Evaluation of Vital Parameter Response to Load Changes using an Ergometer System in a Group of Healthy Subjects

Alejandro Mendoza García [1], Ulrich Schreiber [2], Alois Knoll[1]

[1]Fakultät für Informatik, Robotics and Embedded Systems, Technische Universität München, Munich, Germany
[2]Munich University of Applied Sciences, Munich, Germany

Abstract

Exercising plays an important role in maintaining a healthy life. For patients who have undergone cardiac surgery exercise may help to restore physical condition and decrease the recovery time. Doctors perform on patients endurance tests such as the VO2 max using an ergometer to evaluate their condition, these tests however are very intense and cannot be used for exercising as a regular basis.

This paper presents a system that can be used for the evaluation of the response of vital parameters to physical activity without exhausting the patient and can motivate them to do exercise. A small study consisting on 14 healthy subjects is presented to show the usability of the proposed system.

1. Introduction

It is known that performing regular physical activity helps maintain good health conditions and has a positive effect on the quality of life [1]. For patients who have undergone cardiac surgery exercise may also help in the recovery process to regain normal physical condition. For medical doctors it is important to know the current physical condition of the patient, and the improvement after a certain time interval. To evaluate this improvement tests such as the VO2 max are performed. This consists of an ergometer or motorized treadmill and a mask that is placed on the subject to measure the volume and gas concentrations of inspired and expired air. During the test the patient is set to do exercise starting at a very light intensity, over time the exercise gets slightly harder until the patient reaches maximum exertion. This is considered the gold standard to measure cardiorespiratory fitness, however due to the intensity of the exercise it is not considered to be an activity to be done in a regular basis. This paper presents a system which can be used for more regular exercising and which can be used to evaluate the response of vital parameters and estimate the patient fitness. This consists of an ergometer with an adjustable load, several sensors and a central system for capturing and monitoring user data. Additionally a game is used to keep the user motivated during the exercise. A study consisting of a group of 14 healthy subjects is presented. A protocol was defined to evaluate the response of the vital parameters to different levels of exercise. The results show the data that can be obtained in an individual session and of the complete group.

2. Methods

For the evaluation of vital parameters during exercise a training system was developed consisting on the components depicted in figure 1: A user interface is used to collect patient data such as age, gender, weight and height. An ergometer (Lode Corival, Lode B.V. Netherlands) with a remote interface captures cycling speed in rounds per minute (rpm) and is capable of adjusting the load in watts through a serial interface. A blood pressure sensor, placed on the left wrist was used to collect systolic and diastolic pressure, a pulse oximeter

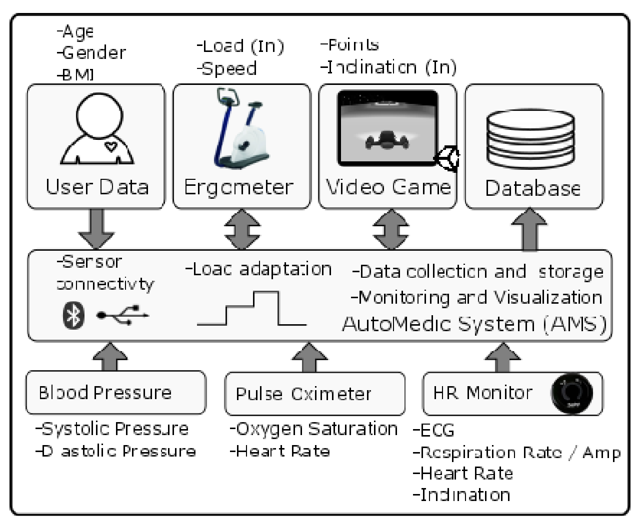

Figure 1Training system developed for evaluation of response of vital parameters to exercise placed on the index finger on the right hand was used to collect oxygen saturation and heart rate. A chest belt (Bioharness 3, Zephyr, USA) provides of a second heart rate, respiration rate and amplitude, body inclination and a 250Hz ECG. A simple game was implemented using Unity 3D to motivate the user during the exercise; it consists of a spaceship that may move to the left or to the right. The movement is controlled by the inclination received from the Bioharness sensor. The user can capture spheres and should avoid the collision with obstacles appearing in the track. The spaceship moves forward as long as the user is peddling on the ergometer and keeps record of the total number of spheres captured and number of collisions.

All of the described components were connected to a central system (AMS) implemented using the AutoMedic platform developed at our department [2]. This system allows the easy integration of the different sensors and devices and allows the addition of other sensors if required. The AMS contains the interfaces to connect to the different sensors using Bluetooth, to the ergometer using a serial interface and the game using a UDP connection. The vital parameters are visualized during the exercise, and stored on a database for further study. Additionally the AMS constantly monitors the vital parameters and in case of receiving a parameter out of a predefined range the operator is immediately notified to check if the exercise should be stopped or the sensor readjusted.

A protocol was defined to be followed by the different participants of the exercise; this consists of first placing and connecting the different sensors, the user is then told to relax for a few minutes. During this period the user data was obtained (age, gender, weight, height). Then the session is started by recording two minutes of a resting period without cycling. At this point a first blood pressure measurement was done. Once this period is finished the user is told to start cycling at a constant speed of 55 rpm. The game is also activated and the spaceship starts to move through the track. The load of the ergometer during this first minute is set to 0 watts. After this first minute is over the load is increased three times in steps of 60 watts with a duration of 2 minutes between load changes, reaching a maximum of 180 watts. On the last step load the pressure is measured, and at the end of the 7 minutes of cycling the user is told to stop and stay in a recovering period for a duration of two minutes. The pressure is then measured for a last time.

A total of 14 healthy participants of ages from 21 to 31 carried out the exercise protocol. After all the sessions were done vital parameters were extracted at different points of the session and a QRS detection algorithm was executed in the recorded ECG signal for the analysis of heart rate variability (HRV). The resulting vital parameters were compared with physiological data of healthy subjects found in literature [3-5].

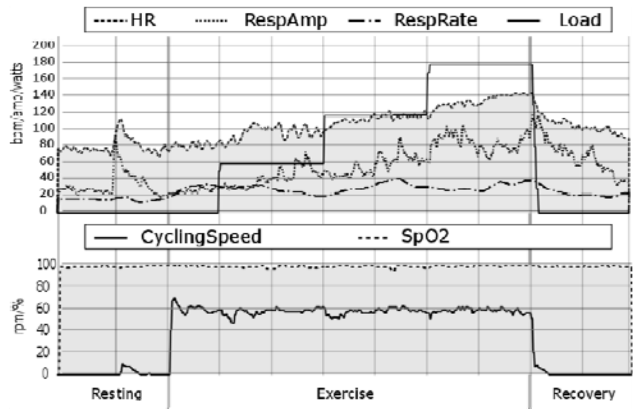

Figure 2 Vital parameters of single session

3. Results

Figure 2 shows the information obtained from a single session of one participant. We can observe the increase of heart rate and respiration amplitude as the load of the ergometer was also increased. At the first minute of the session in the resting period we see a sudden increase in the heart rate and respiration. The reason for this was that at the resting period the participant was sitting on a chair, and before one minute of starting the session he was moved to the ergometer, which can be seen in a small increase of cycling speed at the bottom chart. Throughout the entire session the user was able to maintain a constant speed of 55 ± 8 rpm. Figure 3 shows the captured ECG signal with QRS-T annotations obtained from the post processing algorithm. From the resting period the minimum heart rate was obtained and captured as the resting heart rate (RHR) of the participant, for this case the RHR was 68 bpm. The maximum heart rate (HRmax) was obtained throughout the entire session, obtaining 146 bpm. After the first minute of recovery the heart rate (HRR1’) was 101 bpm and after two minutes 97 bpm (HRR2’). Considering the RHR received and HRmax an estimated heart rate reserve (HRRsv*) is calculated, obtaining 78 bpm. Using this term together with the HRR we get a percentage of 57% recovery after 1 minute and 62.8% recovery after the second minute. Table 1 shows a summary of the obtained parameters in all the sessions with the corresponding average, minimum and maximum values.

	RHR	HRmax	HRR1’	HRR2’	SpO2	BMI	Age
Units	*bpm*	*bpm*	*%*	*%*	*%*		
Min	48	124	17	35	93	20.3	22
Avg	69.5	156	43.7	58.4	96.1	24	25
Max	97	183	75.4	82.7	99	29.4	31

Table 1 Parameters extracted from all sessions

Figure 3 shows the average heart rate obtained through out the exercise from all the sessions with the different load steps, and the recovery period.

Figure 4 shows the average systolic and diastolic pressures obtained during the resting, exercise and recovery period.

Figure 5 shows a two second interval of the ECG signal and respiration curve obtained from the Bioharness chest belt. Additional annotations show the results of the QRS algorithm with a correct detection of the heart beats. This information was used to obtain the N to N intervals and HRV information. Table 2 shows the results of the average NN time (AVNN) and the standard deviation (SDNN).

	AVNN	SDNN
Units	*ms*	*ms*
Min	432	93
Avg	531	134
Max	652	205

Table 2 HRV results of average NN intervals and standard deviation

Figure 6 shows a histogram of the RR intervals (left) and of the change of time between the RR intervals (right) for two particular cases: the one shown in black color represents a participant that gave a high effort during the session, his maximum heart rate was 181 and the RHR was 75. The results of HRV were 641 AVNN and an SDNN of 176. The second participant shown had a lower effort during the exercise, his RHR was 51 and his maxHR was 138. The AVNN was 641 and the SDNN was 176. This changes were also represented in the recovery HR where for the first participant it was a 30% recovery after the first minute and for the second participant it was a 70% recovery. These differences can easily be seen in the left graph with a shift from the values to the left, indicating a higher frequency. The graph to the right shows that the person with a lower effort also had more variations, indicating a lower number of subsequent RR intervals without change.

Regarding respiration the Bioharness sensor gives the respiration amplitude based on how much the belt stretches while the person is inhaling and exhaling. This gave quite different values between users since it depends on how tight the band is placed and the body size of each participant. As for the respiration rate the obtained values could be comparable between users. The results are given in table 3.

	Resp Amp			Resp Rate		
	Resting	Mean	Max	Resting	Mean	Max
Min	6	15	112	5	11	27
Avg	67	176	399	13	24	34
Max	165	606	1239	26	33	42

Table 3 Respiration rate and amplitude

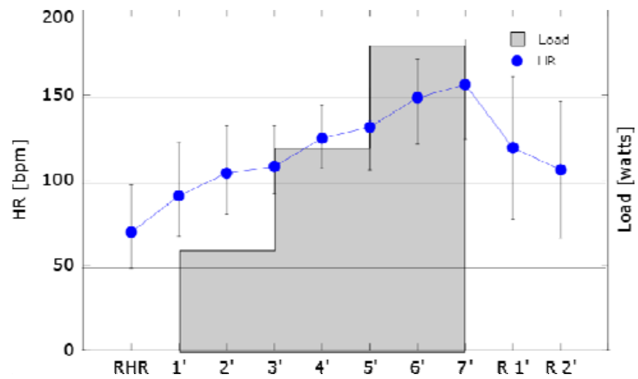

Figure 3 Average heart rate of all sessions.

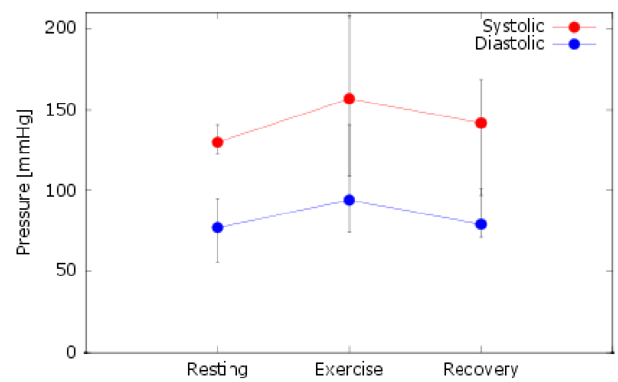

Figure 4 Systolic and diastolic pressure values during resting, exercise and recovery

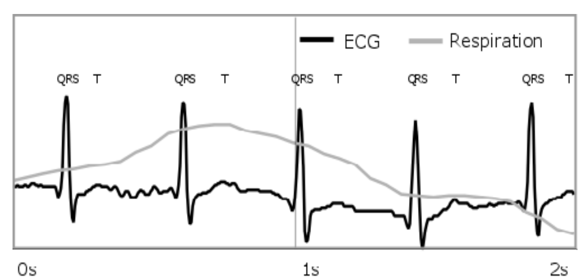

Figure 5 ECG signal with QRS-T detection and Respiration curve

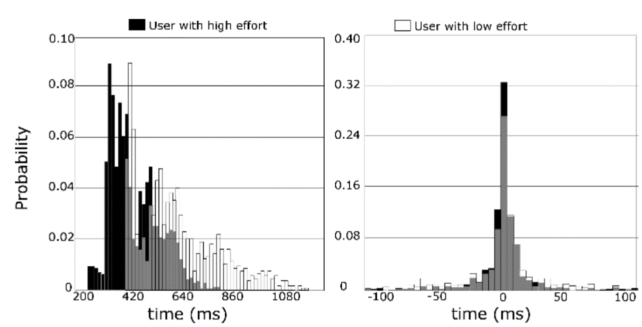

Figure 6 Histogram of RR intervals and changes from one RR to the next

The values received by the game regarding collisions and objects collected did not have a direct correlation to the physical response of the participant, however they did state that it made the procedure more entertaining and motivating to continue doing the exercise.

4. Discussion

Having the possibility to evaluate the response of vital parameters to moderate exercise allows doctors and patients to gain more knowledge about their current physical condition. This may also show progression and motivate the person to do more exercise to reach a better fitness level. Obtaining accurate vital parameter information with the use of different sensors may represent a challenge when there is significant movement involved, or the sensor is not correctly placed. From the values obtained by the pressure sensor we can notice higher values than expected since the measurement sensor was not located at the level of the heart; additionally the sensor was sensible to movement, meaning pressure measurement during exercise was not as accurate. However the heart rate information obtained from the heart rate monitor was quite reliable, and this could be validated by analyzing the ECG signal.

In the presented study there could be noticed significant differences in the response of vital parameters, indicating that some participants did exercise more regularly than others and were more physically fit.

The results obtained from the HRV analysis were compared to values presented in the physionet toolkit for a study of 72 subjects [7], showing an AVNN mean value of 787.7 ± 79.2 msec and an SDNN mean value of 136.5 ± 33.4, this study includes a wider range with a mean age of 55, which could explain the slightly higher values compared to the ones presented.

Other studies have also shown the effectiveness of using a virtual system such as a game or a virtual coach to motivate the user during exercise [8-10]. Further studies will focus on integrating different types of games into the system to increase the level of motivation to do exercise.

5. References

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Address for correspondence.

Dr. Alejandro Mendoza García
Lehrstuhl für Informatik VI
Technische Universität München
Boltzmannstraße 3, 85748 Garching
mendozag@in.tum.de