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ORIGINAL RESEARCH ARTICLE

Health and biosensor technology—A revolution underway for the well-being of the population

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ABSTRACT

This document mentions characteristics of portable devices that highlight their applicability in healthcare because they fundamentally allow monitoring outside hospital institutions and allow the prediction of health events. This writing is achieved with the review of updated information available in the world scientific literature. Additionally, the challenges and disadvantages associated with the implementation of wearable sensors are shown. The aim of the above is to highlight that portable devices improve medical care in a wide variety of environments, but are particularly useful for the remote management of pathologies.

Keywords: remote sensors; biomedical technology; mobile health; digital health

1. Introduction

Biomedical technology currently marks the course of health action in countries with high economic income, especially in the so-called mobile and digital health, because it allows continuous and longitudinal monitoring of health outside the hospital environment, whether public or private one of the attributes that leads healthcare professionals to adopt these portable devices to monitor their patients[1–3].

Also mentioned as positive characteristics that define mobile and digital health are that its devices allow the development of algorithms for the prediction, prevention and automated intervention of health events, and that the information recorded in them is online instantly, that is, at an amazing pace, and that allows greater access to medical care, since the patient can receive medical care from home regardless of the distance at which the health professional who cares for them is located[1,4,5].

The level of complexity of health care does not seem to be an obstacle to the implementation of this system because it has proven to be useful for the treatment of simple pathologies up to those that require intensive care, thereby substantially improving the quality of health care provision health services, particularly in environments with limited resources such as rural and marginal urban areas, in this sense, it has proven to be useful in clinical and neonatal temperature monitoring, as well as in the detection of out-of-hospital arrhythmias and in the improvement of the system of alarms in intensive care units[1,2,6], therefore, the objective

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of this document is to precisely show the characteristics that define portable technological devices for use in the field of health care as a result of the analysis of the information that exists on the subject in world scientific literature.

2. Methodology

This is a narrative-type documentary review of articles based on descriptors or keywords (remote sensors, biomedical technology, mobile health and digital health) in online databases such as Biorxiv, Medrxiv, ChemRxiv, Google Scholar and PubMed. The bibliographic review included original documents published until March 2024, through the independent double-blind method. After analyzing the information, the relevant ideas regarding health and biosensor technology were grouped into sections with the aim of facilitating reading: portable devices used in health in general, revolution in intra- and extra-hospital medical care by the use of biosensors, portable biosensors used in cardiac and metabolic disorders, portable devices in neurology and mental health, biosensors in the maternal and newborn sphere, participation of portable biosensors in pulmonary disorders and environmental exposure and conclusions.

2.1. Portable devices used in general health

Portable devices integrated into routine clinical practice are of the mechanical type (using inertial measurement, accelerometers, gyroscopes, magnetometers and pressure measurement based on piezoelectric components), physiological (based on optical, electrical, acoustic and thermal detectors to measure biological signals) and biochemical (they combine a chemically sensitive layer and a transducer to convert a chemical or biological analyte into an electrical signal) that record useful data for: Gait monitoring, detection of cardiac arrhythmia, determination of blood parameters such as glucose, vital signs, bioelectrical activity (electromyography, electrocardiogram, electroencephalogram, bioimpedance and electrodermal activity)[7–9].

Digital biomarkers surpass traditional clinical methods in cases such as the detection of arrhythmias due to their capacity for continuous monitoring outside healthcare institutions. The extraction of useful and actionable health information from individuals in a community represents a major challenge of the widespread adoption of wearable biosensor technologies, an obstacle that can be overcome with the development of algorithms for automatic processing and interpretation. Also the maintenance of data privacy and security. Likewise, physiological monitoring studies to discover new applications (from the detection of acute health events, monitoring and treatment of chronic diseases) of mobile health technologies continues to be a great challenge, which can probably be overcome with analytical methods of machine learning type data[1,10,11].

2.2. Revolution of intra- and extra-hospital medical care through the use of biosensors

Care in hospital settings, public or private sector, is clearly revolutionized with biosensors due to the continuous collection of data, real-time analysis and presentation of health information that allows the historical accumulation of data before the presentation of the patient to the health institution in search of medical attention that facilitates rapid classification and immediate health care, reducing complications and sequelae[1,12,13].

Monitoring (electronic triage), also, is useful in emergency rooms particularly scanning vital signs for automated patient triage, in the category of ambulatory patient monitoring is a challenge overcome by the wireless nature of wearable sensors providing an unprecedented opportunity in improving follow-up and ensuring patient comfort[1,14,15].

Telemedicine is revolutionized by wearable sensors because it provides information to remote doctors while the patient is at home or hospital that can be integrated into the electronic medical record through the use of integration/interoperability applications that aggregate data from hundreds of wearable devices to their associated electronic medical record systems[1,2,13].

2.3. Wearable biosensors used in cardiac and metabolic disorders

Wearable biosensors are useful in a wide range of healthcare-related areas, for example, in the diagnosis and management of metabolic syndrome (including high blood pressure, abdominal obesity, high blood glucose, abnormal cholesterol or triglyceride values) and especially in the diseases it triggers, that is, diabetes mellitus, stroke and cardiovascular disease. In this sense, since 1999 there has been the first continuous glucose monitor, if you like, invasive because they require a subdermal needle or insertion of flexible filaments[16–18].

The development of non-invasive devices for measuring blood glucose is expected, including smart watches, contact lenses (with tears as a material for determination) and those based on the transmission of high-frequency radio waves and low power through thin sections of skin with high blood flow such as the earlobe and the area between the thumb and index finger[19–21].

In cardiac health, Holter has been the standard in monitoring events in this area in out-of-hospital environments since 1965. Since then, several advances have been recorded, for example, improvements in adherence and data collection based on replacing lead-based monitoring, also passive monitoring (usually lasting 1 to 2 weeks) with patches and continuous or band passive monitoring using optical heart rate sensors (sensors with smart watch combined with a heart rate engine) analysis that allows specifying atrial fibrillation with an accuracy of 97%)[22–24].

In the field of cardiovascular diseases, technological development has achieved combined devices that detect arrhythmias with a portable interventional defibrillator that allows automatic resuscitation of patients when necessary. In this order of ideas, a smart phone system has been used in cardiac rehabilitation to recommend exercise intensity by comparing portable heart rate data in real time with a predefined value, with the purpose of ensuring the recovery of the cardiovascular system in general[25].

The problems observed in measuring blood pressure are mainly the difficulty in determining the real average blood pressure, because it fluctuates throughout the day depending on heart rhythms and daily activity, to which is added the white coat syndrome that usually leads to higher pressures. Since arterial hypertension is a growing public health problem, continuous monitoring throughout the day and longitudinally over time is key for diagnosis and determination of treatment effectiveness[26–28].

In the monitoring of arterial hypertension, cuff-based oscillometric measurements, non-passive or continuous ambulatory blood pressure monitors that allow monitoring at home, inflatable bracelets or metrics based on optical pulse waves for continuous monitoring have been used of blood pressure and oscillometric methods or case prediction algorithms based on heart rate and steps[29,30].

In another field of health, that of gastrointestinal diseases (which can coexist with metabolic syndrome) with direct and indirect cost of care estimated at 142 billion dollars per year, digestive telemetry using non-invasive vibration has proven to be really useful and sound detection to evaluate in real time the reintegration of the gastrointestinal tract after surgery. With the electrogastogram, the potential of gastric monitoring has been significantly expanded, since with the electrodes the motor activity of the stomach, small intestine and colon can be measured[31,32].

Currently being tested with an ingestible sensor (in early development stage) that attaches to the stomach wall or intestinal lining to measure rhythmic contractions of the digestive tract for diagnosing gastrointestinal slowing or monitoring food intake through of gastrointestinal movement, with these sensors it is expected to drastically improve gastrointestinal care[33].

2.4. Portable devices in neurology and mental health

Wearable sensors allow, through improvements in monitoring, the early diagnosis of neurological, sleep, mental health and movement disorders. Currently the gold standard for sleep monitoring is polysomnography, but it often conflicts with subjective self-reports of sleep. Among the promising wearable sensors for sleep monitoring, the Oura ring stands out with sensitivity of up to 96% to detect sleep and with agreement of 65%, 51% and 61% in the detection of light sleep, deep sleep and REM sleep, respectively. In the case of sleep pathologies such as obstructive sleep apnea (one of the most common disorders, affecting up to 7% of adults) wearable devices have proven to be very effective[33].

With the single-channel EEG and an IMU sensor, five different levels of drowsiness can be detected with an average accuracy of 95.2%. Mood disorders (depression, anxiety and fatigue) can be evaluated in real time and with a significant reduction in dependence on the participant's interaction, while increasing the volume of data and including additional data. Using portable actigraphs, it has been possible to determine that different activity patterns may correspond to a worsening of depressive symptoms. With support vector machines trained on features of heart rate variability and prior mood, mood states of bipolar disorder including depression, mania, and euthymia can be detected[33,34].

Sentio Solutions' Feel bracelet is expected to provide personalized interventions to the user according to their mood based on its neural network model (with artificial intelligence platforms that can effectively predict the interventions required by an individual based on the combination of personal historical data with population data in the optimization of the moment and type of treatment required) patented that can detect mood (relaxed, anxious, excited and fun) in up to 75% of cases[35].

Just-in-time intervention is possible for people with autism spectrum disorders through a platform for emotional self-regulation using physiological and movement metrics from a smartwatch to predict outburst patterns and provide self-regulation exercises in real time[36]. With a smart watch, neurological disorders of motor control deregulation, that is, seizures from common pathologies such as epilepsy, can be detected through electrodermal and accelerometry activity, with notification, with a positive value, to emergency contacts[37].

Measurement and correction of gait in patients with multiple sclerosis is possible with the vest and shoe insole system, as the system detects and converts the pressure produced in the insole when walking in the vest with a built-in vibrotactile matrix for re-teaching to walk patients with this pathology. This system has also been useful in preventing diabetic foot ulcers through pressure release alerts. Gait analysis (allows longitudinal monitoring of gait changes) is also used in the evaluation of patients with Parkinson's disease through video-based motion capture in specialized laboratories. With a triaxial accelerometer placed in any location and orientation on the body, falls can be detected with a sensitivity of 99% and specificity of 100%[38,39].

2.5. Biosensors in the maternal and newborn sphere

Remote monitoring and telemedicine-based approach substantially improve access to healthcare for women and their newborns. Note that to improve the probability of conception, fertility monitoring devices are used specifically for women based on monitoring ovulation based on physiological changes such as body temperature, for example, the Ava bracelet (which measures nine physiological parameters: skin temperature, heart rate variability, sleep, respiratory rate, movement, perfusion, bioimpedance, heat loss and resting pulse)[40–42].

Ovulation cycles can be determined through temperature trackers, the Yono headset, and the Tempdrop armpit bracelet (based on measuring basal body temperature). Work is underway on devices to measure heart rate and track fetal movements, as well as to identify and measure uterine contractions in the third trimester of pregnancy using electrohysterography and heart rate[40–42].

The Moodo wearable device and non-wearable Bellabeat Shell smartphone accessory record and amplify sounds to track fetal heart rate and count fetal kicks. Apnea alarms (physiological monitors for detection of heart rate, respiratory movement and pulse oximetry), tachycardia, bradycardia and oxygen desaturation help in neonatal and infant physiological monitoring. Furthermore, the Bempu neonatal bracelet allows determining the temperature of the premature newborn and detecting hypothermia[43–45].

2.6. Involvement of wearable biosensors in lung disorders and environmental exposure

Portable multisensors have been designed based on adventitious noises, abnormal sounds that characterize lung diseases, such as the bronchial asthma detection multisensor (assesses wheezing [due to narrowing of the airways and limited airflow]) with precision in the detection of this pathology is 71%, and these devices also allow predicting the progression of the disease[46]. These devices can identify not only asthma, but are also useful in the detection of chronic obstructive disease (assesses wheezing), pneumonia (assesses crackles [due to explosive opening of the small airways]), congestive heart failure (assesses crackles) and pulmonary fibrosis (evaluates crackles)[46,47].

Work is being done on remote biosensors for the detection of airway obstruction caused by anaphylaxis based on the detection of early reaction signs and the automatic administration of epinephrine in response to it. Finally, environmental exposure detection devices are being developed, such as patches to measure ultraviolet light and radiation exposure, and other devices to quantify personal exposure to ozone and volatile organic compounds[48–50].

3. Conclusions

The different innovations in wearable sensors are of great benefit in healthcare, in a wide variety of disciplines, as they are useful in cardiology, gastroenterology, endocrinology, neurology, mental health, pulmonary health, maternal care, prenatal and neonatal care, and environmental exhibitions, among others. In this sense, it is recognized that digital biomarkers in some cases surpass traditional clinical methods in monitoring or tracking, for example, cardiac arrhythmias, blood parameters, vital signs, bioelectrical activity, and physiological events.

Wearable biosensors are also used in acute and chronic health diseases, as they collect continuous data information, allow real-time analysis and offer health information to professionals or health institutions in charge of providing medical care, which reduces complications and sequels. Emphasis should be placed on maintaining the privacy and security of the data provided by wearable biosensors.

Author contributions

Conceptualization, GB; methodology, GB and RI; software, RI; validation, GB, and RI; formal analysis, GB; investigation, RI; resources, GB; data curation, RI; writing—original draft preparation, GB; writing—review and editing, RI; visualization, RI; supervision, GB; project administration, GB; funding acquisition, RI. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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