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The Role of Wearable Devices in Tracking the Well-Being of Patients Suffering from Chronic Conditions - the review

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ABSTRAKT

Na przełomie ostatnich lat technologia ubieralna, w tym smartwatche, opaski fitness czy inteligentne pierścienie, stanowi element monitorowania zdrowia pacjentów z chorobami przewlekłymi. Umożliwiają one nieinwazyjne, ciągłe śledzenie ważnych parametrów zdrowotnych, takich jak tętno, poziom glukozy, jakość snu czy aktywność fizyczna. Artykuł analizuje ich zastosowanie w kontroli cukrzycy, zaburzeń rytmu serca, depresji oraz przewlekłej obturacyjnej choroby płuc (POChP), podkreślając korzyści w zakresie wczesnego wykrywania nieprawidłowości oraz personalizacji opieki zdrowotnej. Badania dowodzą wysokiej skuteczności urządzeń w poprawie wyników leczenia, redukcji ryzyka powikłań oraz wspieraniu samokontroli pacjentów. Mimo licznych zalet, takich jak zwiększone zaangażowanie pacjentów, technologia ta napotyka wyzwania, takie jak prywatność danych i integracja z systemami opieki zdrowotnej. Wnioski wskazują na konieczność dalszego rozwoju urządzeń ubieralnych w celu ich pełniejszej implementacji w praktyce klinicznej i codziennym życiu pacjentów.

KEY WORDS: wearable devices, health management, smartwatch, chronic disease management, diabetes, COPD, depression, cardiac arrhythmias

ABSTRACT

In recent years, wearable technology, including smartwatches, fitness bands, and smart rings, has become an integral part of health monitoring for patients with chronic diseases. These devices enable non-invasive, continuous tracking of key health parameters such as heart rate, glucose levels, sleep quality, and physical activity. This article analyzes their application in managing diabetes, cardiac arrhythmias, depression, and chronic obstructive pulmonary disease (COPD), highlighting their benefits

in early detection of abnormalities and personalized healthcare. Research indicates that these tools significantly enhance treatment results while minimising the likelihood of complications and supporting patient self-management. Despite numerous advantages, such as increased patient engagement, this technology faces challenges, including data privacy and integration with healthcare systems. The conclusions point to the necessity for further development of wearable devices to ensure their broader implementation in clinical practice and patients' daily lives.

INTRODUCTION AND OBJECTIVE

In today's world, advancing technologies and the growing popularity of mobile applications have created opportunities for continuous health monitoring. Devices available on the market, such as bands counting steps or watches measuring heart rate and oxygen saturation, have turned into a crucial element of the daily routines of many people.ranging from athletes to the elderly, including individuals suffering from chronic diseases. These devices enable the collection of comprehensive information about current health status and facilitate appropriate actions to improve it.

In the treatment process, they assist in monitoring the course of various diseases, provide insights into the effectiveness of therapy, or signal the need for its modification. Wearable technology has gained popularity thanks to its ability to track the intensity of daily physical activity by measuring steps taken, distance covered, or calories burned. Over time, these devices have evolved into advanced tools enabling continuous and dynamic monitoring of various health parameters. They can detect pre-symptomatic conditions in numerous ailments, including cardiovascular and mental health disorders. This allows users to receive real-time alerts about detected abnormalities, enabling prompt medical intervention in life-threatening situations, which is particularly critical for those with chronic illnesses.

Moreover, wearable devices enhance patient engagement and responsibility in the health management process, support personalized healthcare, and promote preventive measures by encouraging the adoption of healthy habits and lifestyle improvements. [1,2,3]

The aim of this article is to highlight the potential offered by wearable devices, such as smartwatches, in monitoring the course of chronic diseases.

CURRENT STATE OF KNOWLEDGE

Wearable devices are electronic tools equipped with sensors that, when worn on the body, collect non-invasive and long-term data on key physiological and biochemical parameters. They come in the form of smartwatches, smart rings, patches, or wristbands and allow data transmission between devices using wireless technologies. They have revolutionized healthcare by enabling remote, non-invasive, and continuous monitoring of vital signs in real-time during daily activities. The first attempts to introduce wearable devices to the market began in 2014 with the launch of products like Fitbit and Apple Watch. These devices allowed users to monitor key aspects of their health, such as physical activity, heart rate, sleep quality, stress levels, and menstrual cycles. Over time, apps like Fitbit Coach and Nike Training Club were introduced, revolutionizing the approach to training by offering personalized workout programs and health coaching support. Additionally, Apple Health launched long-term studies, such as the Apple Heart and Movement Study, which collect data from users to support medical discoveries and the advancement of health knowledge.

Studies have demonstrated the effectiveness and reliability of the recorded variables in predicting atrial fibrillation, diabetes, sleep apnea, and hypertension. [4,5]

I. DIABETES

There are various devices available on the market for monitoring blood glucose levels. Beyond traditional glucometers, innovative systems now allow for continuous glucose monitoring (CGM). These solutions, integrated with mobile applications, enable patients to track glucose levels in real time. The FreeStyle Libre Flash glucose monitoring system, introduced in 2014, was one of the first devices that allowed individuals with type 1 and type 2 diabetes to monitor their glucose levels. The first-generation FreeStyle Libre Flash was used to make therapeutic decisions focusing on diabetes management, including insulin dosage adjustments. The updated FreeStyle Libre 2 system includes hypo- and hyperglycemia alerts that are generated every minute when data is transmitted to a receiver. One major advantage of such a system is the reduction in the user's involvement in daily measurements, the minimization of test strip usage typical of traditional glucometers, and improved accuracy in glucose monitoring. [6]

In a study conducted over 14 days, the accuracy and performance of the FreeStyle Libre 2 system in glucose monitoring across different concentrations, including hypo- and hyperglycemic states, were evaluated without requiring user calibration. The study included 144 adults and 1129 children aged 4 to 17, with most participants diagnosed with type 1 diabetes. During the study, participants wore sensors for 14 days, and glucose readings were compared to reference laboratory results. Glucose levels were manipulated through carbohydrate consumption or insulin administration to obtain data for both low and high glucose ranges. Venous blood was collected every 5-15 minutes, and measurements were conducted during 10-hour clinical sessions. Results demonstrated high accuracy: 93.2% of readings in adults and 92.1% in children fell within ±20% or ±20 mg/dL of the reference values, with a mean absolute relative difference (MARD) of 9.2% in adults and 9.7% in children. Performance was consistent regardless of age, diabetes type, insulin delivery method, or HbA1c level. The system showed superior accuracy in hypoglycemic ranges, with over 94% of readings falling within 15 mg/dL of reference values, and successfully generated alerts for glucose thresholds set at low (e.g., 60 mg/dL) and high levels (e.g., 300 mg/dL). The sensor's accuracy and stability remained consistent throughout the 14-day usage period. [7]

Key advantages of the system include the speed and accuracy of data collection, real-time glucose level readings when paired with a mobile application, and the ability to promptly intervene in life-threatening situations caused by excessively low or high blood sugar levels. Continuous diabetes monitoring can also reduce the risk of chronic complications, such as atherosclerosis, diabetic nephropathy, retinopathy, and neuropathy. Furthermore, this non-invasive glucose monitoring method can significantly improve the well-being of patients, particularly pediatric ones, by eliminating the need for frequent and painful finger pricks. [7]

Wearable devices can also accelerate the detection of hypoglycemia by alerting users, enabling timely interventions. In a study conducted by Sevil M. and colleagues, researchers focused on using data collected from a multi-sensor wristband to classify physical activity types and estimate energy expenditure. They highlighted how this information could be used in automated insulin delivery systems for better diabetes management and reduced risk of hypoglycemia. Five physical states were monitored: resting, daily activities, running, cycling, and strength training, while biological data such as heart rate, temperature, skin conductivity, accelerometer readings, and energy expenditure were analyzed in a group of 25 participants. Machine learning techniques such as k-NN, SVM, neural networks (NN), and Long Short-Term Memory (LSTM) networks were applied. Over 430 hours of wristband data and additional calorimetric data for validation were collected. Researchers achieved a classification accuracy of 94.8% using the LSTM model, a high result in the context of physical activity monitoring. The study also demonstrated that using multiple sensors, compared to a single one (accelerometer), provided better classification and energy expenditure estimation results. For instance, classification accuracy using only the accelerometer was 90%, whereas sensor fusion improved it to 94.8%. This allows for tailored insulin dosing for diabetic patients, reducing the risk of exercise-induced hypoglycemia and maintaining optimal blood glucose levels. The study results open new perspectives on physical activity monitoring. [8]

II. CARDIAC ARRHYTHMIAS

The usefulness of mobile devices has been recognized in cardiology. Popular smartwatches increasingly feature single-lead ECG capabilities, enabling the detection of potential cardiac arrhythmias, such as atrial fibrillation (AF), atrial flutter (AFL), and supraventricular tachycardia (SVT). Studies assessing the performance of various smartwatches in detecting arrhythmias compared to traditional diagnostic methods, such as 12-lead ECGs, highlight their accuracy, sensitivity, and specificity in identifying different cardiac arrhythmias. Devices like the Apple Watch have demonstrated high effectiveness in detecting atrial fibrillation and other arrhythmias, which may contribute to their growing use in diagnostics and prevention. [9]

Atrial fibrillation (AF) is one of the most commonly diagnosed cardiac arrhythmias. It is characterized by uncoordinated atrial activation, leading to a loss of effective contraction. On ECG recordings, AF manifests as the absence of discernible and regular P waves. It is connected to an elevated risk of stroke, heart failure, acute coronary syndrome, and dementia. Symptoms such as fatigue, reduced exercise tolerance, dizziness, or fainting can significantly reduce patients' quality of life. Several types of AF are distinguished: paroxysmal AF, which resolves spontaneously within 24 hours; persistent AF, defined as episodes lasting longer than seven days that do not self-resolve (this can either be the first clinical manifestation of arrhythmia or the result of recurring paroxysmal AF episodes); and long-standing persistent AF, lasting over a year, with the decision made to attempt restoring sinus rhythm. [10, 11]

The main goal of the article by Bogár et al. is to review the literature on the use of smartwatches for arrhythmia detection, including clinical cases and cohort studies. The article argues that smartwatches are effective tools for the screening of various cardiac arrhythmias and may serve as valuable diagnostic and preventive devices. Study participants ranged in age from 10 days to 72 years, underscoring the broad applicability of arrhythmia monitoring across different age groups. Atrial fibrillation and supraventricular tachycardia were the most frequently recorded arrhythmias, emphasizing their prevalence in clinical practice and the importance of early detection, particularly in high-risk patient groups. Studies showed that the Apple Watch achieved an accuracy rate of over 90% in detecting atrial fibrillation. Diagnostic sensitivity and specificity remained around 90%. Additionally, the Apple Watch proved effective in accurately measuring heart rates, even during tachyarrhythmias. [12]

In a 2019 study by Perez et al., the effectiveness of the Apple Watch's irregular heart rhythm detection algorithm in diagnosing atrial fibrillation was evaluated. The results indicated that the algorithm correctly identified AF in 34% of participants, as confirmed by ECG readings, and 84% of notifications were consistent with AF. Moreover, the notifications prompted many participants to consult a doctor, demonstrating the utility of wearable devices in encouraging health-related actions. [9]

The growing popularity and accessibility of electronic devices equipped with increasingly reliable algorithms enable the monitoring of heart rhythms and the detection of rare and brief atrial fibrillation episodes, as well as estimating arrhythmia risk. Traditional methods for detecting atrial fibrillation, such as 12-lead ECGs, have limitations, including short recording times and the need for specialized equipment, which restricts their use for screening asymptomatic patients or cases of paroxysmal arrhythmia. Although smartwatches are increasingly used for both preventive and therapeutic purposes due to their convenience and reliability, they remain underutilized in clinical practice. This occurs despite their potential benefits, such as facilitating the initiation of anticoagulant therapy in cases of acute atrial fibrillation detection. False positives should also be considered, as smartwatches may incorrectly indicate arrhythmia, leading to healthcare system overload. It is crucial that results are interpreted by specialists and verified through professional medical devices like ECGs, as not all detected arrhythmia episodes have clinical significance. [12, 13,14]

III. DEPRESSION

Depressive disorder, or depression, is a mental health condition that is being diagnosed more frequently in our society. It is characterized by a low mood or an inability to experience pleasure or interest in activities for an extended period. Symptoms persist for most of the day for at least two weeks. People with depression may also report sleep disturbances, loss of appetite, fatigue, and impaired concentration. [15]

Wearable devices have also found application in the field of psychiatry, where their potential to improve the treatment and diagnosis of depression by monitoring physiological parameters has been explored. Researchers have focused on long-term analysis of the vital signs of patients with depression, which were then used to analyze physiological data and their correlation with depression severity, measured using the Hamilton Anxiety Rating Scale (HAMA) and Hamilton Depression Rating Scale (HAMD). [17]

In a study conducted by Y. Jin and Y. Huang, physiological data such as heart rate, physical activity, and sleep quality and duration were collected from 302 hospitalized patients over a period of more than six months. Data were recorded every five minutes and then correlated with clinical assessments. Measurements included heart rate (average during wakefulness and sleep), sleep patterns (duration, activity during sleep, length of naps), and physical activity (duration and intensity, number of inactivity episodes). Logistic regression, supported by correlation analysis with the HAMA and HAMD scales, was used for classification. [17]

The analysis demonstrated that higher heart rate variability, longer sleep duration, and greater physical activity were observed in patients with milder depressive episodes compared to severe cases. The logistic regression model achieved high classification accuracy with an AUC value of 0.84, suggesting that data from wearable devices can effectively predict depression severity. These devices detect subtle changes in autonomic nervous system functioning related to depression, which may not be measurable through traditional methods, allowing for earlier therapeutic interventions. [17]

The study highlighted the possibility of integrating modern wearable technology into psychiatric care. Monitoring vital signs can significantly enhance understanding and support the treatment process for depression, steering toward a more personalized approach. Smartwatches, for instance, provide real-time feedback to both patients and doctors, which can lead to improved treatment adherence and reduced costs. Additionally, patients can monitor their condition independently, giving them greater control over their treatment. [16,17]

IV. CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)

The application of wearable devices has been studied in the context of monitoring and managing respiratory diseases, including Chronic Obstructive Pulmonary Disease (COPD). COPD ranks as the fourth leading cause of death globally. In 2021, it accounted for 3.5 million deaths, representing approximately 5% of all global deaths.

COPD is a common respiratory condition, primarily affecting smokers, characterized by airflow limitation and breathing difficulties. It is often referred to as emphysema or chronic bronchitis. In COPD, the lungs may sustain damage or accumulate excess mucus. Common symptoms include coughing (sometimes with phlegm), shortness of breath, wheezing, and fatigue. [18]

Key parameters for monitoring COPD progression and assessing the risk of exacerbation include oxygen saturation, respiratory rate, heart rate, and physical activity. Built-in pulse oximeters in wearable devices can detect drops in oxygen saturation, signaling disease aggravation. Changes in respiratory rate can help identify lung ventilation abnormalities, while heart rate and physical activity measurements support encouraging patients to maintain an active lifestyle. Additionally, wearables equipped with air quality sensors can alert patients to environmental pollution levels, a known risk factor for COPD exacerbation. [19]

In a study by Iorio OC et al., the focus was on evaluating the use of wearable technology in monitoring COPD exacerbations. Severe disease progression presents significant challenges in patient care, leading to increased hospitalizations and higher mortality rates. With the growing availability of remote monitoring technologies, the study assessed whether patients with severe COPD could independently use such devices to continuously track vital signs at home. [20]

The study included nine patients over the age of 40 with spirometry-confirmed COPD in the "severe" (GOLD 3) or "very severe" (GOLD 4) stages, all experiencing exacerbations. Physiological data were recorded using EmbracePlus wristbands and Oura Gen III rings. The wristband measured heart rate, respiratory rate, skin temperature, physical activity, and sleep, while the ring recorded heart rate, oxygen saturation, and sleep quality. Data from the ring were collected at 5-minute intervals. Participants wore the devices for 94% and 88% of the study period for the wristband and ring, respectively, over 21 days. Data were collected every minute (wristband) and every 5 minutes (ring), transmitted remotely via a tablet, and then analyzed and compared with nurse-collected data. [20]

Heart rate measurements from the wristband were of very high quality, with 99.2% of the data deemed useful. For the ring, 84.5% of the data met quality standards. However, only 17.6% of respiratory rate data from the wristband were usable due to technological limitations such as motion-related disturbances. A strong correlation was observed between the ring and wristband data for heart rate (r = 0.86), while the correlation between device data and nurse-collected respiratory rate measurements was weak. Patients rated both devices highly for usability, with a mean SUS score of 86.4/100 for the wristband and 89.2/100 for the ring, indicating convenience and user-friendliness. [20]

Wearable technologies in the care of patients with severe COPD offer a promising tool for managing the disease, enabling early detection of exacerbations and significantly improving patient care. These devices promote patient autonomy, as individuals with severe COPD could independently operate them even during exacerbations. Furthermore, wearables allow for the monitoring of vital signs in a patient's natural environment, providing more accurate and reliable data compared to measurements taken in stressful clinical settings. They can also detect subtle parameter changes indicative of impending exacerbations, allowing for earlier intervention. [20]

Despite these benefits, the study revealed some limitations. First, the low quality of respiratory rate data highlights the need for further technological improvements to reduce disturbances. Second, the small sample size limits the generalizability of the findings to larger populations. Lastly, the lack of feedback features for patients—such as utilizing measurement results to engage them in self-management—restricts the potential benefits of active health monitoring. Future studies should focus on increasing sample sizes, improving respiratory rate monitoring technology, and integrating devices with telemedicine programs, enabling more effective disease management and enhanced patient care. [20]

Shah AJ et al., evaluated the acceptability of wearable technology among patients with chronic respiratory diseases such as asthma, COPD, and sleep apnea was assessed. The study was based on a 24-item survey designed using four recognized technology acceptance models (e.g., the Technology Acceptance Model, Theory of Planned Behavior), and patient responses were analyzed. Among the 74 participants, 72% were women, and half belonged to the 51–70 age group, characteristic of populations with chronic lung diseases, which are more common in middle-aged and older individuals. 51% of the participants had asthma, 23% had COPD, 16% had obstructive sleep apnea, and 8% had interstitial lung diseases. Of the respondents, 35% had previously used wearable technology, most commonly smartwatches, which they used primarily to monitor symptoms (69%), encourage exercise (50%), and track overall health (85%). The most frequently cited desirable features of wearable devices were measurement accuracy (73%), ease of use (63%), and intuitiveness (50%). Less importance was given to aesthetics (23%), battery life (27%), and price (27%). Additionally, most respondents (81%) wanted devices to alert them to health deterioration. An overwhelming 93% of participants expressed willingness to learn how to use new technologies, and 95% reported that such technology increased their confidence in self-monitoring their health. Furthermore, 76% of individuals indicated a desire to take responsibility for health monitoring using personal mobile devices, and 88% believed wearables would become increasingly popular as part of everyday life. [21]

Patients are willing to adopt wearable technology, especially when the devices are accurate, easy to use, and possess appropriate regulatory approvals. Further development of wearable technologies tailored to patient needs, combined with education and support, is essential to facilitate widespread adoption. [21]

Additionally, in the meta-analysis by Shah AJ, Saigal A, et al., where out of 7,396 initially identified studies, 37 studies meeting inclusion criteria were selected for analysis (a total of 2,955 patients). The analysis included randomized controlled trials (RCTs) and observational studies that assessed the impact of wearable technologies in patients with spirometry-confirmed COPD diagnosis. Various technologies were used in the studies, such as pedometers, pulse oximeters, smartphones with monitoring applications, and telemedicine systems. The duration of interventions ranged from a few weeks to 12 months. The focus was on measuring physical activity, such as daily step count and the six-minute walk test (6MWT), as well as quality of life, assessed using the CAT score, a tool typically employed for evaluating COPD patients. [22]

The results showed that wearable technology increased the average daily step count by 850 steps, while interventions combining wearable devices with health coaching (e.g., motivational telephone calls) increased the step count by 998 steps per day, proving to be more effective than using the technology alone. In the six-minute walk test, the improvement was 5.81 meters, which is below the clinically significant threshold (≥25 meters). Additionally, in a study utilizing pulse oximeters, it was demonstrated that changes in heart rate and oxygen saturation could predict exacerbations up to 7 days in advance with a precision of 91.7%. Regarding quality of life, participants recorded an average reduction in the CAT score of 0.99 points, which is below the clinically significant change (−2 points). [22]

The obtained data suggest that improving physical activity through a moderate increase in daily step count may be clinically significant, especially when wearable devices are combined with other interventions such as pulmonary rehabilitation or coaching. [22]

CONCLUSIONS

In summary, wearable devices, initially designed for tracking physical activity, are now becoming valuable clinical tools. By continuously monitoring health indicators such as heart rate and physical activity in real-time, they can detect diseases at an early stage, assist in health management, and promote personalized care. They help reduce treatment costs and improve patient outcomes.

For example, according to *The National Diabetes Statistics Report*, in 2021, 38.4 million U.S. residents (11.6% of the population) were diagnosed with diabetes. The estimated annual treatment cost for diabetes is approximately $307 billion, a significant increase from $227 billion in 2012. [23]

Wearables have demonstrated potential in detecting and monitoring cardiovascular diseases and changes in mental health conditions, such as depression. Systems like FreeStyle Libre, despite their greater invasiveness, enable better control of blood glucose levels and identification of individual reactions to consumed foods. They encourage increased physical activity by identifying healthy and unhealthy patterns based on the user's individual profile. By providing real-time health data, these devices enhance patient engagement in the treatment process, allowing them to independently monitor their results.

Although wearable technology in healthcare offers vast possibilities, it still faces numerous challenges, such as data privacy concerns and integration with healthcare systems. Further development is necessary to improve data security and maximize the technology's benefits. Future advancements focus on incorporating advanced sensors, analytical algorithms, and artificial intelligence to expand diagnostic, monitoring, and treatment capabilities.

DISCLOSURE

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