

Measuring Physical Activity with Sensors: A Qualitative Study

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Abstract. Long term wearing of motion and heart rate sensors are essential aspects for longitudinal studies on physical activity measurement studies. We conducted a qualitative study with 7 subjects in a total of 13 test sessions to identify usability and handling problems associated with Stayhealth RT3, Actigraph GT1M and Polar RS800 sensors. We found that battery life limitation is the most recurrent technical problem and long term wear of heart rate sensors produces discomfort and skin irritation.

Keywords. Chronic Obstructive pulmonary disease, cystic fibrosis, activity measurements, wearable sensors, accelerometers, heart rate sensor

1. Introduction

Low physical activity has a huge impact on chronically ill persons and their ability to have a comfortable daily living. Most notably, in Chronic Obstructive Pulmonary Disease (COPD) and Cystic Fibrosis (CF) patients, low physical activity levels induce a vicious circle of reduced pulmonary capacity, and this in turn further reduces activity level [1].

In COPD it is widely known that exercise training increases functional physical capacity and health status, reducing the admittance rate of patients to the healthcare system [2]. Indirect indications suggest it may also improve survival, but, to date, no direct evidence has been produced [2]. Smaller studies suggest the same for CF [3]. In order to improve patient's activity levels numerous exercise training programmes have been created. This could lead to a shift in patients' lifestyle and have permanent effects of rehabilitation. Whether this is really achieved with the current rehabilitation programmes is unknown. Little is known about physical activity at home, as mostly subjective methods such as activity questionnaires and diaries are used to assess patients' activities. Although these methods have shown limited validity and reliability [4], they provide a patient's personal perception of functional status and difficulties in performing activities. Recently, physical activity has become directly measurable by means of pedometers and accelerometers [5] and several studies have used such methods and provided evidence of their reliability and usefulness.

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We envisage a scenario where intelligent systems provide a non-intrusive care for the patient, with minimal or no interaction. Personally tailored systems and sensors provide overview and care over some parameters in the most discrete way as possible, alerting the patient if abnormal or dangerous patterns arise, in a effort to prevent degradation of health status.

Such a scenario also implies the long term use of sensors by the patient given rise to a series of questions regarding the usability and technical robustness of such devices. The focus of this paper is on accessing such questions on a feasibility and usability trial for related sensors. All sensors used in this project have previously been validated by other scientific studies. Our goal is not to develop or validate new sensors, but to assess its value as tools for medical aid.

For this study the goals were to assess the feasibility of a long-term, longitudinal use of motion and heart rate sensors on a large cohort. We aimed at identifying technical and usability problems that arise from the long term use of such sensors.

2. Materials and methods

We conducted a feasibility study with volunteers to identify potential problems and measure the usability of long term use of wearable sensors.

2.1. Sensors

We used a uniaxial accelerometer, Actigraph GT1M from Actigraph LLC (Ford Walton Beach, Florida, USA), a tri-axial accelerometer, RT3 from Stayhealthy Inc. (Elkader, Iowa, USA) and a heart rate sensor, Polar RS800 from Polar Electro Oy (Kempele, Finland).

Actigraph GT1M and RT3 have been used in other physical activity measurement studies [6,7]. Polar RS800 is a recent model and was not used, to our knowledge, in any scientific study to date. According to the manufacturer the RS800 model is functionally equivalent to S810 model, which was independently validated [8], differing only on the interface software.

2.2. Subjects

Table 1. Relevant characteristics of the seven trial subjects

Age	Gender	Activity level	Height (cm)	Weight (Kg)
22	F	5	178	59
25	M	3	181	70
56	F	4	162	70
62	M	4	178	77
78	F	4	151	78
85	M	1	160	65
86	M	2	163	76

We asked 7 persons to wear the sensors while carrying daily life activities and report their opinions on the sensors, namely the comfort, ease of use and problems if any. We did not request any information on their health status as it was considered irrelevant for the objectives of this study.

2.3. Acquisition and handling of sensor data

The subjects were given a brief demonstration of the placement and use of the three sensors. They were asked to wear the sensors during their daily life, from getting up in the morning until going to sleep. When returning the sensors for data collection, the subjects also returned their remarks on the usability of the sensors.

The motion sensors were placed at the hip and ankle of the subjects and the heart rate sensor (belt with integrated electrodes) on the chest. Before each measurement period the data memory was cleared and batteries recharged on each sensor. All sensors were configured to record measurements in one minute intervals.

We conducted a total of 13 measurement periods. Data was collected in the lab using the software provided by the manufacturers and exported to a spreadsheet. For the RT3 sensor we summarized the tri-axis measurements into a single acceleration value by applying a simple formula (1) with x, y and z the acceleration vectors measured by the sensor.

$$|\vec{a}| = \sqrt{x^2 + y^2 + z^2} \quad (1)$$

3. Results

Our goal in this study was not to use the measurements for a quantitative assessment, but rather to perform a qualitative evaluation of the sensors in order to assess the feasibility for bigger studies. In particular, we were interested in checking out limitations and identifying problems that arise when using the sensors in long measurement periods.

We identified several technical limitations of the sensors. The most severe one is the short battery life on RT3 and the inability to recharge it while on use. Furthermore and even worse all the values stored on the sensor are lost if the battery runs empty. This leads to a limited time window for measuring, collecting the sensors and store the acquired data in a permanent storage.

The RS800 heart rate sensor has a software limitation on the length, 99 hours, of the recording period.

Both RT3 and Actigraph are very comfortable to wear, with no reported problem due to the presence of the sensors on the body. The units are very small and easily attached to the belt or the provided straps. The RS800, on the other hand, becomes uncomfortable after only a few hours of use. The electrodes have to be fastened tightly to the chest, in order to produce good quality signals, and this produces some irritation on the skin after some time.

The data quality is very high, on average, for all sensors, with stable measurements and few or none missing values. The only exception was the RS800 after a few hours of use in some of the subjects. The electrodes need some moisture to provide a good electrical conductivity with the skin. With long uninterrupted use they tend to dry out severely and the signal quality is significantly degraded. The wrist unit on the sensor warns the user on this situation most of the times, and allows a solution by moistening the skin under the electrodes.

The memory and battery problems are so important that the data of 4 out of 13 measurement periods were severely impaired by missing data from one or more of the

sensors. Either the battery on RT3 was empty before the sensor was returned to the subject, or the memory of the RS800 was left full by a handling mistake at the lab.

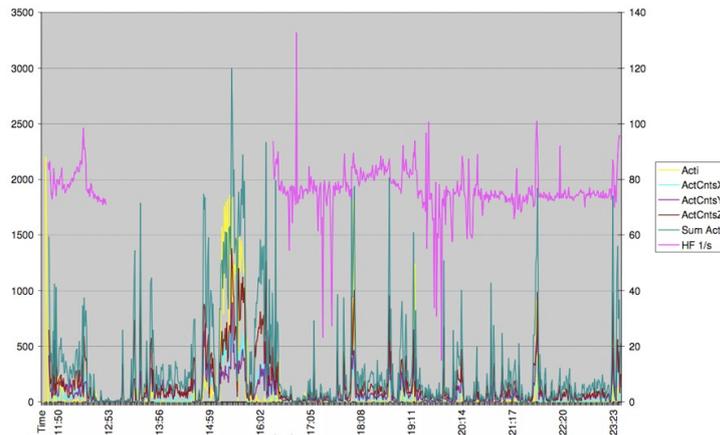


Figure 1: Subject: 86y old, man, 76kg

Figure 1 illustrates the data collected for one of the measurement period, with an 86 years old subject. The data of the heart rate sensor from 12:50 until 16:00 is missing, due to poor conductivity of the electrodes. Some spikes in the measured heart rate, around 16:40 and 17:10 are most likely also due to poor contact, as the activity level was very low and stable at these times.

Figure 2 shows the data for a session with a man, 26 years old and 70 kg. The data

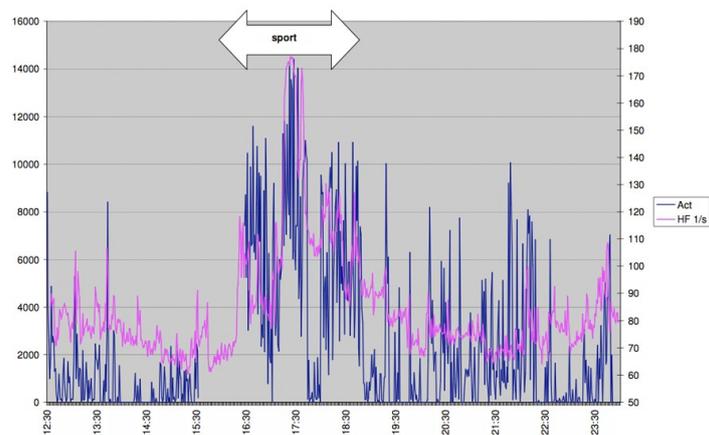


Figure 2: Subject 26 years, man, 70kg

from the Actigraph sensor was lost due to misconfiguration and subsequent error. Data from 15:30 until 16:30 for the RT3 sensor was lost due to misconfiguration, at the lab, of the sampling period. From the heart rate and RT3 sensors data we can observe a clear relation between activity and heart rate, and a clear increase in the values when performing strong activity (sporting).

4. Discussion

It became clear that some technical aspects of the sensors can become a big drawback on the setup of a large study. The battery life and its implications on the storage of measured values is a critical one, not only limiting the duration of the trial but putting the whole data collection into jeopardy.

Correct preparation and handling of the sensors by the staff is also crucial, as proved by the high rate of unsuccessful measurement periods due to mishandling and preparation of the sensors. For this we produced an extensive set of work instructions, covering all aspects of the data collection, reset and handling of the sensors.

The skin irritation from prolonged use of heart rate sensors is also critical, as the data quality is affected and the user must be prompted to take an active role by moistening the electrodes. Although other kind of electrodes do exist, they are inappropriate for a passive, non-interfering use of sensors.

5. Conclusion

Sensors can provide more objective and reliable data in a daily living scenario of chronically ill patients. The long term use of such sensors poses some usability and technical challenges.

During this study we found several technical limitations, mostly related to battery life of the sensors, and very strong usability problems. Battery, besides limiting the time frame of the trials can also jeopardize the whole data collection process if it is exhausted before data is saved. This limitation is more critical than memory capacity.

Usability and body reactions to long term wear of contact sensors such as heart rate sensors is also critical to be taken into account.

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