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Measuring Health: Wearables in Fitness Tracking, Stress Relief, and Sleep Management

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Abstract

Introduction

In today's fast-paced world, the quest for better health has led to the rise of wearable devices. These innovative tools, from smartwatches to activity trackers, offer real-time insights into our physical activity, stress levels, and sleep patterns. By seamlessly integrating into our daily lives, wearables empower individuals to take control of their health and well-being like never before.

Aim of the study

The present review aims to provide the readers with a broader knowledge of the impact of wearables on health.

Materials and methods

This article provides a foundation for understanding the significance and potential of wearable devices in promoting health and wellness. Comprehensive literature searches were performed across the main electronic databases of PubMed and Google Scholar for studies published in the English language about use and validation of wearables.

Results

Wearable devices are effective tools in promoting physical activity, managing stress, and monitoring sleep. With advanced sensors and algorithms, these devices enable users to track their health progress in real-time and provide personalized strategies for improvement. By combining fitness tracking, communication, and stress management capabilities, these devices possess the capacity to empower individuals in maintaining a healthy lifestyle and have become a potential option at the point where technology and personal health meet. As a result, wearable devices have tremendous potential to transform healthcare and enhance quality of life.

Keywords: wearables, physical activity, stress, sleep

Introduction

Nowadays, maintaining an active lifestyle and improving physical fitness have become priorities for many individuals. In response to this growing need, wearable devices have emerged as innovative tools that not only track our physical activity but also encourage and enhance our efforts toward a healthier lifestyle[1].

Living a healthy and fulfilling life, or even simply carrying out everyday activities, depends on participating in physical exercise of different levels of intensity. Therefore, it is crucial to evaluate the levels of physical activity in both healthy individuals and those who are ill, in order to accurately assess their needs for general wellness. Wearable sensors possess the capacity to gather the data in both those who are in good health and those who have diseases, regardless of the ambient conditions and activities involved. The progress of technology in the domains of sensors, communication, and data analysis has broadened the scope of remote monitoring and led to the emergence of a novel discipline called "telemedicine"[2].

A wearable is a mobile device that is worn on the body and provides useful services while the user is occupied with other tasks. This category includes items such as smartwatches, wearable technology, pedometers, and activity trackers. Advancements in mobile technology have recently improved the capability to identify and assess activity patterns, providing a high level of accuracy in self-monitoring[3]. Wearables possess the primary characteristics that they are connected to the internet for the purpose of transmitting, recording, or analysing data. In addition, these gadgets can be connected to other electronic devices in order to enhance their capabilities. For example, smartwatches have typically been created to track users' performance during physical activities, which can then be accessed through a dedicated smartphone applications[4].

Currently, wearables are utilised for health management as they integrate many intelligent sensing and communication features, which appeal to consumers and facilitate market expansion[4]. The use of wearable activity trackers has experienced a significant surge, with a staggering 1444% rise in global shipping from 2014 to 2020. Furthermore, the expenditure on these devices reached nearly USD 2.8 billion worldwide in 2020[5]. Wearable technologies and their associated smartphone applications now provide more reliable and easily understandable data visualisation, leading to a rise in popularity[6].

Wearables can be essential for tracking physical activity[7]. These gadgets are equipped with sophisticated sensors that can monitor multiple metrics associated with physical activity, such as step count, distance travelled, calories expended, heart rate, and even sleep habits. Their main goal is to offer customers valuable information about their daily behaviours, encouraging them to participate in consistent physical activity and adopt a more active way of life[8]. Contemporary wearable technology comprises accelerometers, gyroscopes, and barometric pressure sensors that are affixed to the body. Various body sensors have been developed to detect physiological and biochemical characteristics, posture, and mobility, according to their intended use. Advancements in microelectronics have recently made it possible to produce small and flexible sensors that include tiny circuits, microprocessors, and radio transmitters. These attributes overcome the obstacles of dimensions and mass that previously impeded the broad adoption of wearable sensors for prolonged monitoring[9].

Monitors of research quality usually save all collected data, often in high resolution, for long periods of time, ranging from weeks to months. The data can be saved either locally on the device or uploaded to a cloud service, principally intended for the usage of the research team. Wearable physical activity monitors typically lack the ability to collect data with high precision. However, they are capable of routinely or simultaneously transmitting data from the device to a visible platform, such as a website or smartphone, for the user to view. Although research-based accelerometers are generally regarded as more reliable and precise, wearables provide users with the opportunity to personally track their levels of physical activity, energy usage, sleep patterns, and sedentary behaviour. Additionally, they facilitate the creation of an individualised preventive strategy[10].

Physical Activity

Traditionally, it has been challenging to quantify and evaluate unintentional physical exercise. Commonly used devices for monitoring physical activity in research and activity interventions include pedometers (which measure steps), accelerometers (which measure body or limb acceleration), and combination devices that measure both acceleration and other physiological parameters like heart rate, sweat rate, and skin temperature[11].

Lack of physical activity ranks as the fourth most significant contributor to global mortality. Despite the availability of evidence supporting the health benefits of physical activity since the 1950s, efforts to promote population health have been slow to catch up with this evidence. Only recently has there been a recognisable infrastructure in place, which includes planning, policy, leadership and advocacy, workforce training and development, and monitoring and surveillance. To increase physical activity worldwide, it is necessary to develop global capacity by building upon existing foundations. However, instead of solely focusing on individuals through a behavioural science approach, a more effective way forward is to adopt a systems approach that considers populations and the intricate interactions among the factors contributing to physical inactivity[12]. Physical inactivity is linked to higher risk of chronic diseases. Ongoing research is consistently uncovering and reporting new facts regarding the prevention of chronic diseases, rehabilitation and treatment, and other health advantages associated with regular physical activity and exercise[13]. A sedentary lifestyle can lead to various health issues such as compromised blood flow, weakened bones (osteoporosis), joint inflammation (arthritis), and other skeletal disorders. It can also result in a lower self-esteem, increased reliance on others for daily activities, limited social interactions, and an overall reduced quality of life[14]. Regular physical activity and exercise have been found to lead to positive changes in cardiovascular health. These changes include a decrease in systolic blood pressure and lower levels of catecholamines in the blood during rest and various degrees of exercise. This can be beneficial in reducing the risk factors associated with cardiovascular disease and can aid in its prevention and treatment[15].

One effective method for encouraging physical activity is through the utilisation of wearable activity monitors. Wearable activity trackers are devices that are worn on the body, typically on the wrist, and are capable of measuring and monitoring activity metrics such as step count, physical activity minutes, and occasionally other factors like heart rate. They can be utilised to evaluate the levels of physical activity in patients and improve the implementation of physical activity therapies by facilitating behaviour modification strategies such as setting goals, self-monitoring, and providing feedback on conduct[16]. Wearable electronics enable users to monitor their development over time, empowering them to evaluate their accomplishments and modify their exercise regimens accordingly[17].

Accelerometry is the best method for measuring physical activity because it directly measures acceleration, which is directly related to external force. This allows it to accurately reflect the intensity and frequency of human movement. Accelerometers are devices that detect and quantify the changes in velocity of objects as they move along specific axes. Velocity and displacement information can be obtained from accelerometry data by integrating the data with regard to time. Certain accelerometers are capable of detecting and measuring tilt in relation to reference planes by responding to the force of gravity. This ability is particularly useful when the accelerometers are attached to objects that are rotating. The obtained inclination data can be utilised to categorise body postures (orientations). Accelerometry possesses the necessary qualities to effectively measure physical activity and various human activities. Accelerometers are widely recognised as valuable and functional sensors for wearable devices used to measure and evaluate physical activity in clinical or laboratory settings, as well as in real-life scenarios[18].

Wearable activity trackers support behaviour modification strategies, such as self-observation and goal establishment[19], and their utilisation has been linked to heightened levels of physical activity[20,21]. Moreover, the utilisation of wearable activity trackers has demonstrated a correlation with enhanced physiological results, including decreased BMI and lowered blood pressure[22]. People who engage in high levels of physical inactivity and sedentary behaviour are more likely to develop chronic cardiometabolic disorders, including ischemic heart diseases, cancer, obesity, and early mortality[23]. Therefore, lifestyle treatments that target the reduction of physical inactivity and sedentary behaviour are seen as interesting methods to prevent the risk of chronic diseases.

Wearables also hold the potential to enhance psychological well-being by promoting physical activity, which has been demonstrated to have antidepressant effects and can help alleviate depression[24] and anxiety[25].

Stress management

Stress arises when an individual interprets a stimulus as a danger, triggering their autonomic nervous system and the secretion of hormones such as adrenocorticoids, glucocorticoids, catecholamines, and growth hormone, among others[26]. These hormones exert a wide range of effects on the body, such as elevated heart rate, heightened muscle tension, raised blood pressure, and accelerated breathing frequency[27]. Chronic psychological stress can have detrimental effects on an individual's health. Stress induces physiological reactions that involve alterations in the neurological and immune systems, such as an increased level of circulating inflammatory factors[28].

A wearable device has the capability to identify elevated stress levels and offer immediate prompts to engage in breathing exercises or mindfulness[29]. Smartwatches have the capability to schedule periods of mindfulness or relaxation. These prompts may motivate users to engage in brief intervals of rest, practise deep breathing, or engage in meditation as a means of managing stress and promoting mental well-being[30]. Several wearable devices monitor stress levels by measuring heart rate, heart rate variability (HRV), and various other measures[29].

Heart rate variability is the term used to describe the variation in the time intervals between successive heartbeats, which are also called R-R intervals. This variation is monitored using electrocardiography or optical sensors[31]. When individuals undergo acute or chronic stress, the sympathetic branch of the autonomic nervous system causes an increase in heart rate and decrease in heart rate variability. On the other hand, during times of rest and recuperation, the parasympathetic branch of the nervous system becomes dominant, leading to a decrease in heart rate and an increase in heart rate variability[32]. These devices can monitor heart rate variability throughout the day and give immediate feedback on stress levels. They can also recommend personalised solutions to help users manage their stress response[33].

The smartwatch's comments and achievements could potentially promote effective stress management. Smartwatches have the capability to link with a wide range of smartphone applications, health platforms, and services. This integration employs meditation applications, guided relaxation programmes, and online support communities to comprehensively address and handle stress[34]. Smartwatches provide users with guidance on stress-reduction exercises such as controlled breathing and mindfulness. Consumers can achieve relaxation through the use of systematic instructions, visual prompts, and physical sensations. This guidance prioritises the reduction and treatment of stress[35]. Smartwatches promote positive habits that decrease stress and enhance overall health and wellness[36].

Sleep tracking

Sleep polysomnography (PSG) is considered the gold standard for objectively assessing sleep and is the primary approach for diagnosing sleep problems in clinical settings as well as in research studies. Nevertheless, conventional in-lab PSG configurations, which use electroencephalography (EEG), possess various drawbacks, including their exorbitant expense, labor-intensive nature, and detrimental impact on the patient's sleep[37]. Nevertheless, PSG has a notable limitation in that it is not well adapted for ambulatory examination[38].

The advancements in sensor technology, such as miniaturisation, low power consumption, low cost, connectivity, and functionality of bio-sensors, enable the latest wearables to consistently capture a wide range of bio-signals. These wearables utilise skin temperature and optical photoplethysmography (PPG) sensors, along with motion sensors, to potentially enhance the classification of sleep stages[39]. Lately, researchers from all around the world have shown significant interest in extracting additional relevant information from the PPG signal, beyond just heart rate estimation and pulse oximetry values. Photoplethysmography (PPG) is a simple and cost-effective optical measuring technique commonly employed for monitoring heart rate. PPG is a non-invasive technique that use a light source and a photodetector placed on the skin's surface to quantify the changes in blood circulation volume[40]. Another method for measuring sleep patterns are wrist-worn wearables accelerometers, or actigraphy[41]. Actigraphs are compact and portable devices equipped with accelerometers that can detect physical movement. These devices transform the detected activity into estimations of sleep and wakefulness. While actigraphy may have limitations in correctly measuring waking after sleep onset, previous studies have shown that it is a reliable method for estimating sleep[42].

There is increasing evidence suggesting that the classification of wake and sleep stages could be improved by combining data on motion and autonomic markers, such as heart rate and HRV indices[43]. Sleep can be categorised into two primary stages: non-rapid eye movement (NREM) and rapid eye movement (REM)[44]. Multiple algorithms have demonstrated the capability to automatically assess sleep stages using heart rate variability (HRV), which is commonly monitored using an electrocardiogram (ECG), often in conjunction with breathing effort. During REM sleep, both the average heart rate and the power in the low-frequency band of HRV are elevated compared to NREM sleep[45].

Precise evaluation of sleep is crucial for gaining a deeper understanding and assessing its impact on health and disease. The present cutting-edge review seeks to emphasise the utilisation, validity, and practicality of consumer wearable sleep-trackers in both clinical practice and research. It is vital to establish guidelines for a standardised assessment of device performance. Before employing these devices in clinical and sleep research protocols, various critical issues such as proprietary algorithms, device malfunction, and firmware changes need to be taken into account. Wearable sleep technology has the potential to enhance our knowledge of sleep health. However, it is important to proceed cautiously, taking into account both the advantages and disadvantages of using this technology in sleep research and clinical sleep medicine[46].

Future prospects

Wearable sensors offer a wide range of applications in specialised medical fields, allowing for the monitoring of acute and chronic illnesses as well as overall health in both clinical and non-clinical settings. Current research is investigating methods to utilise this longitudinal data in order to shift the medical paradigm from a reactive approach to a proactive healthcare system[47].

Wearable devices have proven to be quite effective in examining cardiac health and identifying irregular heart rhythms outside of medical facilities. Enhancements to Holter monitoring, which is the established method for monitoring cardiac events outside of the clinic, involve substituting lead-based monitoring with the aim of enhancing compliance and data gathering. Additionally, there is an effort to extend the duration of continuous monitoring by using different form factors[48].

Hypertension is an escalating global issue[49]. The diagnosis and monitoring of hypertension, as well as the assessment of therapy efficacy, pose challenges due to several factors: A solitary blood pressure (BP) reading taken in the clinic frequently fails to accurately represent the actual average BP. BP levels vary throughout the day due to circadian rhythms and everyday activities, and the phenomenon known as 'white coat syndrome' can result in elevated BP readings in a clinical setting[50,51]. Compact and affordable blood pressure monitors allow for monitoring at home, although they are not continuous or passive. Emerging devices employ optical pulse wave-based measurements of blood pressure, offering a potential shift in the existing approach to hypertension monitoring[52].

With the rising prevalence of diabetes and metabolic syndrome, there have been significant advancements in the technology used to continually monitor blood glucose levels[53]. All of them can be worn, but they involve some level of invasiveness, either through the use of a subdermal needle or the insertion of a flexible filament. Noninvasive continuous glucose monitors (CGMs) hold potential for managing and preventing chronic diseases in patients with prediabetes or noninsulin-dependent Type II diabetes. They also offer the possibility of integrating with insulin pumps to create a 'artificial pancreas' for Type I diabetics[54].

Conclusion

The integration of wearable devices into healthcare has brought about a paradigm shift in how we monitor and manage our health. As evidenced by their widespread adoption and the surge in global shipments, wearables have become indispensable tools in promoting physical activity, managing stress, and monitoring sleep patterns.

Wearable activity trackers enable individuals to actively manage their physical fitness by offering immediate feedback and supporting strategies for changing behaviour. These gadgets promote a more active lifestyle and improve overall health outcomes by precisely tracking parameters like step count, heart rate, and sleep quality.

Moreover, wearable devices play a crucial role in stress management by identifying elevated stress levels and prompting users to engage in relaxation techniques such as deep breathing and mindfulness. Through continuous monitoring of heart rate variability and other physiological parameters, wearables offer personalized solutions for stress reduction, thereby enhancing mental well-being.

In the realm of sleep monitoring, wearable devices equipped with advanced sensors enable the continuous capture of bio-signals, facilitating the classification of sleep stages and providing valuable insights into sleep quality. While there are challenges to overcome, such as ensuring the accuracy and reliability of sleep tracking algorithms, wearable sleep technology holds immense promise in enhancing our understanding of sleep health and its impact on overall well-being.

In the future, wearable sensors have the potential to transform healthcare by allowing for the proactive monitoring of chronic diseases and supporting early intervention options. The rapid progress in sensor technology has the capacity to transform the healthcare industry through wearables.

Author's contribution

Conceptualization, Julia Sieniawska and Patrycja Proszowska, methodology, Adrianna Orzeł and Daria Sieniawska, software, Aleksandra Pich-Czekierda and Adrianna Orzeł, check

Zuzanna Kotowicz and Patrycja Proszowska, formal analysis, Magda Madoń and Aleksandra Pich-Czekierda, investigation Adrianna Orzeł and Julia Sieniawska, resources, Zuzanna Kotowicz and Daria Sieniawska, data curation, Zuzanna Kotowicz, writing-rough preparation, Magda Madoń, Aleksandra Pich-Czekierda, visualization, Patrycja Proszowska, supervision, Adrianna Orzeł, project administration, Daria Sieniawska, Magda Madoń and Julia Sieniawska.

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