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The use of wearable devices to monitor selected functions of the human body

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ABSTRACT

Because of the widespread use of wearable devices in everyday life, there is a growing demand to acquire good-quality data on as many vital functions as possible for better and faster diagnosis and treatment implementation. This review focuses on the recent advancements and progress of wearable devices' technology and their possible implementation for improving users' health, mainly in cardiology, sleep, and stress. In cardiology, there is a focus on creating a device that records good-quality electrocardiograms and can diagnose more than atrial fibrillation. A growing number of studies also focus on finding the best way of estimating blood pressure using wearable devices. Acquiring reliable data on experienced stress can help users to manage it and professionals to alleviate it, resulting in better compliance. Sleep monitoring can help raise awareness, prevent many diseases, and improve users' overall health. In conclusion, there are constant attempts for improving wearable devices to better monitor vital signs in everyday life. Most wearable devices lack validation in their accuracy for detecting, tracking, and analyzing some vital signs. With their ever-growing popularity, it is of utmost importance to ensure the data they gather is of good quality.

Keywords: wearable devices, stress, arrhythmias, blood pressure, sleep pattern

1. INTRODUCTION

In recent years, wearable devices like smartwatches or wristbands have become widespread and are, for many people, essential in their daily lives. Their use quickly evolved from tracking activity-related signs like heart rate and step count to more complex parameters for achieving broadly understood well-being.

Most wearable devices available today have built-in detectors to non-invasively assess physiological criteria such as heart rate, temperature of the skin, blood oxygen levels, and movement. For specific research, it is also possible to acquire sugar levels. Furthermore, concerning surroundings, wearable devices can record atmospheric temperature, G-force, and elevation (Jolly et al., 2025). Thanks to their small size and ability to measure and record many vital

parameters, wearable devices have been the focus of many studies trying to find new ways to help in everyday life.

A built-in photoplethysmography detector is the most common method for detecting heart rate (Jolly et al., 2025) and the most universally used detector in wearable devices. It measures the blood volume of the skin’s microvascular layer by shining light and measuring the absorption and reflection of tissues (Zijlstra et al., 1991). To receive the most reliable photoplethysmography signal and adequately evaluate the data provided by a wearable device, several wearing requirements must be met. Proper data acquisition depends on the type of skin, placement on the wrist, tightness around the wrist, and movement of the wrist when the data is gathered (Volkova et al., 2023).

This review focuses on the latest advancements and progress in developing wearable devices for better- monitoring life parameters and their possible implementation for improving users’ health, mainly in cardiology, sleep, and stress.

2. METHODS

This review was based on selected studies from PubMed. The search was conducted with use of Medical Subject Headings and keywords: smartwatch devices, ECG, stress, sleep patterns, and lifestyle. The search included articles written between 2022 and 2024 and some applicable articles outside that range. We have included articles that were applicable based on the scope of the review and were written in English or translated.

3. RESULTS AND DISCUSSION

Cardiology

An increasing number of wearable devices have the option to record a single-lead electrocardiogram (ECG) and have built-in software to diagnose atrial fibrillation automatically. While many studies focused on checking the quality of those analyses, the studies concerning other diseases have been limited (Strik et al., 2024). Table 1 summarizes different methods of detecting symptoms and diseases by wearable devices.

Table 1. Methods used in wearable devices for detecting symptoms and diseases.

Methods	Symptoms/disease	References
Single lead ECG	Atrial fibrillation	Strik et al., 2024
ECG acquired by placement change	Myocardial ischemia, perdicarditis, repolarization abnormalities	Samol et al., 2019
Photoplethysmography and pulse transit time	Blood pressure	Henry et al., 2024
HRV	Stress levels	Jerath et al., 2023
Cortisol levels in sweat and HRV	Stress levels	Ding et al., 2024
Accelerometry and photoplethysmography	Sleep disturbances	Meyhöfer and Wilms, 2024
Oxygen saturation	Obstructive sleep apnea	Kim et al., 2022

Standard ECG lead recorded by a wearable device corresponds with Einthoven lead I and is acquired by placing the wearable device on the left wrist and thumb and index finger of the right hand on the crown. However, by changing the placement of the wearable device on the body, it is possible to record in total six good-quality single-lead ECGs - Einthoven I to III and three Wilson-like

leads, which in cases of myocardial ischemia, pericarditis, or repolarization abnormalities are needed for proper diagnosis (Samol et al., 2019). Moreover, using artificial intelligence to analyze the collected data could also expedite the diagnosis (Choi et al., 2025).

This potential for early detection of hazardous heart problems may lead to seeking medical help earlier and, thus, increase the chances of successful interventions. Ensuring wearable devices can screen for other arrhythmias would significantly impact detecting dangerous rhythms and acting upon them in the pediatric population. It would require changes in built-in software to look for these cardiac abnormalities and find an easy way of acquiring ECGs. The aforementioned method of acquiring ECG may be too difficult for younger children (Leroux et al., 2022). With this method, it is also impossible to screen for arrhythmias when the patient is unconscious (Strik et al., 2024). One study reports a patient who was able to record part of his polymorphic ventricular tachycardia before syncope (Avidan et al., 2024). Therefore, to increase the chances of surviving cardiac arrest out of hospital, efforts are being made to find a solution. Schober et al. propose to create a technical solution using commercially available detectors to detect cardiac arrest and trigger a response from the emergency unit. This has the potential for saving thousands of lives each year because many cardiac incidents happen without anyone to react (Schober et al., 2022).

There are almost no studies concerning diagnosing bradycardia with wearable devices. Only one study reported a case where a wearable device alerted the user of low heart rate (Cordova Sanchez et al., 2022). In the current state, wearable devices are a good tool for diagnosing bradycardia when the user is experiencing symptoms and triggering the recording of ECG.

Even at this moment of development, wearable devices can help monitor the outcomes of growing numbers of patients after Transcatheter Aortic Valve Implantation. This procedure, preferred in older patients with more comorbidities, which, given the aging of the population, is steadily increasing in numbers (Cierpiszewska et al., 2022). Eerdekens et al., (2024) found that contrary to the 6-minute walk test and questionnaire taken in the hospital, parameters measured by wearable devices, such as heart rate and daily step count, did not improve after TAVI. This difference may suggest that patients felt more motivated to reach better results in the hospital and in their daily lives they returned to their routines. This result paves the way for further research on improving motivation for the older people to improve their daily activities.

Blood pressure

Hypertension is one of the significant health problems (Zile et al., 2020), increasing the all-cause mortality risk (Cohen et al., 2019). Blood pressure is one of the most basic vitals for assessing the risk of cardiovascular diseases. Often, at the beginning, elevated blood pressure does not cause any symptoms. Therefore, recent attempts have been made to revolutionize blood pressure measuring using wearable devices and machine learning algorithms - cuffless blood pressure measurement. A device that is worn daily and measures blood pressure, could help raise awareness, cause positive changes in users' lifestyles, and possibly prompt visiting medical professionals (Yen and Huang, 2022). Currently, possible methods of monitoring blood pressure with wearable devices are pulse wave analysis using photoplethysmography and pulse transit time by combining photoplethysmography and ECG (Henry et al., 2024). The quality of measurements taken with this cuffless method is still under research and lacks validation standards (Cohen and Brady, 2022). Falter et al., (2022) report that this method tends to be biased toward the calibration point in patients with and without hypertension. They compared the results gathered by ambulatory blood pressure monitoring and a smartwatch. Wearable devices underestimated the high blood pressure and overestimated the low.

Some wearable devices deliver reliable results for blood pressure measurement. However, they do not allow continuous monitoring because they have specific restrictions regarding how the measurements are supposed to be taken. For example, some may require a sitting position with the wrist at heart level. With proper instruction, this monitoring method can still be a step toward better management of hypertension treatment (Lee et al., 2023).

Another issue regarding cuffless blood pressure measurement is recalibration. One study proposes that wearable devices that use pulse transit time can be recalibrated using a learning algorithm and wrist-cuff blood pressure monitors. Regular recalibration made these wearable devices as accurate in measuring blood pressure as the regular arm-cuff monitor. This technology could allow for continuous non-invasive blood pressure monitoring (Seo et al., 2023). Li et al., (2024) created a model utilizing photoplethysmography for cuffless monitoring that met the standards for continuous monitoring for 60-second and 10-second periods. Continuous blood pressure monitoring could potentially become another standard and commercially available feature with more research.

Stress

All people, at some point in their lives, suffer from stress. It may be caused by the fast contemporary way of living, like changing dietary habits, demanding work environment, increasing workload or even advancements in technology (Jolly et al., 2025). Stress has been linked to not only health problems like chronic pain, cardiovascular diseases, rheumatoid arthritis, and cancers but also premature mortality and acceleration of aging (Slavich, 2016). Therefore, it is vital to find a way to diagnose early stress, and smartwatches that are so widespread should be the primary focus of instruments for detecting, monitoring, and preventing stress.

One of the most widely researched parameters for assessing stress and overall well-being used in most commercially available wearable devices is heart rate variability (HRV) (Jerath et al., 2023). HRV indicates the autonomic nervous system (ANS) activity by measuring changes in time between consecutive heartbeats (Shaffer and Ginsberg, 2017). When experiencing chronic or acute stress, the sympathetic part of the ANS prevails, increasing heart rate and decreasing HRV. Conversely, the parasympathetic part active during relaxation decreases heart rate and increases HRV (Jerath et al., 2023).

Another parameter that can be measured is the cortisol level in sweat. Many studies have tried to find the most effective way of assessing cortisol levels on the skin surface. Ding et al., (2024) propose combining an HRV detector and a cortisol level sensor to better provide stress level monitoring in short-term stress.

However, de Vries et al., (2025) found that using only wearable devices can also help optimize stress, self-efficacy, and well-being awareness. Additional interventions like ecological momentary assessment, peer support groups, and feedback reports did not statistically improve effectiveness.

Assessing stress levels in patients in medical environments could allow medical staff to act to alleviate it actively. Jeong et al., (2024) found that in patients undergoing radiotherapy, levels of stress increase during the therapy, especially during the first two sessions. It may be caused by unfamiliarity with the situation, not understanding the process, and the cancer diagnosis. As the patients' positioning is vital during radiotherapy to ensure the best possible treatment outcome, alleviating anxiety and stress at the beginning of the intervention is crucial.

The prime goal of wearable devices was to track physical activity, and studies show that there is a positive correlation between time spent on physical exercise and mental health (Robinson et al., 2023) and that days with physical exercise per week are a strong mental state predictor (Antza et al., 2021). Therefore, combining this with the continuous development of new detectors, wearable devices will continue to deliver users more and more information on the stress levels they experience and allow connected applications to help manage and reduce stress by offering interventions (Dalmeida and Masala, 2021).

Sleep disorder

The quality of sleep affects many aspects of human life. Nowadays, lack of sleep is widely noticeable, be it because of the fast pace of life, shift work, or increased workload. Poor sleep quality has been linked to increased mortality irrespective of cause and many chronic conditions (Zheng et al., 2024). Concomitant with sleep deprivation, the prevalence of obesity and type 2 diabetes mellitus is also increasing. This may be due to the changes in β -cell function and insulin resistance caused by lack of sleep (Antza et al., 2021). Moreover, sleep restriction leads to increased release of ghrelin and leptin, feelings of hunger, and reward signals after food consumption (Meyhöfer and Wilms, 2024). Therefore, preventing sleep disruption and delaying or preventing the development of chronic diseases should be deliberated.

Polysomnography is considered to be the golden standard for diagnosing sleep disorders. However, this method has limitations because it does not monitor patients in their everyday lives and requires trained professionals and a complex setup (Guillodo et al., 2020). Therefore, the potential for wearable devices to monitor patients' sleep at home is also being studied. Many wearable devices can track sleep with accelerometry and photoplethysmography detectors. Even though the quality of those records has not been adequately investigated, they can still impact awareness of sleep quality (Meyhöfer and Wilms, 2024).

Sleep quality is connected irrevocably to the experienced levels of stress. People who suffer from prolonged exposure to stress often experience sleep disruptions like challenges in falling asleep or many awakenings (Åkerstedt et al., 2012; Burton et al., 2010). Moreover, a sedentary lifestyle also reflects poorly on sleep quality, probably because sitting for many hours disrupts the body's sleep cycle and wake by changing levels of sleep-regulating hormones (Park et al., 2025). Conversely, walking improves sleep quality and lowers the risk of sleep problem development by reducing stress levels and inducing relaxation (Kredlow et al., 2015). Therefore, wearable devices alert people to stay active and track their daily steps, which can help improve sleep quality.

Patients with multiple sclerosis are at risk of sleep disturbances that, in turn, add to fatigue and may cause other symptoms of the disease. Even though weariness is often considered a specific symptom of multiple sclerosis, early diagnosis and implementation of treatment could lead to alleviation of at least some of it (Braley and Boudreau, 2016). Woelfle et al., (2023) found that using wearable devices for at least a week offers reliable measurements of activity, heart rate, and sleep in patients with multiple sclerosis. In this group, devices that track sleep using accelerometry and photoplethysmography are more desirable because they deliver complementary information, thus giving better insight into sleep quality.

Patients with Parkinson's disease are another group that benefits from using wearable devices. In this disease, sleep disturbance is prevalent. Ko et al., (2022) propose that even though the quality of sleep prediction delivered by wearable devices was lower than by professional equipment, wearable devices are a valuable and convenient tool for monitoring sleep in Parkinson's disease patients by medical professionals.

Wearable devices can not only help monitor patients with sleep disorders but also can trigger diagnostic measures. This is the case for obstructive sleep apnea. It is a condition in which, during sleep, breathing stops for periods, causing increased sleepiness during the daytime and fatigue (Lee, 2020). Kim et al. found that by using oxygen saturation wearable devices were quite accurate in diagnosing obstructive sleep apnea. However, wearable devices used in that study were more accurate when the time of oxygen saturation below 90% was short. In other words, wearable devices were more accurate in diagnosing mild obstructive sleep disorder, and their precision decreased as the disease's severity increased (Kim et al., 2022).

Using wearable devices' prevalence, researchers can associate sleep duration, regularity, and stages with the incidence of chronic diseases. The shorter the rapid eye movement and deep sleep stages, the higher the risk of incident atrial fibrillation. Regularity of sleep is inversely connected to anxiety disorders, metabolic disorders, and hypertension (Zheng et al., 2024). Therefore, wearable devices that keep track of users' sleep parameters and provide personalized advice on healthy sleeping habits can help prevent the development of chronic diseases or at least help improve one's well-being.

4. CONCLUSION

Many studies that have been published tried to find new and better ways to utilize wearable devices for monitoring vital signs in everyday life. However, most wearable devices have yet to be validated in their accuracy for detecting, tracking, and analyzing vital signs. With their growing popularity, it is essential to make sure the data they gather is of good quality. However, with the current ability to measure many parameters and give feedback and advice, wearable devices can be described as holistic well-being tools. With proper use they can empower users to control their health and lifestyle better.

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Author's Contribution:

Katarzyna Cierpiszewska: Conceptualization, methodology, investigation, writing

Aleksandra Garczyk: Resources, methodology, investigation, writing

Jakub Klamecki: Resources, investigation, data curation, writing

Dominika Kuc: Visualization, data curation, writing

Dagmara Skowrońska: Resources, visualization, writing

Informed Consent

Not applicable.

Ethical approval

Not applicable. (This study is a systematic review and does not involve human or animal participants.)

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Conflict of interest

The authors declare that there is no conflict of interests.

Data and materials availability

All data sets collected during this study are available upon reasonable request from the corresponding author.

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