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Editorial

Smart Clothes to Take Care of People or Smart People Who Use Clothes to Take Care of Themselves?

¿Prendas inteligentes para cuidar a las personas o personas inteligentes que utilizan prendas para cuidarse?

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Since the dawn of human life, we have used clothes and accessories to protect our health and defend ourselves from the elements and danger. From the mid-1990s onward, researchers from the Massachusetts Institute of Technology began to explore the possibility of incorporating microprocessors into textiles.[1] Since then, 3 areas of innovation have strongly promoted the development of smart clothing: the introduction of new fibers in textiles (eg, conductive materials), the miniaturization of electronic devices, and the development of wireless communication. The latter enables clothes to communicate and interact with personal computers and mobile phones.

Smart clothes were originally designed for use in clinical settings. However, thanks to miniaturization and mobile technology, their use has recently proliferated in the general population as a tool for health and wellbeing. According to the World Health Organization, mobile health (known as mHealth), will soon be available to 90% of the world population. mHealth has undergone exponential growth and currently there are more than 100 000 medical applications that can be used on computers or mobile phones. Of these applications, 30% are for the use of patients and health professionals and 70% for the general population.[2,3] It is estimated that within a few years 65% of mHealth applications will be used for monitoring chronic diseases. In global terms, it is thought that the mHealth business will have a turnover of more than $27 000 million in 2017, with 90% of the market share divided proportionally between Europe, Asia, and North America. However, this figure is small when compared with the indirect benefits of this technology. A report published in May 2011 estimated that the use of data generated by mobile applications (big data) could reduce fraud and improve efficiency to the point of saving €150 000 million per year in the European public sector.[4]

In general, smart clothes are based on using sensors to detect a variety of signals, which are usually converted into electrical signals. Currently, sensors can measure almost any parameter: pressure, stretch, temperature, humidity, and even various substances in blood, such as glucose. In addition, sensors are sufficiently small to allow them to be mounted in a tooth or a contact lens.[5]

Since the time of the first textile sensors and smart clothes, a fundamental aim has been to obtain a good ECG signal.[6,7] The first sensors measured and transmitted all the information that can be obtained from an electrocardiographic lead (ie, a signal with a sampling frequency of 4 ms). This signal is difficult to store on mobile devices due to the amount of space required and the difficulty of interacting with different operating systems. Most applications have been limited to measuring and transmitting the heart rate alone and to using technologies with well-defined standards, such as Smart Bluetooth, which has solved the problem of interoperability and drastically reduced costs.[8] Thus, heart rate can now be indirectly acquired without the need for an electrocardiographic signal. Nevertheless, the ECG signal remains the most widely used signal because its quality is sufficiently reliable to measure heart rate and because the devices used for its measurement are inexpensive and durable (they can last up to a year without changing the battery even when used for several hours a day). This technology is used in many textile sensors just to measure heart rate. However, some sportswear incorporates proprietary technology to analyze the ECG signal and provides the heart rate as well as QRS and P wave morphologies in some leads. These technologies are similar to conventional Holter monitoring but have the advantage of being more comfortable, having greater mobility, and providing a longer observation period.[9]

In addition to devices able to acquire ECG signals, other technologies have been developed, such as photoplethysmography (PPG). This technology seems likely to become established and is based on detecting changes in blood volume by using an emitter and detector at the same site to measure reflected light (reflective PPG). This technology is used in bracelets and watches to measure heart rate. Companies such as Apple, Google, and Samsung are staking their smart watches on this technology. Although entrepreneurial drive is very powerful, the cost of these devices is still higher than the cost of ECG-based monitors and their batteries still have to be recharged.

The Modulated Magnetic Signature of Blood (MMSB) is another upcoming technology, which detects fluctuations in the magnetic

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field created by the blood flowing through a section of the cardiovascular system. The magnetic flux can be used to show pulse and blood flow information, and can propagate through materials such as fabric (eg, clothing), through the body (eg, as blood), and through environmental pollutants (eg, water). Information on heart rate can be obtained by MMSB without the need for electrical or optical contact with the skin and has been favorably compared with ECG and PPG signals.[10]

With the exclusion of military projects, most trials using smart clothes have addressed health monitoring in general and cardiovascular health in particular.

Some of the most pioneering European projects have been developed by the MyHeart[6] and HeartCycle[7] consortiums. These projects began more than 10 years ago as part of the sixth and seventh European Union Framework Programs, which included more than 30 international associates (medical technology and telephone companies, universities, and hospitals). Their aim was to devise solutions for patient self-care, encourage heart-healthy lifestyles, and provide safety through widespread access to rapid and effective care. They designed and used textiles and clothes with sensors to detect respiratory rate, heart rate, ECG analysis, proper acceleration, 3-dimensional movement, and oxygen saturation. They also made available devices for monitoring obesity and depression, for preventing myocardial infarction and stroke, and for remote cardiac rehabilitation, relaxation, and stress prevention. These projects particularly addressed the issues of patients with heart failure and the rehabilitation of patients with ischemic heart disease. Given the huge amount of healthcare resources needed to assist patients with these diseases, one of the main aims of these projects was to obtain sufficient information on the daily life of patients to allow prediction of recurrences before they occur, provide early treatment, and avoid hospitalization.

Currently, smart garments are available that can analyze heart rate and changes in heart rate and ECG morphology. They can determine the presence of bradycardia or tachycardia, measure heart rate variability, and provide a rough differential diagnosis between supraventricular and ventricular arrhythmias. These advances are already a great achievement. A more difficult task is to assess ST-segment abnormalities, especially if they do not match symptoms suggestive of myocardial ischemia. However, this task is just as difficult when using conventional Holter monitoring.

In clinical practice, cardiac monitoring tools are needed such that when symptoms arise it is possible to identify what is happening in the heart, thereby helping us to provide patients with correct treatment. It is essential to be able to detect silent atrial fibrillation and initiate anticoagulation if needed, as well as to prevent sudden death in patients with damaged hearts and warning ventricular arrhythmias. Irrespective of these considerations, smart clothes provide immense amounts of information, thus leading to huge increases in knowledge, and are clearly changing health worldwide. Their capacity to monitor a wide variety of diseases will soon provide vast amounts of information. In addition to its use by professionals and patients, this information will allow many processes to be automated, thus changing the physician's role. In the near future, patients and nonpatients alike will experience a fundamental change by becoming active elements in the prevention, diagnosis, and treatment of disease. It is easy to imagine all this information being connected via an electronic medical record and managed by an artificial intelligence network.

Currently, the greatest area of uncertainty lies in knowing whether the use of smart clothes will be able to change lifestyles. It is extremely complicated to design and conduct clinical studies to determine the independent benefit of smart clothes in chronically ill patients. Factors such as adherence to protocols are both decisive and difficult to address. We do not know if the trend to use smart clothes is driven by people who care more about their health than others and are willing to follow a healthier lifestyle. In contrast, adherence is most difficult to achieve in chronically ill patients with multiple comorbidities who sometimes appear to have given up altogether. Within this group, elderly patients represent the greatest challenge: they have few resources and need constant assistance to help them persevere with the self-care needed to maintain their health. In many cases, the main issue is to replace hospital care with home monitoring and office consultations with virtual consultations. To date, few studies have been published on the clinical success of the help provided by the use of smart clothes.[11,12] Studies are underway, but until the results are available, we will continue to be surprised by new developments in medical technologies and by the information provided by implantable and nonimplantable sensors.[13,14] For example, despite the lack of adherence to specific treatments, a better clinical course than expected has been observed in some patients with heart failure.[7,15]

CONFLICTS OF INTEREST

J. Pérez-Villacastín has participated as a researcher in the MyHeart and HeartCycle projects.

REFERENCES

1. Post R, Orth M, Russo P, Gershenfeld N. E-broidery: design and fabrication of textile-based computing. IBM Syst J. 2000;39:840–60.
2. Aitken M, Gauntlett C. Patient apps for improved health. From novelty to mainstream. IMS Institute for Healthcare Informatics. 2013 October [cited 2015 Mar 13]. Available at: http://www.imshealth.com/deployedfiles/imshealth/global/Content/Corporate/IMS%20Health%20Institute/Reports/Patient_Apps/IIHI_Patient_Apps_Report.pdf
3. The App Date. El crecimiento de las apps de salud en el mercado internacional. Informe 50 mejores Apps de salud en español (p. 9-10) [cited 2015 Mar 13]. Available at: http://madrid.theappdate.com/wp-content/uploads/2014/03/Informe-TAD-50-Mejores-Apps-de-Salud.pdf
4. Manyika J, Chui M, Brown B, Bughin J, Dobbs R, Roxburgh C, et al. The next frontier for innovation, competition, and productivity. McKinsey Global Institute. 2011 (p. 2) [cited 2015 Mar 13]. Available at: http://www.mckinsey.com/insights/business_technology/big_data_the_next_frontier_for_innovation
5. Bandodkar AJ, Wang J. Non-Invasive wearable electrochemical sensors: a review. Trends Biotechnol. 2014;32:363–70.
6. MyHeart Consortium. MyHeart Project [cited 2015 Mar 12]. Available at: cordis.europa.eu/project/rcn/71193_en.pdf.
7. HeartCycle. Compliance and effectiveness in HF and CHD closedloop management. HeartCycle Consortium; 2013. [cited 2015 Mar 13]. Available at: http://www.heartcycle.eu/
8. Bluetooth Developer Portal. Heart Rate Monitor. Heart Rate Profile Specification [cited 2015 Mar 13]. Available at: https://www.bluetooth.org/docman/handlers/downloaddoc.ashx?doc_id=239865&_ga=1.34851812.452980616.1426172354
9. Olmos C, Franco E, Suárez-Barrientos A, Fortuny E, Martín-García A, Viliani D, et al. Wearable wireless remote monitoring system: an alternative for prolonged electrocardiographic monitoring. Int J Cardiol. 2014;172:e43–4.
10. Phua CT, Lissorgues G, Gooi BC, Mercier B. Statistical validation of heart rate measurement using modulated magnetic signature of blood with respect to electrocardiogram. Int J Biosci Biochem Bioinforma. 2012;2:110–6.

11. Cleland JG, Louis AA, Rigby AS, Janssens U, Balk AH; TEN-HMS Investigators. Non-invasive home telemonitoring for patients with heart failure at high risk of recurrent admission and death: the Trans-European Network-Home-Care Management System (TEN-HMS) study. J Am Coll Cardiol. 2005;45:1654–64.
12. Hamine S, Gerth-Guyette E, Faulx D, Green BB, Ginsburg AS. Impact of mHealth chronic disease management on treatment adherence and patient outcomes: a systematic review. J Med Internet Res. 2015;17:e52.
13. Rogers JA. Electronics for the human body. JAMA. 2015;313:561–2.
14. Lau CP, Siu CW, Tse HF. Future of implantable devices for cardiac rhythm management. Circulation. 2014;129:811–22.
15. Vera-Muñoz C, Arredondo MT, Ottaviano M, Salvi D, Stut W. HeartCycle: User Interaction and Patient Education. Conf Proc IEEE Eng Med Biol Soc. 2013;2013:6988–91. http://dx.doi.org/10.1109/EMBC.2013.6611166.