Monitoring Physical Activity with Wearable Technologies

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ABSTRACT

Living a healthy and fulfilling life or at least carrying on the daily activities inevitably depends on some physical activity in different scales. Therefore, measuring the physical activity is necessary to evaluate both healthy people and patients in order to plan their needs for wellbeing. Objective and accurate measurements can be made with wearable

sensors and related technologies. Evaluating health and wellness, efficacy of treatment, safety, physical ability and disability are in the scope of monitoring physical activity with wearable technologies.

Key words: Wearable technology, sensor, physical activity, disability

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INTRODUCTION

Living a healthy and fulfilling life or at least carrying out daily activities inevitably depends on some physical activity in different scales. Therefore, measuring physical activity is necessary to evaluate both healthy people and patients in order to plan their needs for wellbeing. Simply, these activities include walking, sitting, sleeping, eating, talking, and hearing, looking, seeing and breathing. Each one of them can be elaborated on widely to include every aspect of daily living and professional activities. Moreover, understanding and treating disorders requires knowledge about the normal functioning of the body. Physical examination with laboratory and radiological investigations, audiovisual recordings may provide some of the necessary information. Even then, there may still be a vast amount of data missing. Wearable sensors could improve data gathering in health and in disease during different environmental conditions and activities. The improvement of technology concerning sensors, communication and data analysis has broadened the remote monitoring scope and created a new field that may be called “telemedicine” (1). Therefore, the use of physiological monitoring could help patients with neurological, cardiovascular or pulmonary diseases such as epileptic seizures, asthma, cardiac insufficiency and, high blood pressure (2, 3). Cardiac rhythm monitoring with portable devices is a well-known example of a wearable technology application which has been widely used for a long period of time and has almost become a usual part of cardiac examinations even if it has some limitations. Home based monitoring of movements has numerous benefits for individuals, family members and also for community health issues. Detecting or preventing falls in individuals in their own environment may increase the feel of self-sufficiency, independence and maximize social participation (4).

Our aim is to review present wearable technology systems for monitoring physical activity and give an insight into their use for healthcare, their potential uses, and handicaps.

Wearable Technology System

By definition, wearable technology means a wearable device which presents information to users. With recent developments user interaction with voice or physical input is possible. The collected data should be relayed to an analyzing center where clinically relevant information can be extracted from the physiological and movement data (3, 5). The technologies needed to conduct these processes are the sensors, communication hardware and software, storage facilities and analyzing equipment. Present devices can be divided into two groups: head mounted gadgets and bodily placed instruments (2). Head mounted devices are usually visual systems which enable users to have hands free use (1). These visual systems are currently 33implemented in surgery, education and simulation and used as a navigation tool for partially sighted people (2). Bodily placed instruments can be either wearable or portable. Present wearable technologies include accelerometers, gyroscopes, sole sensors, and barometric pressure sensors mounted over the body. According to the purpose of the use, different body sensors have been developed with a capacity to monitor physiological and biochemical properties, posture and motion. Recent advances in microelectronics have provided a means to produce small flexible sensors which also include miniature circuits, microprocessors, and radio transmitters. These properties overcome some of the hurdles such as size and weight of devices which prevented adoption of wearable sensors for long-term monitoring. Innovations in fabric production have led to “e-textile” production. Current wearable technology integrates sensing capability into clothing. It is possible to collect electrocardiographic and electromyographic data by weaving electrodes into the materials which garments are made of (3). Collected data should be transmitted to a system where clinically relevant data can be stored before or after analysis. This can be done via cables and wires or low power wireless communication. Standards for wireless communication should fulfill some requirements such as low cost, small size of the equipment, low energy use. Data can be transmitted to a

nearby computer or cell phone then via internet to a remote monitoring system center (5). Information processing can be done by computers or people. Therefore, if a need arises an intervention can be executed according to information type and characteristics.

Wearable technology devices

Historically the first wearable device was a watch which gave information about time. It was worn as a necklace or carried in a pocket. Later on to keep hands unoccupied, watches were worn on wrists which became very fashionable at the beginning of the 20th century (6). A similar phenomenon occurred when a smart watch came onto the market a century later. Sensors which were integrated into these devices can measure blood pressure and heart rate, count steps as well as storing data. Data can be shared via smart phones or personal computer and can be analyzed offline. Smart phones can also be integrated with wireless sensors recording heart rate and send the relevant findings to a remote center. Small storage capacity and computational power of the phones do not allow long term monitoring yet (7). Some other commercially available devices can measure vital signs such as blood pressure, heart rate, oxygen concentration continuously. Their accuracy of measurements may cause some concern in home based monitoring due to possible misplacement of electrodes. Small, flexible sensors that have integrated microprocessors and radio communication systems result in “System on Chips” implementation. These devices can perform laboratory tests such as lactate, glucose, sodium, potassium. Sweat analysis and fatigue relation can be investigated with them (8). Motion sensors are mostly inert sensors that have accelerometer and gyroscope parts. These are relatively inexpensive small devices with low energy consumption. Accelerometers can detect change of direction and axis and also acceleration. Accelerometers and pedometers are used widely for measuring physical activity (9). There are projects to develop smart garments for the safety of emergency rescuers such as firemen. These garments integrate sensors which detect environment temperature, oxygen levels, communication and GPS antenna, microphone, motion sensors (10). Health and wellness monitoring in an aging population gain more importance especially in western countries. Older people with or without chronic conditions can remain in the home environment safely if reliable systems can be established. Accuracy of wearable sensors is widely investigated to classify activities of daily living. Monitoring vital signs, motion, and posture increases compliance to exercise and medication. Evaluation of the data can help to manage treatment protocols and follow up. The ambient sensors can detect temperature, light, motion, vibration or pressure changes. Chemical sensors can detect gas leaks. The combined use of the wearable sensors and ambient sensors can give valuable information about the person living in the monitored environment (3).

Potential uses of wearable technologies in medicine

The head-mounted devices, glasses worn by medical professional and wearable devices worn by patients can be used for medical education, patient interaction and consultation.

Vital activity monitoring for congestive heart failure, dysrhythmia, and asthma is helpful for the assessment of the status of the patients. It can be used to evaluate efficacy of treatment. Motion sensors and posture detection devices will probably be very important in monitoring patients with balance problems, Parkinson's disease, patients in rehabilitation processes and sleep disorders (2, 3, 11, 12). The motor symptoms of Parkinson's disease have hypokinetic and hyperkinetic features. The motor fluctuation is almost an inevitable complication of L-dopa treatment. Unexpected offs also become troublesome in the course of the disease. The autonomic involvement and loss of postural reflexes can be seen in the later stages of Parkinson's disease (PD) but it can be seen

earlier in patients with atypical parkinsonian syndromes. When motion and position sensors are used together, falls can be detected or predicted. PD patients with a history of falls or no falls have different properties. Those findings are elicited by studies using wearable motion sensors (13). Galvanic skin activity, electrocardiography can be recorded with wearable sensors in a patient's own environment to disclose autonomic abnormalities. Use of motion sensors to monitor motor symptoms gives better information than the use of a diary. Therefore, more satisfactory planning of treatment can be possible. Freezing of the gate is one of the most disabling symptoms in the late stages. Wearable devices delivering auditory commands or light may help to overcome immobility (11).

Multiple sclerosis (MS) affects young people in their productive age. Therefore, physical activity is very important for quality of life. There are several performance scales to measure different domains of physical activity such as gait, hand movements, fatigue, vision, and spasticity (14). Questioners, observation and timing of the activities are the traditional methods of evaluation. It has been shown that more precise measurements are possible with different types of motion sensors and actigraph on computer based settings (15) in the first paper published on this topic. They are useful for monitoring gait in laboratory and remote settings. Commercially available equipment is used to record step numbers and temporal parameters of gait such as stride time, swing time, and step time (12). Sedentary behavior seems more common in MS patients with mobility disability than those without mobility disability (11). One study assessed sedentary behavior with actigraph. The results showed a significant correlation between disability and self-reported disability status scale scores whereas no significant correlation was found between cognitive function and sedentary behavior (16). Brain atrophy and sedentary behavior is also an area of interest which should be investigated.

Prediction and prevention of falls have aspects involving the person and the environment. The ability of walking, vision and cognitive functions are patient characteristics that may affect falls. While slippery or irregular floors, poor lightening, cluttered spaces are environmental risk factors of falls. Thus the ideal system should have the ability to evaluate all of the aforementioned properties.

A remote monitoring operator might be alarmed if there is no motion at the expected time and arrange necessary interventions. Additionally, individuals can alert a designed operator or a family member during an emergency using a device consisting of a necklace or watch with a push button. Rehabilitation of patients with trauma, surgery, stroke, multiple sclerosis, Parkinson's disease and with many different conditions is an important matter in today's community. Wearable sensors tracking motion with audiovisual or “KinoHaptics” feedback might be useful in institution or home based programs (17). Another important area for wearable technology is assessment of treatment efficacy. Results of multiple sclerosis, Parkinson's disease, obesity treatments and, stroke and trauma rehabilitation can be measured with wearable technologies.

Handicaps of wearable technologies

Sensors placed over the body or deployed in garments may cause some discomfort and prevent natural movements. Therefore, almost half of the patients stop using these systems partially after one year (4). The accuracy of the collected data is a major concern especially for remote monitoring. The normal values are yet to be determined. False positive or false negative findings may create social and medico-legal problems. Continuous monitoring creates a huge amount of data waiting for offline or real time evaluation. Each one of them has its own difficulties. Safety and privacy of the information are important issues. Important information concerning health and living habits of people may be used against people's wishes. Thus some important questions may arise: Who

should be an authorized person? Who is competent for evaluation? Who should make the decisions? Who will finance the system? (5) European AALIANCE (Ambient Assisted Living Innovation Alliance) provides support development of solutions regarding wearable sensors, ambient sensors and assisted living in smart homes. This is an active project which includes commercial companies, universities and research institutes (3).

Future perspectives

There are centers devoted to carrying out research with regards to wearable and ambient sensor technologies. In the near future many more items will probably be integrated into health practice and daily activities of living. Unobtrusive devices which do not affect daily activities of living and appearance should be developed. Safety, accuracy and privacy of the patients as well as collected information should be closely protected. Imagination, creativity and development of new technologies have produced the means to monitor physical activity which were previously displayed in science fiction movies (18). It is not mere optimism to expect more developments to appear in close future

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