and strong cybersecurity measures. Implementing fair data collection practices, auditing algorithms for bias, and promoting algorithmic transparency are essential. Technology should be used to complement and enhance human interaction, not replace it. Engaging in open dialogue and ethical considerations. Public discourse and collaboration among stakeholders are crucial to address ethical concerns and ensure responsible development and deployment of technology.

Investing in research and development. Continued research is needed to further develop these technologies, evaluate their effectiveness, and address potential risks.

Technological advancements have the potential to revolutionize global health by making care more accessible, efficient, and personalized. However, navigating this transformation effectively requires a focus on equity, ethics, and responsible implementation. By addressing the challenges and ensuring that technology serves as a tool for good, we can create a healthier and more equitable future for everyone.

3.3 Challenges and Opportunities for Future Integration

Challenges and Opportunities for Future Integration of Artificial Intelligence in Healthcare

Despite its immense potential, integrating AI into healthcare faces several challenges and presents exciting

opportunities. Addressing these challenges and leveraging the opportunities will be crucial for unlocking the full potential of this transformative technology.

Ensuring patient privacy and securing sensitive medical data is paramount. Robust data governance frameworks and cybersecurity measures are essential. AI algorithms can perpetuate existing biases present in training data, leading to discriminatory outcomes. Addressing bias requires diverse datasets, transparent algorithms, and ongoing monitoring. The “black box” nature of some AI models makes it difficult to understand their decision-making processes, hindering trust and acceptance. Explainable AI techniques can address this issue. Clinical validation and regulatory hurdles. AI solutions require rigorous clinical validation and approval by regulatory bodies before widespread adoption. Integrating AI seamlessly with existing healthcare infrastructure can be complex and costly. Healthcare professionals need training and support to adapt to AI and integrate it effectively into their practice.

AI can revolutionize healthcare by enabling personalized diagnosis, treatment, and disease prevention based on individual genetic profiles and health data. AI can assist healthcare professionals in diagnoses, predict disease progression, and personalize treatment plans, leading to improved patient outcomes. AI can automate administrative tasks, streamline workflows, and optimize resource allocation, leading to increased efficiency and reduced costs. AI-powered tools can provide patients with personalized health insights and support self-management, fostering patient engagement and better health outcomes. AI can accelerate drug discovery by identifying promising drug candidates and optimizing clinical trials. AI-powered telehealth platforms can expand access to healthcare, particularly for underserved communities and patients with limited mobility.

Future Directions will Focus on data privacy and security. Developing robust data governance frameworks, implementing strong cybersecurity measures, and ensuring patient control over their data are crucial. Developing and implementing fairness-aware AI. Mitigating algorithmic bias requires diverse datasets, implementing fairness audits, and employing explainable AI techniques. Promoting human-centered AI. AI should be used to complement and enhance human decision-making, not replace it. Investing in research and development. Continued research is needed to further develop AI tools, improve their interpretability, and validate their clinical efficacy. Developing ethical guidelines and regulations. Establishing ethical guidelines and regulations for AI development and deployment in healthcare is essential. Providing healthcare professionals with training and support to utilize AI effectively is crucial for successful integration.

AI holds immense potential to transform healthcare by improving patient care, enhancing efficiency, and reducing healthcare disparities. Addressing the challenges and leveraging the opportunities will be crucial for realizing this potential. By working collaboratively and prioritizing ethical considerations, we can ensure that AI serves as a force for good in healthcare, leading to a healthier and more equitable future for everyone.

3.4 Envisioning the Next Frontier in Digital Health Technologies: The future of digital health technologies is brimming with possibilities, promising to revolutionize the way we approach healthcare. As technology continues to evolve at an unprecedented pace, we can expect to see advancements that transcend current limitations and usher in a new era of personalized, predictive, and preventative medicine.

Some of the potential frontiers in digital health technologies are here presented. Personalized medicine will be further personalized by integrating individual genetic and protein profiles into diagnosis, treatment, and prevention strategies. AI-powered diagnostics will analyze individual biomarkers and health data to identify disease risks with greater accuracy and earlier detection. Treatment plans will be tailored in real-time based on individual responses to therapy and continuous monitoring of health data. Predictive and Preventative Medicine. AI algorithms will analyze vast datasets to predict individual disease risks and identify early signs of illness, enabling preventative interventions. Virtual representations of individuals based on their biological data will be used to simulate disease progression and test potential treatments, allowing for

personalized preventative measures. Software-based interventions will be used to treat and manage chronic conditions, providing personalized and accessible care.

Securely storing and sharing medical data across diverse platforms will enable decentralized and accessible care, empowering patients and breaking down geographical barriers. Internet of Medical Things (IoMT). Connected medical devices and sensors will continuously monitor vital signs and health data, enabling remote monitoring and personalized interventions. Virtual consultations and immersive experiences will enhance patient access to specialists and provide personalized care remotely.

3.4.1 Human-Machine Collaboration: AI-powered decision support. AI will assist healthcare professionals in diagnosis, treatment planning, and risk assessment, leading to more informed and personalized care. Surgeons will be aided by AR overlays providing real-time anatomical information and guidance, enhancing surgical precision and safety. AI-powered virtual coaches will provide personalized health advice, behavior modification support, and ongoing motivation to individuals.

3.4.2. Ethical Considerations and Social Impact: Robust measures will be essential to protect sensitive health data and ensure patient privacy in the digital health landscape. Addressing and mitigating potential biases in AI algorithms will be crucial to ensure fair and equitable access to healthcare. Bridging the gap in access to technology and digital literacy will be critical to ensure inclusive healthcare and address potential disparities.

The next frontier in digital health technologies promises a future where healthcare is personalized, proactive, and accessible to all. However, navigating this transformation responsibly requires addressing ethical concerns, promoting equitable access, and investing in research and development to ensure that these technologies serve as a force for good in improving global health.

RECOMMENDATION

There is need for more advocacy for the development and adoption of global interoperability standards for digital health technologies. Standardized communication protocols and data formats will facilitate seamless information exchange between different systems, improving continuity of care for individuals with chronic diseases across borders. There should be an encouragement of international collaboration to harmonize regulatory frameworks for digital health technologies. Streamlining regulations across countries can expedite the approval and deployment of innovative solutions, ensuring global access to effective tools for chronic disease management. Data privacy and security by prioritizing the establishment of robust global standards for data privacy and security in digital health. Addressing concerns related to patient confidentiality and data protection is essential to foster trust among users and promote the responsible use of health data. Capacity building and training by investing in global initiatives for capacity building and training healthcare professionals on the effective use of digital health technologies. Providing standardized education can empower healthcare providers worldwide to leverage these tools optimally for chronic disease management. Patient Education and Engagement by developing and implementing global campaigns to educate individuals about the benefits and usage of digital health technologies. Promote patient engagement by fostering a better understanding of how these tools can empower individuals to actively manage their chronic conditions and improve their overall health.

There should be inclusive design and accessibility by emphasizing the importance of inclusive design and accessibility in the development of digital health technologies. Ensure that solutions are user-friendly, culturally sensitive, and accessible to individuals with varying levels of digital literacy, promoting equitable access on a global scale. There should be cross-sector collaboration by facilitating collaboration between the healthcare sector, technology companies, research institutions, and policymakers on a global scale. Foster a multidisciplinary approach to digital health, bringing together diverse expertise to address challenges and

drive innovation in chronic disease management. Promote international research collaborations to generate robust evidence on the effectiveness and impact of digital health interventions in chronic disease management. Encourage the publication and dissemination of research findings to inform best practices and guide the development of evidence-based policies. Telemedicine Reimbursement Policies by advocating for the establishment of consistent and globally accepted reimbursement policies for telemedicine services. Clear reimbursement structures will incentivize healthcare providers to integrate digital health technologies into routine care, ensuring sustainable and widespread adoption. Prioritize global health equity in the deployment of digital health technologies. Work towards reducing disparities in access to these technologies among different populations and regions, ensuring that vulnerable and underserved communities benefit from advancements in chronic disease management. Develop standardized monitoring and evaluation frameworks for digital health implementations. Regular assessments of the impact, usability, and outcomes of these technologies will facilitate continuous improvement and guide future developments in chronic disease management.

By implementing these recommendations, stakeholders can contribute to the establishment of a cohesive global approach to leveraging digital health technologies for effective chronic disease management. This approach ensures that individuals worldwide, regardless of geographical location, can benefit from the transformative potential of digital solutions in healthcare.

CONCLUSION

The landscape of healthcare is undergoing a profound transformation propelled by the integration of digital health technologies in chronic disease management. This review has delved into the multifaceted dimensions of these technologies, examining their impact on personalized medicine, real-time monitoring, patient empowerment, and their potential to bridge global healthcare disparities. However, the journey toward widespread adoption is not without its challenges, and regulatory considerations play a pivotal role in shaping the trajectory of this digital revolution.

Digital health technologies have empowered individuals in managing chronic conditions through personalized interventions. The ability to tailor healthcare strategies based on individual profiles fosters a more patient-centric approach, aligning with the evolving paradigm of precision medicine. The integration of real-time monitoring systems facilitates a dynamic understanding of chronic diseases. Data analytics transforms this influx of information into actionable insights, providing a foundation for evidence-based decision-making by healthcare providers and patients alike. Infrastructure limitations, socio-economic factors, and technology literacy disparities present substantial hurdles to the global adoption of digital health technologies. Bridging these gaps requires collaborative efforts and innovative solutions that consider the diverse contexts in which these technologies are implemented.

The regulatory landscape significantly influences the successful implementation of digital health technologies. Standardization efforts, licensing considerations, data protection laws, and ethical guidelines form the regulatory framework that must evolve to accommodate the dynamic nature of digital healthcare. The interoperability of digital health systems is crucial for seamless data exchange and integration into existing healthcare infrastructures. Overcoming the challenges of inconsistent technical standards and ensuring connectivity between different platforms are imperative for the holistic success of these technologies. As the global healthcare community navigates these challenges, a united call to action emerges. Collaborative approaches, capacity building, and advocacy for policy changes are essential elements in overcoming barriers to adoption. By fostering partnerships between public and private sectors, investing in education, and advocating for supportive policies, stakeholders can collectively pave the way for the widespread integration of digital health technologies. The future of chronic disease management lies in the hands of a globally interconnected healthcare community. As technology continues to advance, the

imperative of global cooperation becomes even more apparent. By addressing challenges collectively and sharing best practices, the journey toward a digitally empowered healthcare future can be navigated with resilience and innovation.

In conclusion, digital health technologies in chronic disease management represent not only a paradigm shift in healthcare delivery but also a catalyst for global health equity. The challenges are substantial, but the potential for transformative impact is equally significant. As stakeholders collaborate, adapt regulatory frameworks, and prioritize inclusivity, the promise of a future where digital health technologies are accessible, personalized, and seamlessly integrated into healthcare systems worldwide becomes increasingly achievable.

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