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Author(s)	Barton, John; O'Flynn, Brendan; Tedesco, Salvatore
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A Review of Physical Activity Monitoring and Activity Trackers for Older Adults

John BARTON[a,1], Brendan O'FLYNN[a] and Salvatore TEDESCO[a]
[a] *Tyndall National Institute, University College Cork, Dyke Parade, Cork, T12R5CP*

Abstract. The objective assessment of physical activity levels through wearable inertial-based motion detectors for an automatic, continuous and long-term monitoring of people in free-living environments is a well-known research area in literature. However, their application to older adults can present particular constraints. This paper reviews the methods of measuring physical activity, adoption of wearable devices in older adults, describes and compares existing commercial products encompassing activity trackers tailored for older participants.

Keywords. Physical activity monitoring, older adults, wearable activity trackers

1. Introduction

Population ageing, and the related increase in chronic diseases, is having a major impact on the healthcare systems of most western countries, and will be having an even more significant effect in the future. For example, as indicated by the United Nations in 2015 [1], by 2030 the number of older persons (those aged 60 years or over) in the world is projected to grow by 56%, from 901 million to more than 1.4 billion, and likewise the global population aged 80 years or over is projected to grow from 125 million in 2015 to 202 million in 2030 and to 434 million in 2050.

Thus, together with this ageing process, it is evident that the burden of chronic diseases is rapidly increasing worldwide as well, as indicated by the World Health Organization [2]. It has been calculated that, in 2001, chronic diseases contributed approximately 60% of the 56.5 million total reported deaths in the world and approximately 46% of the global burden of disease, where almost half of the total chronic disease deaths are attributable to cardiovascular diseases. It has been projected that, by 2020, chronic diseases will account for almost three-quarters of all deaths worldwide.

Chronic diseases could be prevented through healthy diet, avoidance of tobacco products, and regular physical activity. However, when manifested, chronic diseases result in limitation of mobility and physical activity of the affected persons, with a slow, progressive, and sometimes unnoticed entry mechanism. Usually, the only observable effects are the reduction of the level of autonomy and the loss of mobility. Thus, as a consequence, monitoring physical activity is a valuable parameter in order to define if persons are performing enough physical activity in order to prevent chronic disease or if they are manifesting early symptoms of those diseases.

A reliable and continuous 24-h measurement and recording of the physical activity in daily life is thus essential and several solutions have been proposed, from video to

[1] Corresponding Author.

smart homes, whose deployment remain intrusive and expensive. Therefore, the use of micro sensors worn by elderly people to analyse body movements seems an acceptable solution for the individuals and their caregivers, and such a solution has been investigated by researchers in the last few years thanks to the massive diffusion of micro electromechanical systems, which made those micro sensors highly available, miniaturised, and low-cost.

2. Methods

2.1. Physical Activity Indicators

In this section, several common indicators of activity behavior are described. Those indicators continuously measure long-term activities in subjects in free-living environments and can be used to identify posture and classify daily activities correlated to the subject's functional status. Fall detection is another important aspect to be considered.

An example of the indicators commonly taken into account by clinicians and researchers may include:

- Physical activity assessment and sedentary behaviour measurement;
- Posture detection with related postural transition times estimation;
- Daily activity classification;
- Energy expenditure and exercise intensity estimation;
- Fatigue detection;
- Detection and prediction of falling events;
- Gait analysis and related balance/stability evaluation;
- Detection of abnormal characteristics (tremor, freezing event, etc…);
- Sleep analysis;
- Location-awareness information;
- Physical Activity Monitoring and Assessment;

Several suitable methods of assessing physical activity and sedentary behaviour have been adopted in the last few years. In order to define which of those methods should be implemented for a specific case the following factors should be considered [3]:

1. purpose of the assessment, such as epidemiological research, specific populations physical activity monitoring, physical activity correlates and determinants definition, health programs effectiveness measurements, and so on;
2. target population, e.g. pre-schoolers, children, teenagers, elderly, people with chronic diseases, or general adult population;
3. components of physical activity being measured, which include the frequency, intensity, amount, type and setting of activity;
4. practicality of the measurement tool, referring to the development, administration, scoring, and administration of an assessment;
5. participant burden;
6. reliability and validity of the tool being used, indicating the stability of the tool to measure the same concept over time and how well the tool assesses what it is intended to assess, respectively.

In adults, typical ways of collecting data on physical activity are by self-administrated questionnaires, or by some form of direct measurement of movement.

2.1.1. Self Report

A simple tool for physical activity assessment is by self-report, through the completion of questionnaires, interviews and surveys, or, alternatively, also physical activity diaries or logs where information on all forms of activity is recorded each day. Those tools require a detailed description of the activity performed, its' intensity and duration which might be done via a 24-hour recall plus an extrapolation to the previous days to arrive at an impression about the habitual activity levels of the subject. A diary method recording what an individual actually does could produce useful data but requires considerable dedication by the observer. The recording has to be relatively simple and extended to several days in order to avoid potential bias to the results. Some well-known examples [4] of those tools are Godin Leisure Time Questionnaire (GLTEQ), the International Physical Activity Questionnaire (IPAQ) in its short and long form, the Sedentary Behaviour Questionnaire (SBQ), Baecke's Physical Activity Questionnaire, Follick's Diary

2.1.2. Video Recording

Video-recording, adopting static cameras, wearable cameras or low-cost systems (such as Kinect) is an example. Even though it has a definite role in the assessment of activity patterns with the advantage of direct observation, this technique is unlikely to be practicable for large groups of individuals requiring a great amount of resources to analyze and quantify the video-recordings.

2.1.3. Smart Home and Ambient Assisted Living (SHAAL)

Smart Home and Ambient Assisted Living (SHAAL) systems utilize advanced and ubiquitous technologies including sensors and other devices (infrared, pressure mats, automatic bedroom lights, biosensors for vital signs, temperature monitors, etc…) integrated in the residential infrastructure, to capture data describing activities of daily living and health-related events [5].

2.1.4. Doubly Labeled Water (DLW), Indirect Calorimetry, and Heart-Rate Recording

The classical gold-standard techniques of measuring energy expenditure are based on the doubly labeled water method (DLW) or indirect calorimetry measuring oxygen uptake, carbon dioxide production and cardiopulmonary parameters. Though accurate, indirect calorimetry is expensive and requires specialized training, and likewise the DLW method is costly and not suitable for large-scale studies. On the other side, heart-rate monitors are low-cost and can provide information on heart-rate. However, while heart-rate can be a good general indicator of activity, it is not a precise indicator of energy expenditure, unless a proper individual calibration is performed [6].

2.1.5. Wearable Motion Detectors

In order to avoid the issues typical of gold-standard technology and guarantee low-cost, accurate and reliable data, wearable motion detectors have been commonly used in clinical and research settings for objective physical activity measurement. Pedometers are step counter devices designed to measure vertical movement. They have been in use for many years, but pedometers are not accurate when used for activities that do not involve footfalls (such as swimming or upper body movements). Moreover, accuracy may be poor among specific populations, and among different models. Accelerometers are technically more advanced than pedometers and being multi-axial can measure horizontal, lateral, and vertical movements. A great number of reviews studying the adoption of wearable motion sensors for physical activity monitoring and assessment is currently available in literature [7-11]. However, little to no consideration is given to wearables for older adults.

3. Discussion

3.1. Review of Current Products

There are many smartwatches, fitness trackers, and other wearable devices available on the market oriented towards active, healthy customers. On the other hand, only a few developers have seen potential in targeting the needs of people who have particular health concerns by proposing products that help older customers maintain an independent lifestyle. This section reviews several commercially available smartwatches/wristbands designed for elderly people to provide a comprehensive outlook of current development status. However, most of those products are provided by startups or have been unveiled and are still in the development phase, thus are not available for consumers.

Lively [12], recently acquired by GreatCall, Inc., combines a safety watch and home sensors to create a monitoring and emergency response system. The adoption of a wearable smart unit differentiates Lively from other elderly-oriented home-based remote monitoring systems, such as GrandCare [13], or Healthsense [14]. PeakFoqus is a company founded in 2014 which produces Vytality Apple Watch Edition [15], an app and mobile package solution for the health and safety of seniors and patients. The watch contains an automatic fall detection, activity level and heart rate monitoring, location tracking, and an emergency beacon.

Several companies have started producing localisation systems built-in to watches and wristbands, as wrist-based sensors are more socially accepted by older people. Examples of such products are PAL from project Lifesaver [16], Safe Link [17], Revolutionary Tracker [18] and the Vega bracelet from Everon [19]. However, additional features have been also considered.

Forthcoming watches announced by companies or crowdfunding ventures include the CarePredict Tempo [20], the Allen Band [21] the WatchRx system [22], SmartKavach from EasyM2M [23] and the Omate Wherecom S3 [24].

Wearable devices can certainly help older individuals to lead healthier and safer lives, but designers must take into consideration the differences in ability among such users and the population in general. Similar outcomes have been diffused by the AARP (American Association of Retired Persons) in the Project Catalyst's report [25]. Project Catalyst is a collaborative effort between Georgia Tech, the AARP, MedStar Health, Pfizer, and UnitedHealthcare, whose initiative is to identify ways to improve wearables devices for 50-plus consumers. Study participants found the trackers beneficial, especially with regards to learning daily activity and sleep patterns, receiving motivation by seeing progress made toward a goal, having their current activity levels confirmed, and finding the device to be easy to use. However, the trackers were also perceived as inaccurate, lacking of instructions, presenting malfunctions, losing data and having a difficult to sync process, and difficult to wear. Therefore, it is essential that wearable devices specifically customized for 50-plus consumers should be studied so that older adults could fully take advantage of the health benefits related to activity and sleep trackers.

3.2. Wearable systems as healthcare devices

As shown in face-to-face interviews with senior citizens [26], older adults see the future of wearable devices in the healthcare sector by indicating the need, for stakeholders in this area, to get involved in promoting physical activity trackers to patients as a possible way to improve their health. Indeed, most of the interviewed subjects wished the devices were available in pharmacies, and that they could learn about the devices from someone in health care, such as pharmacists, similarly to what is done with other health-monitoring systems (e.g. blood glucose meters, blood pressure meters). Moreover, they were interested if doctors or other health care professionals would potentially take advantage of the data provided from the devices.

Nowadays, in Canada, activity trackers are not taxed if bought with a prescription [26], and in 2016 the PiezoRx [27], a medical-grade exercise prescription device produced by StepsCount, was recognized as a Class 1 Medical Device by Health Canada and is now prescribed also by the physios' Sports Care Centre.

Similarly, in the US, a fitness tracker device is only eligible for reimbursement with a Letter of Medical Necessity (LMN) from a physician with a flexible spending account (FSA), health savings account (HSA) or a health reimbursement arrangement (HRA), in order to treat a legitimate medical condition, such as obesity [28]. The Internal Revenue Service (IRS), indeed, has ruled that fitness trackers are used to promote one's "general health" and are only medically necessary under special circumstances.

Analogous considerations have been analysed by the Food & Drug Association (FDA) which, in the guidance published in July 2016 [29], indicates that it does not intend to examine low-risk general wellness products, which include fitness trackers, as those products do not make a medical claim but are marketed as improving a person's general state of health. Thus, it is evident that manufacturers can produce fitness trackers without being subject to FDA oversight, with the downside of being excluded by the healthcare service.

Therefore, it is envisaged that the future challenges and evolution for wearables are related to regulatory hurdles, compliance, and reimbursement. The current pilot programs are aiming to generate data which can validate the medical relevance of the devices and benchmark them against existing clinical solutions, so that accuracy and reliability issues would be reduced and FDA clearance can be obtained. This medically relevant, clinical-grade data can initiate the integration of wearable devices into medical technologies, thus, persuading insurance companies to cover the cost of the systems for certain patients. Even though fitness trackers are not typically covered, there are some examples of wearable systems which are starting to receive some form of reimbursement, such as Zio Patch by iRhythm [30] for remote arrhythmias detection, or the inertial-based gait analyzer LEGSys by Biosensics [31], while the US Department of Veteran Affairs [32] will soon begin reimbursing for monitoring devices that can deliver continuous and accurate data on the effectiveness of prosthetic devices. The technology is advancing rapidly and the market for wearable technology will expand significantly. Despite potential restraints and barriers, such data can cause a dramatic shift in the future life and health insurance industry. The evolution of wearable technology in healthcare is expected to revolutionize the health insurance industry, according to a new report from Timetric's Insurance Intelligence Center [33].

4. Conclusions

Chronic and aging-related diseases are affecting a great amount of resources in western countries healthcare systems. Even though they can be prevented by increasing the level of an individual's Physical Activity (PA), an objective and accurate PA assessment is still an issue. Among the several devices considered for this purpose, it has been reported that wearable motion detectors are the most promising technology enabling an automatic, continuous and long-term assessment of subjects in free-living environments.

In the future, the adoption of wearable inertial-based activity monitors by older adults should be tailored by tracker manufacturers. Obtained inertial data can be shared with healthcare providers and insurance platforms to better describe behavioural pattern and functional ability in high-risk subjects, thus providing important feedback regarding the overall health status of an individual and even prediction of potential adverse health events.

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