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Comparison of two motion sensors for use in cardiac telerehabilitation

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Comparison of different motion sensors in a telerehabilitation program for cardiac patients.

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Full title: Comparison of different motion sensors in a telerehabilitation program for cardiac patients.

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Summary

After completion of cardiac rehabilitation, most patients return to their sedentary lifestyle. [1] Previous studies [2] have shown that repeated intervention by the rehabilitation team or dedicated nurse after program completion improves adherence to physical activity guidelines. The aim of this study was to evaluate different motion sensors for the assessment of habitual activity for cardiac patients following phase III cardiac rehabilitation. Motion sensors allow telemonitoring and internet-based interventions, a potentially time saving way to stimulate patients' physical activity. We compared the estimated habitual activity assessed by a pedometer and an accelerometer for a duration of 4 weeks each, in a group of 10 coronary artery disease patients included in a phase III cardiac rehabilitation program. The daily exercise level was measured for each patient and compared with VO2 peak and ventilatory threshold as determined by ergospirometry at the end of the study. None of the measurements correlated with VO2 peak, but accelerometer recordings correlated significantly with the patient's ventilatory threshold (i.e. the sub-maximal capacity), whereas those of the pedometer did not. A questionnaire concerning ease of use of the sensors obtained at the end of the monitoring period indicated that the cardiac patients favoured the pedometer.

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Introduction

To date, ischemic heart disease still constitutes one of the main mortality causes in the Western world. A physically active lifestyle and healthy food choices could significantly reduce mortality associated with ischemic heart disease.[3] After admission for an ischemic event, patients are educated about this healthy lifestyle during a cardiac rehabilitation program. The challenge however is to construct a rehabilitation program that is able to motivate patients to continue being physically active also after program termination. [4-6] Several studies indicate that daily physical activity declines significantly after completion of rehabilitation, starting from hospital discharge till 10-12 weeks after hospital discharge.[1] According to a recent study, less than 30% of patients admitted to the hospital for acute coronary artery disease still adhered to the recommended minimal physical activity 18 months after rehabilitation program cessation. [1]

However, the GOSPEL Study demonstrated that a multifactorial, continued intervention up to 3 years after rehabilitation following a myocardial infarct is effective in decreasing the risk of several important cardiovascular outcomes. Regular contacts with the patient thus seem to encourage the adoption of a healthier and more active lifestyle in the long run. The GOSPEL study recorded a 6% increase in activity for the intervention group compared to the usual care group.[2]

The prohibitively large investment in manpower needed to follow up actively the growing number of patients with ischemic heart disease has led to small studies using information and computer technology in this setting. Several studies indicate that telecare using pedometers can increase physical activity in overweight and obese people.[8] But not much information can be found on the necessary characteristics of activity monitoring devices to assist cardiac patients in their rehabilitation process. The rare papers [21] addressing cardiac patients reported mainly qualitative results such as the patient's self-assessment of his health condition.

The aim of our pilot study was to select and assess portable exercise monitors for use in phase III long-term cardiac telerehabilitation programs. .

Methods

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Ten cardiac patients agreed to participate in this pilot study. After the first week, one patient left the study. No data from this patient were used in the analysis. The unblinded, two treatment, two period cross-over pilot with these remaining nine patients was run in the Rehabilitation and Health Centre at the Jessa hospital (Hasselt, Belgium). The mean age of the patients was 63 (SD 9), their mean weight was 77 (SD 11) with a mean height of 166 (SD 10) resulting in a mean BMI of 28,2 (SD 5). The patients were in the chronic cardiac maintenance phase (phase III rehabilitation), the rehabilitation period starting 10-12 weeks after hospital discharge.[1] They visited the rehabilitation centre two or three times a week to engage in aerobic exercise, supervised by professional staff, and were asked to do 30-60 minutes of aerobic exercise on the other days of the week. The following exclusion criteria were applied when selecting the patients: presence of important arrhythmias, presence of angina pectoris or dyspnea during exercise, unstable patients at risk of heart failure while training. All participating subjects signed an informed consent, and the study was approved by the hospital's ethics committee.

The OMRON 720IT (pedometer) and the POLAR FA20 (accelerometer or activity watch) were selected for the pilot as these two sensors are able to record measurement data for several weeks, have a long battery-life, a low cost, an easy user-interface and both of them found favorable judgments in existing reports. [10-13] Both systems allow transfer of the data to a website, which is a prerequisite for telerehabilitation purposes. The data measured by the pedometer included the number of calories burned, distance walked, the total steps and the aerobic steps. Aerobic steps are defined as steps done during more than 10 minutes of continuous brisk walking (more than 60 steps per minute). The data measured by the accelerometer included the calories burned and the time of exercise. Also the accelerometer differentiates between two levels of activity: low intensity exercise that is supposed to bring health benefits and high intensity exercise that increases fitness. For both sensor devices, the calories burned are calculated based on the number of steps made; the patient's stride-length, weight and height using a proprietary algorithm.

Other state-of-the art exercise monitors were also considered, but not used in the pilot study for different reasons.

Intervention

The cardiac patients were divided in two groups. In the first group, 5 patients wore the pedometer for 4 weeks, and then subsequently they wore the accelerometer for 4 weeks. In the second group, 5 patients wore the

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accelerometer for 4 weeks and then subsequently they wore the pedometer for 4 weeks. Patients received at the onset of the pilot the instruction to put on the monitor all day long, including when exercising at the rehabilitation centre. Only during the night, while sleeping, they could take off the monitoring device. In this pilot phase, the uploading of the data from the accelerometer and the pedometer was done in the rehabilitation centre on a weekly basis during the patient's visit. Here data from the sensor devices were transferred to a computer by means of an USB connection. Allocation of the cardiac patients to the two intervention groups was random.

At the end of the study, all patients performed a maximal cardiopulmonary exercise test on a cycle ergometer. [14,15] During the exercise test an electronically braked Ergo 1500 cycle (Ergofit, Pirmasens, Germany) was used. The cycling frequency was set at 70 cycles/min and the test was ended when the patient failed to maintain a pedal frequency of at least 60 cycles/min. [14,15] In addition, exercise tests were prematurely ended when myocardial ischemia and/or severe ventricular arrhythmias occurred. Both the starting and incremental cycling resistance was set between 10 and 40W and increased every minute to volitional fatigue. [16] Pulmonary gas exchange analysis was performed by using cardiopulmonary ergospirometry device (Schiller CS200; Schiller AG, Switzerland). Before every test, a gas and volume calibration was executed. During the tests, environmental temperature was kept stable (19–21°C). Oxygen uptake (VO2), expiratory volume (VE), and respiratory exchange ratio (RER) were collected breath by-breath and averaged every 10 s. Using a 12-lead ECG device, heart rate (HR) was monitored and averaged every 10 s. In addition, maximal cycling resistance (Wpeak) and total test duration were reported. By V-slope method, ventilatory threshold was calculated. [17] In this method, exercise VCO_2 was plotted against exercise VE, so the break point of the two slopes was determined. The sub-maximal capacity corresponded to this ventilatory threshold.

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Outcome measures

The outcome measures were the recorded daily exercise level (total daily steps and burned calories) and their correlation with the ventilatory threshold as well as the VO2 peak, and participant satisfaction with the two sensor devices.

Recorded daily exercise level and their correlation with ventilatory threshold and VO2 peak

At the end of the pilot study a statistical analysis was made, based on filtered data. Some patients did forget to wear their sensor on some days. These days with zero steps counts have been replaced by an average day of this patient (average number of total steps in a day, average number of calories burned in a day). The number of calories burned and steps walked by day for each patient collected by the two sensor devices was correlated with ventilatory threshold measurement data to assess if these sensor devices could serve as good reflectors of sub-maximal capacity. [18]

Also the daily number of calories burned and steps walked was correlated with VO2 peak values as determined by ergospirometry. This analysis was done to assess whether the recorded data from the two sensor devices could be potential reflectors of the patient's maximal capacity. Correlations have been searched for with a significance level of 5 %, using the statistical software package Medcalc.

Satisfaction

At the end of the pilot study, patients were asked to share their experiences with both monitoring devices by means of a satisfaction questionnaire. The questions are shown in figure 1 on the x-axis. Answers from this questionnaire were analyzed, using the Fisher's exact test, to detect whether they differed significantly for both devices. The questionnaire was constructed by a multidisciplinary team at the Jessa hospital. The objective of this questionnaire was to learn more about the barriers for use of these devices and the potential specific characteristics of the sensor devices seen as benefits by the patients in the pilot.

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Results

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Recorded daily exercise level and their correlation with ventilatory threshold and VO2 peak

The recorded measurements by the two sensor devices are provided in table 1. For each of the nine patients, the average daily step counts are depicted, as are the average daily calories burned, and this for the two sensor devices. The obtained calorie measurements for the pedometer have been corrected with an energy coefficient

(EC) of walking for people with different ages, published in the technical report MPCL-08-09 (NIH Grant number 5R21DA024294-02, University of Florida). The real calories burned were calculated as the product of the EC and the calorie measurement from the pedometer. For patient 2 no data from the accelerometer were available, so complete data are shown for only 8 patients.

In the statistical analysis, correlations between the ventilatory threshold and the average daily calories burned/ steps walked by patient for both monitoring devices were looked for. Figure 2 shows a significant correlation of the calories measured by the accelerometer and the ventilatory threshold with a correlation coefficient r=0,75 (P-value= 0.05). For the pedometer no correlation could be found (P-value= 0.42).

The measured steps on the accelerometer showed a strong trend to correlation with the ventilatory threshold values (P-value= 0.07). For the pedometer no significant correlation could be found (P-value= 0.82).

Correlations were searched for between the VO2 peak and the average daily calories burned/ steps walked by patient for both monitoring devices. The results from this assessment indicate no significant correlations with VO2 peak. The probability of correlation (P-value) for the activity watch is 0,17 for the average steps walked by day for the patient and is 0,15 for the average calories burned by day for the patient. For the pedometer the P-value for the average steps walked by day for the patient is 0,79 and the P-value for the calories burned by day for the patient is 0,49.

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Satisfaction

The answers to the questions of the questionnaire, given by the patients at the end of the pilot study are graphically summarized in figure 1. This figure shows two strong trends (P-value<0.1): the pedometer appears to be easier to read, when compared with the activity watch and it also appears to be more user-friendly.

Discussion

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This pilot study evaluated two different movement sensors in terms of usability and relation with exercise capacity for patients in the chronic cardiac maintenance phase of a rehabilitation program. Both sensors can send data remotely to a care centre and support in this way a telerehabilitation program. The main finding of the

current study was a significant correlation between the calories burned (energy expenditure) as measured by the accelerometer and the ventilatory threshold for the corresponding patient at the end of the pilot. This finding supports the hypothesis that the accelerometer measurements are good reflections of the physical condition and habitual activity of the patient.

Furthermore none of the patients selected for the pilot found the use of the activity monitoring device troublesome and only a minority (<30%) found it inconvenient to wear the device. More than half the number of patients preferred automatic data uploading, by means of an USB connection. During the present study, the uploading was done at the rehabilitation centre, but patients could easily upload the recorded data from a computer at home thereby creating a form of communication allowing use in a telerehabilitation program. The satisfaction analysis also showed that nearly half the patients engaged in additional exercise while wearing the sensor devices. This observation was promising, given the fact that it has been found difficult to encourage cardiac patients to increase their activity level. [19] Our findings are also in line with another controlled study published in 2009 [20] that monitored patients' adherence to physical exercises during 6 months after having completed a cardiac rehabilitation program by wearing a pedometer and 2 counseling sessions. The researchers observed significant improvements in cardiorespiratory fitness (P=0.01) compared to a control group that did not wear a pedometer. Another older qualitative study (2004) was done in Japan [21] assessing the quality of life using questionnaires involving cardiac patients that have been requested to wear a pedometer to monitor their daily activity level. The study concluded that the patients that wore a pedometer experienced a higher quality of life than the control group.

The present study does have its limitations. The limited sample size of the pilot and high variability in the recorded data make it more difficult to find statistically significant differences. Also a longer time frame could be advised for a future study, to find out whether the more active lifestyle of the participating patients found in this study remains also over a longer period.

In conclusion, our study shows that the measurement of physical activity in phase III rehabilitation, and the transfer to a central computer can be done by using the Omron 720IT pedometer and the Polar FA20 activity watch. For use in telerehabilitation programs, the accelerometer is to be preferred, as it correlates with submaximal exercise capacity. The acceptance rate by the patients was good in this short term study. Large studies with long-term follow up are needed to prove the potential value of telemonitoring of daily physical activity in the phase III rehabilitation after acute ischemic events.. At the time of writing, a study is being prepared that will take into account the results discussed in this manuscript. In this study, we will examine

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whether an accelerometer-based telerehabilitation program is able to increase the cardiac patient's daily physical activity in the long-term, as compared with a conventional cardiac rehabilitation program.

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Legend to the figures

Figure 1 Patient satisfaction survey (dark color: accelerometer; light color: pedometer). *: P-value< 0.1

Figure 2 Scatter plots of average calories (kcal) measured by day for each patient on both sensor devices in function of ventilatory threshold (l/min).

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Table 1 Collected steps, calories of both sensor devices, VT and VO2 peak

	Average steps/day pedometer (b)	Calories pedometer (kcal)	Cal. Pedo-meter multiplied by EC (kcal) (c)	Average steps/day accelero-meter (b)	Calories accelero-meter (kcal) (c)	VT (l/min)	VO2 peak (%)
Patient 1	13825	447	447	12505	458	1,878	125
Patient 2	5990	182	175	(a)	(a)	1,258	138
Patient 3	5046	156	153	4239	194	1,332	105
Patient 4	7478	148	141	5433	155	0,800	97
Patient 5	12072	441	428	4863	138	1,228	116
Patient 6	5298	191	181	8799	382	1,326	120
Patient 7	3558	151	143	9094	375	1,900	104
Patient 8	7963	207	203	6792	227	1,596	131
Patient 9	7495	264	251	5346	255	/	/
Mean (SD)	7636 (3348)	243 (119)	236 (119)	7134 (2808)	273 (118)	1,415 (0,365)	117 (14)

(a) Note that for patient 2, no data from the accelerometer could be collected.

(b) The daily steps, recorded by the pedometer, did not differ significantly from those of the accelerometer (P-value = 0,54)

(c) The daily calories burned, recorded by the pedometer, did not differ significantly from those of the accelerometer (P-value= 0,20)

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Figure 1

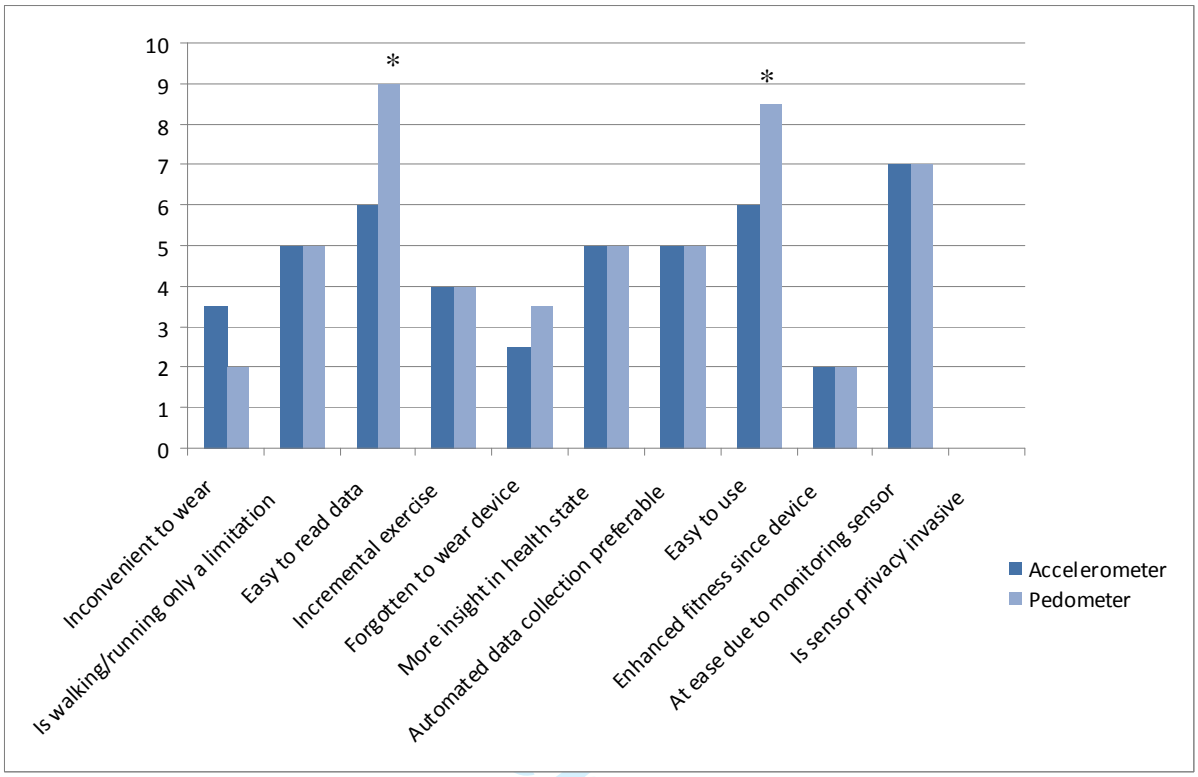

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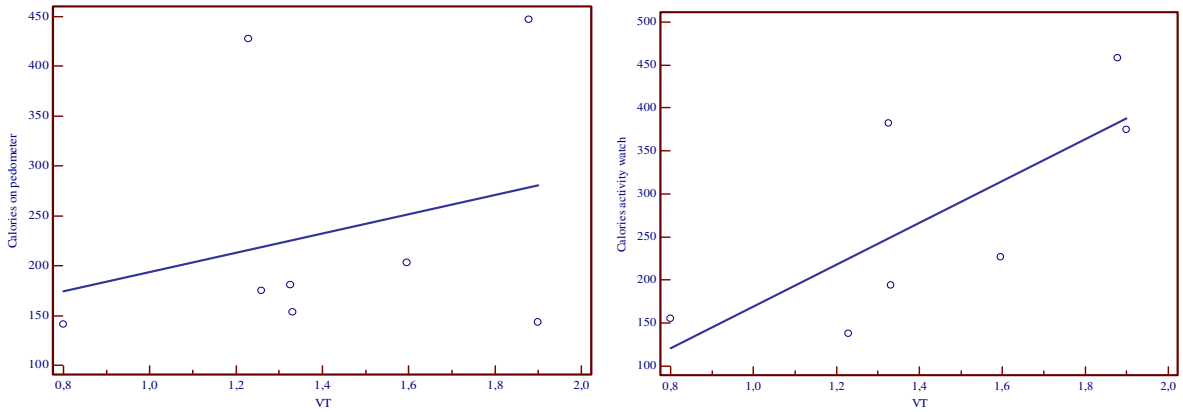
Figure 2



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