

Application of Wearable Technologies and Devices in Fostering Better Rehabilitation through Telemonitoring and Telerehabilitation

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Abstract

The adoption of innovative technologies in medical science helps in providing better care to patients. Especially, in the pandemic situation remote healthcare technologies are introduced for providing quality care to patients. Presently, Smartwatches, Continuous Glucose Monitoring (CGM) devices, and fitness trackers are used by a lot of people to know about their health condition. In addition, telemonitoring and telerehabilitation technologies are also used by a lot of people in this world for better treatment procedures. Popular wearable technologies like Fitbit Charge, smartwatches, web-enabled glasses and many others are used by people in worldwide regions. However, the market of wearable technologies is expected to grow in the upcoming years. Moreover, the aim of this study is to analyse the impact of wearable technologies as well as devices for developing rehabilitation through telerehabilitation and telemonitoring. In order to conduct this study, the researcher has collected data from secondary sources. Online databases of various journals and articles are collected for fulfilling the aim of this paper. The data that are published in the last 5 years has been collected and interpreted. The discussion section provided enough information regarding the process of telemonitoring as well as telerehabilitation. The findings of this study suggested that wearable technologies are beneficial for helping patients suffering from various long-term diseases. The sensors that are used in these wearable devices are helpful for clinicians to monitor the patient and also offer proper treatment of multiple illnesses. Real-time data can be accessed by using these devices.

Keywords: Wearable Technologies, Rehabilitation, Telemonitoring, Telerehabilitation, Treatment

1. Introduction

Technologies in modern days have improved the medical facilities for the population of the world. Quality care can be provided through the introduction of new technologies in business. Wearable technologies are devices that can be attached to patients' bodies for collecting health as well as fitness information which may be provided to health providers, doctors, insurers, as well as other relevant people. Presently, biosensors, blood pressure trackers, and fitness trackers are the most useful wearable technologies that are popular among the population. Neurological and orthopaedic issues comprise an important part of treating rehabilitative patients. Thus, post-treatment care of elderly people is possible through the use of some wearable sensors. Force-based sensors are the most common form of wearable sensors that are used for rehabilitation. Moreover, multiple forms of sensors are applied by patients in order to gather visual, auditory, as well as biofeedback along with "force-based measurement". Some common examples of these sensors are magnetometers, accelerometers and

gyroscopes. These are the main 3 types of sensors that are combined with some inertial measurement units (IMUs) which also optimise the force-based sensors.

Falls management can be determined through the use of kinematic gait variables for all post-stroke patients. In the opinion of Snoek et al. (2021), pathological motor elements can be analysed through the use of modern innovative technologies. The new wearable technology is a "nano-material based sensor" which can easily analyse musculus fatigue from the patient's sweat. However, this innovative device is based on an ultra-thin nano-material called MXene. This is a non-toxic metal which is created through nitrogen and carbon. This is used for strong surface charges as well as high conductivity. Through the use of an MXene composite armband with an electrode, the researchers designed an innovative modular system which is loaded with some proper enzymes for analysing multiple analytes within the sweat of the patient along with lactic acid, as well as glucose and absorbing perspiration.

This prototype is used for muscular movement and the mechanical stress can be easily analysed by the chemical components such as acid and basic solutions. However, mechanical loads can result in enhanced muscular fatigue that creates lactic acid. After that, this lactic acid is translated as an enhanced pH level of the sweat (Vismara et al. 2022). Thus, it can be stated that this sensor has the ability to track all types of muscular movement as well as it can change the pH of sweat. The use of this innovative technology can cause muscular damage in order to avoid overexerting patients during rehabilitation. According to the reviews of Lo Presti et al. (2022), the pandemic situation caused by the Covid-19 virus instigated healthcare professionals to adopt a remote medication process and thereby a lot of technologies are launched that can provide quality care to patients. Nowadays, there are multiple wearable technologies used by patients such as smartwatches, Continuous Glucose Monitoring devices, fitness trackers and so on. However, telerehabilitation and telemonitoring technologies are now used by a lot of people in this world. Popular examples of these technologies are web-enabled glasses, the FitChargearge, Smartwatches and so on.

The industry of wearable technology is experiencing huge growth and it is expected that the industry revenue will increase in upcoming years. As said by Sanchez-Ramirez et al. (2022), the advancement of materials in wearable technologies is helping to develop the current features of sensors. Present wearable sensors are limited the application of proper research in the use of automated sensors can help to improve the facilities provided to patients in worldwide regions. The main issue of wearable technologies is found in poor clinical practices as well as limitations regarding wearable sensors. However, the main barriers to developing wearable technologies also include the underappreciation of values and a busy clinical environment (Mocan et al. 2022). Another main limitation of this technology is the poor accuracy of the customer-grade gadgets for the physical rehabilitation population. Hence, sensitivity to pH, humidity and temperature, limited direct measurement and susceptibility to mechanical wear over time are the main challenges of using this technology on the human body.

2. Aim and objectives

The main aim of this research is to determine the application of different wearable devices and technologies for developing rehabilitation through telerehabilitation and telemonitoring. Based on this aim, the objectives are as follows;

- To determine the current challenges of wearable technologies among rehabilitation patients
- To analyse the importance of wearable technologies for remote healthcare services
- To provide some suggestions for the betterment of telemonitoring and telerehabilitation

3. Methods and procedure

The application of correct methods in research can help in fulfilling the aim of the study. Thus, adopting a proper research strategy in a study is important for providing accurate results associated with the study. This paper, an online database of multiple articles and journals regarding telerehabilitation, telemonitoring and

wearable technologies was collected by the researcher. All the data which are published from 2019 to 2023 that include enough information regarding wearable technologies, telemonitoring systems and rehabilitation patients' needs are discussed in this paper. However, the appropriate strategy of data collection procedure has been followed for collecting the data regarding wearable technologies.

4. Results

Rehabilitation of patients can help in following a long-term recovery process in case of severe injuries. Therefore, the main goal of the therapy is to decrease the pain of the patient as well as develop the functions of muscles, joints and other tendons. In the opinion of Arens et al. (2021), rehabilitation exercises are essential in providing relief from pain, reducing inflammation, anxiety, fatigue, and developing mood. Furthermore, it is also beneficial in developing sleep quality and preventing falls. However, the muscles can be relaxed effectively through the use of proper rehabilitation technologies. The bone health and immune system of an individual can be improved through the use of these innovative exercises. Therefore, presently a lot of force-based sensors are used by a lot of patients for rehabilitation. Thus, there are multiple forms of these sensors that are helping in providing biofeedback, visual and auditory feedback to the patients. Moreover, all these technologies that are used in modern days are an essential part of achieving growth and development in providing quality care to patients. Especially after the pandemic situation, the need for telemonitoring systems for patient rehabilitation has increased rapidly in different regions of the world.

Rapid changing demands of customers in the USA are impacting the critical care treatments for multiple patients suffering from different diseases. However, there is a growing need for wellness management as well as rehabilitation promotion.

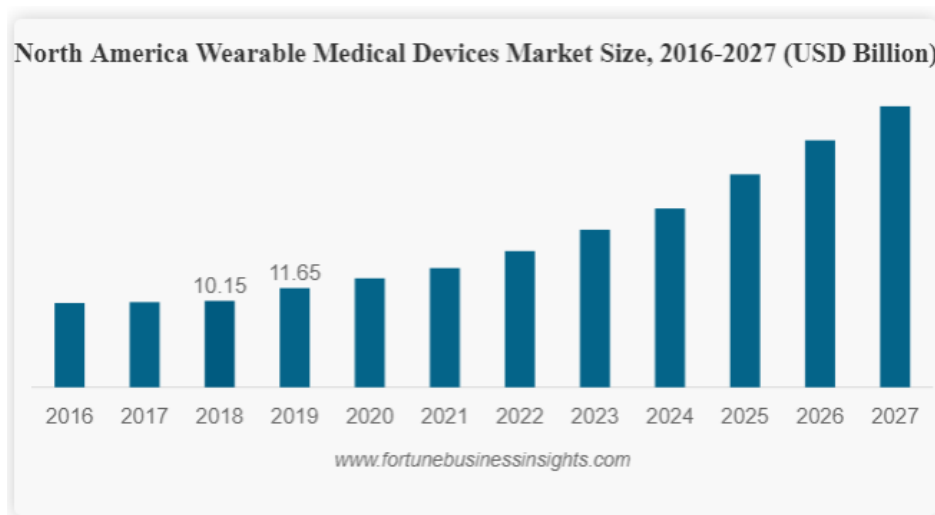


Figure 1: Wearable medical device market in North America
(Source: Fortune Business Highlights, 2023)

According to the above image, it can be stated that the wearable medical device market in North America has grown from 10.15 billion USD in 2018 to 11.65 billion USD in the year 2019. Apart from that, it is expected that the market size and revenue will grow in the upcoming years. The pandemic outbreak has had a positive impact on the wearable medical technology market. Significant growth in the revenue of the wearable technology market is observed after the pandemic situation. In the opinion of Rodgers et al. (2019), the growing need for self-monitoring devices among the population is observed during the pandemic situation. However, the global "wearable medical device" (WMD) market is currently valuing 29.76 billion USD in the year 2019 which is expected to reach 195.57 billion USD by 2027. Hence, around 26.4% of CAGR can be expected in the upcoming 4 years. In addition to this, the wearable healthcare market includes medical devices which customers can wear easily such as smartwatches and activity trackers. These are designed for monitoring as well as

collecting data regarding the fitness and health of the user. Recent data published by Accenture represents that the adoption of wearable technologies increased from 9.0% in the year 2014 to 33.0% in the year 2018. Therefore, technological advancement in recent years is increasing the demand for different kinds of wearable technologies in the market.

The healthcare market is running through the proper marketing strategies adopted by a lot of modern companies. According to the reviews of Moon, Baker & Goughnour (2019), the increasing demand for multiple wearable technologies in the market increases the need to manufacture biosensors, as well as hearing aids. Furthermore, the growing prevalence of different lifestyle-related disorders and chronic diseases is the main reason for the growing need for WMDs. As per the reports of "The International Diabetes Federation (IDF)," it can be estimated that around 463 million people suffered from diabetes in the year 2018 which is around 9.3% of the population of this world. Additionally, it is expected that the number of diabetic patients will increase to 10.2% by the end of 2030.

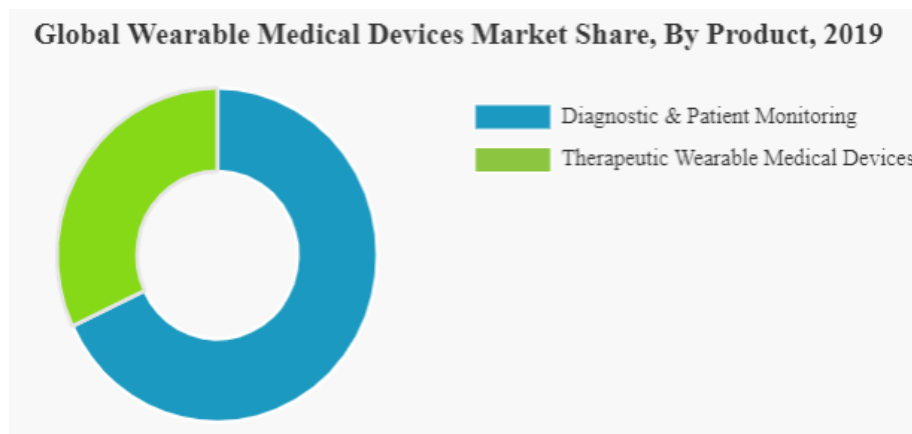


Figure 2: International market shares of wearable devices
(Source: Fortune Business Highlights, 2023)

Global wearable devices are expected to increase in the upcoming years. In the opinion of Campo-Prieto, Cancela-Carral & Rodríguez-Fuentes, (2022), the need for diagnostic and patient monitoring devices in the market is higher than the therapeutic WMDs. Based on the demand for the product, the segmentation can be divided into two categories that are therapeutic and patient monitoring wearables. Therefore, the diagnostic, as well as patient monitoring segment, has provided a lot of opportunities to analyse the prevalence rate of chronic disease. Moreover, wearable sensors are having proper monitoring and diagnostic capabilities. The monitoring capabilities of these products encompass biochemical and physiological sensing. Furthermore, motion sensors are also included in these medical devices.

5. Discussion

The importance of wearable technologies for rehabilitation

The evolution of wearable technologies can help in telerehabilitation and telemonitoring the patients' condition in a better manner. Thus, adequate information regarding the health status of patients can be gathered through an effective medical diagnosis process. However, wearable biosensors are essential to be improved in upcoming years in order to develop the current use rate of these devices. After any kind of critical surgery or treatment, telemonitoring is an essential part of providing post-quality care to the patient. In that situation, these smart wearable technologies can help to improve the current condition of patients. Thus, the evolution of these technologies can facilitate the expansion of these accessories. In the opinion of Kim & Kang (2022), presently there are ingestible and implantable devices used by physicians in order to prognosis and diagnosis multiple diseases. However, long-term and remote patient monitoring capabilities are possible through the use of these

technologies. All these wearable technologies are created through radio frequency identification, infrared, near-field communication and Bluetooth technology.

Harnessing wearable technology

There are multiple kinds of wearable sensors used for rehabilitation. In accordance with the words of Bahadori et al. (2020), the prime concern of rehabilitation is to determine the motor function of the patient in the field of orthopaedics and neurology. Hence, rehabilitation intervention inspires motor learning through harnessing task-oriented facilities. However, the central nervous system of the patients can be easily analysed through the use of these important technologies. Besides that, it has been found that rehabilitation is dependent on the capability to monitor the dynamics of the human body and thereby physical as well as chemical interventions can be taken effectively through the constant use of these wearable technologies. In this context, the use of bioelectric sensors can help in determining the movements of the user. Apart from that, detailed information regarding muscle functioning can be analysed through the use of these automated sensors. Pressure sensors and inertial sensors are also implemented in order to control the movement of patients. All of these sensors are helping in providing high-quality care to patients suffering from critical neurological disorders.

Future of Wearable Technologies for Rehabilitation

According to the prior discussion of this research, it can be stated that the need for wearable sensors in the rehabilitation process of multiple patients will increase in the upcoming days. In addition to this, the nano-material-based sensors which can analyse musculus fatigue from sweat are the most innovative technology in modern days. An ultra-thin material known as MXene is used in these devices. Thus, the use of this device can help in determining the muscular movement of patients. Recent advancements in technologies can boost the need for multiple wearable sensors in business. In the opinion of O'Neill et al. (2020), devices which can be worn by humans in a continuous manner for monitoring the activities of an individual are known as wearable technologies. However, the smart as well as advanced materials that are used in protective equipment and clothing purposes are having three types of benefits. The use cases for different kinds of wearable technologies are 1) analysing anomalous and critical events, 2) predicting future events, and 3) and diagnostic monitoring for improved decision-making.

There are tremendous advances that can be observed in the use of wearable technologies for health monitoring. In the opinion of Bowman et al. (2021), wearable sensors are important for health monitoring services that are helping in psycho-social and cognitive rehabilitation. These wearable sensors are an essential part of health monitoring through proper evidence and theories. The rehabilitation of these technologies can improve the behavioural changes of various nerves in the body. However, societal issues and data security-related challenges such as cultural barriers, and battery life. The technological issues facing medical companies are providing a lot of opportunities to patients. Wearable systems and sensors are relevant and are important for the rehabilitation process followed by a lot of companies. The current opportunities and challenges for moving these technologies forward for wider application for the clinical research area. Future developments which may alter the present paradigms are essential for analysing the importance of these technologies.

The present applications and techniques of wearable technologies are increasing rapidly in different regions of the world. Hence, functional electrical stimulation, virtual reality, as well as activity trackers, are essential for present wearable technologies that are being applied to the rehabilitation process. Moreover, it is necessary to determine the advanced features of wearable technologies for rehabilitation. As per Moesl et al. (2022), interactive wearable technologies are beneficial for completing neurological conditions, chronic pulmonary impairment, musculoskeletal conditions and so on. Maximum systems are facilitating rehabilitation programs that are beneficial for specific health applications. Most systems are used for gathering feedback on extremity movements and posture movements. Smart and continuous use of these networks is helping to improve the current system.

Designing these automated devices is difficult due to the complex mechanism of these systems. However, the intuitive and non-obtrusive system can be helpful in completing internet services in a proper way. As per the reviews of Simmich et al. (2021), advanced wearable sensors are important for tracking the motion and its range of an individual. Smart clothing could be considered the ultimate wearable system that can be used for tracking the biometric or contextual and physiological attributes of an individual. Accompanying technology can help in developing the care of patients. Wearable cameras are developed for remote rehabilitation and clinician consultation. In addition to this, incorporating motion sensors and wearable cameras in rehabilitation exercises can help in self-managing the progress. The accuracy of these exercises can help in improving the rehabilitation assessment. Emerging technologies such as deep learning, artificial intelligence, and VR as well as computer vision are included in wearable camera experiences for devices.

Current challenges of wearable technologies

Wearable technologies are beneficial in providing data regarding the health of a patient. Hence, the reproducibility and accuracy of the healthcare models are used in effective monitoring processes. In the opinion of Leese et al. (2022), effective and cost-efficient care can be maintained by improving the ability of the current wearable devices used by patients. Power consumption rates of wearable technologies are essential to be reduced in order to improve product quality. However, the use of proper consumption processes can help in improving the quality of the services given to all patients.

Privacy and ethical issues are the main negative sides of the technological development of a country. Moreover, a potential commercial value can be provided to customers that can help in following different kinds of works. Thereby, the use of calorie trackers, health monitors, gyroscopes, pedometers, accelerometers, and breath-sensing devices can help in improving the quality of life of every patient. Privacy data is leaked regarding non-health-related concerns (Kim et al. 2020). Data breaching activities are considered a major fault of technological development in the healthcare system. Moreover, designing as well as developing seamless and persuasive technologies which engage users as well as reinforce the positive behaviour of patients is essential to determined by healthcare professionals.

Suggestions for betterment

Telerehabilitation and telemonitoring patients are essential for providing quality care to patients. This study revealed that all the sensors used in wearable devices are beneficial for providing better help to monitor the current situation of patients. In this regard, real-time information on the patient's current condition can be analysed through the use of these innovative technologies. In the opinion of Lang et al. (2020), patient rehabilitation can help in reducing hospital time of stay, and costly hospitalisation as well as preventing readmission. However, rehabilitation also provides an opportunity to reduce the need for caregiver support. Wearable devices are helpful in providing high-quality treatment to patients suffering from critical muscle injuries. Wearable devices are essential in helping clinicians and patients in order to create a better plan for providing quality care to patients as well as tracking outcomes. In addition to this, the data of this study represents that self-management protocols can also be followed through the use of these wearable technologies. These new technologies are important in determining clear movement patterns among patients. In addition to this, future diseases can also be predicted effectively through clinical trials. The efficiency of clinical trials can be improved through the use of these innovative technologies.

However, the findings of this study suggested that the use of wearable technologies is important for increasing productivity as well as efficiency in work thus these can be improved in future. Although there are multiple ethical and privacy-related issues associated with the use of these devices, improved safety and more efficient exercises can be followed through the use of these technologies. In the opinion of Adlakha, Tully & Mansour (2022), wearable healthcare technologies that are used in modern days are important in monitoring the current functionality of the muscles. Thus, the biosensors used in these devices can help in analysing the internal functionalities of the human body that may help in the further medication process. Moreover, all of these wearable technologies are an important part of the telerehabilitation process and through the use of these

technologies, the quality of the treatment procedure can be improved. The use of proper telemonitoring systems in the healthcare sector can improve the future of these wearable technologies. Multiple kinds of illnesses can be treated effectively through the use of these technologies. Proper initiatives are important to be taken by healthcare professionals in order to improve the current rehabilitation process related issues and provide a better quality service to all patients.

6. Conclusion

The above details in this research highlight that the use of wearable sensors in medical diagnosis has increased rapidly in the last few years. The pandemic situation especially increased the need for different types of biochemical and physiological devices for people. Effective prognosis and diagnosis methods followed by these medical devices are helping people in order to get remote monitoring health facilities. In addition to this, telemonitoring and telerehabilitation treatment are greatly used by people. Thus, adopting more technologies in business can help in fulfilling the needs of patients in different regions of the world. Upgrading wearable technologies is essential in developing the business of different healthcare organisations. Wearable biosensors in the form of watches, glasses, clothing, bandages and many others are constantly attached to the patient's body. Hence, the evolution of these innovative technologies can facilitate the current diagnosis as well as prognosis methods. In addition to this, a long-term and remote patient monitoring system is important for improving connectivity with the patients. Hence, physicians from worldwide regions are using these innovative technologies. In future, research regarding the success rate of wearable technologies can be conducted to get more information regarding these technologies. The capability of this technological equipment can be increased through the adaptation of new strategies and thereby proper research is essential to be done.

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