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Interactive Information Environment for the controlled practice of physical training to improve cardiovascular fitness

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Abstract—**Physical inactivity is one of the risk factors of Coronary heart disease. Physical activity protects against the development of CVD and also favorably modifies other risk factors, however a huge part of the population lead a relatively sedentary lifestyle. Virtual Trainer (VT) Concept is a technological platform for the controlled practice of physical training to achieve better cardiovascular fitness results that includes a motivational environment crated to support the long term compliance with the training program. VT consist of a technological platform, a method for the fitness condition assessment and the motivational multimedia environment. This paper describes the firsts results achieved in the project on the technological platform and the fitness condition assessment.**

I. Introduction

CORONARY heart disease and stroke have many causes. Modifiable risk factors include smoking, high blood pressure, blood lipid levels, obesity, diabetes, and physical inactivity, understanding physical inactivity as a level of activity less than that needed to maintain good health. Physical activity protects against the development of Cardiovascular Diseases (CVD) and also favorably modifies other CVD risk factors, including high blood pressure, blood lipid levels, insulin resistance, and obesity. Physical activity is also important in the treatment of patients with CVD or those who are at increased risk for developing CVD, including patients who have hypertension, stable angina, or peripheral vascular disease, or who have had a prior myocardial infarction or heart failure [1,2,3,4,5]. Despite the well-known benefits of physical activity, a huge part of the population lead a relatively sedentary lifestyle and are not active enough to achieve these health benefits. The main problem this people reports is the lack of support during the practice and the difficulty to fit physical activity in their daily life.

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Virtual Trainer (VT) Concept is one realization within My Heart IST-2002-507816 project [6] funded by the EU Commission aiming at fighting CVD by prevention and early diagnosis using advanced Information and Communication Technologies (ICT) systems. The Virtual Trainer Concept is an ***interactive information environment*** oriented to the primary prevention of CVD that offers the users a tool to achieve better cardiovascular fitness results through a fun and motivational experience during the exercise, according with their preferences and personal training goals.

Three important issues have been addressed in the project:

A. The technological platform: the tool that the user will use anywhere and anytime to perform controlled exercise.

B. The fitness condition assessment: the methodology used to provide feedback to user regarding the progress over his/her cardiovascular fitness condition.

C. The motivational ambient: the multimedia environment created to motivate the user to achieve the exercises goals and to support the long term compliance with the training program.

This paper describes the results achieved during the first year of the project, on the technological platform and the fitness condition assessment.

II. Materials and Methods

A. The Virtual Trainer technological platform

It is composed by four main components: the training static bicycle, the biomedical sensor, the data processing and user interaction module, and the VT service centre. See Fig.1

1) Training static bicycle. We used a PRECOR [7] model for the construction of the VT prototype. This is a semi-professional training bike used in fitness centers.

2) Biomedical sensor. Wearable biomedical sensors built on electronic textile fabrics with sensor function and interconnections woven into them. The development of suitable biomedical sensors is part of the R&D activity within My Heart project. VT Concept uses a two-layer band with 4 textile electrodes on the internal layer, in contact with the skin, and one temperature sensor. The electronics is removable and inserted in a pocket on the external layer.

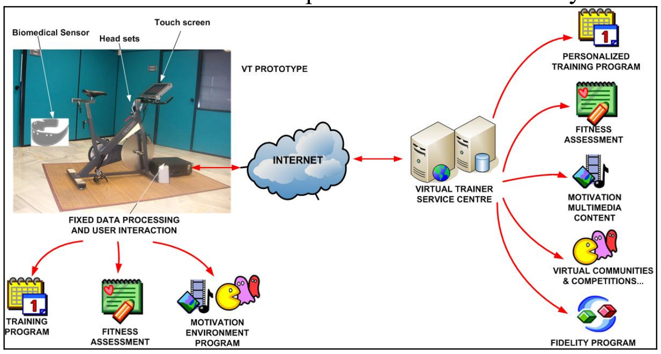

Fig. 1. Architectural view of the components and communication links.

Bluetooth technology is used for the data link. The monitored signals are 1 ECG (Heart Rate), 1 respiration (impedance) and 1 skin temperature [8].

3) Data processing and user interaction (DPUI). These are hardware and software components providing computing, communication, local data storage, and user interface functionality. We used two DPUI platforms: *a)* a mobile DPUI implemented over a personal digital assistant HP iPaq Pocket PC mod hx2415 w/ Windows Mobile 2003 edition, 64MB SDRAM, Bluetooth wireless technology, 802.11b WLAN [9]; *b)* a fixed DPUI on a PC w/ Pentium 4 processor @ 1GHz, 512MB RAM, 40GB HD, 10/100 MHz Ethernet network adapter and USB Bluetooth interface. A touch screen monitor is screwed on top of the bike handle.

The software was developed within Visual Studio .NET 2003 [10] using C# as programming language. Among the various reasons for this selection, we emphasize the following: *i)* previous knowledge of language and environment, *ii)* reuse of code between programming PC version and Pocket PC version, *iii)* libraries and components available, *iv)* code and data capacity of migration to any language or data structure. The local database was implemented on Microsoft SQL Server, using XML syntaxes to send data via web services.

4) Service Centre. It is a web server providing VT services to clients. It is under development at the time of wiring this paper.

B. The fitness condition assessment

The aim of the fitness condition evaluation is to provide intelligent, evaluative feedback in a way that the user has an objective measurement of his progress and performance. Fitness status is based on the study of oxidative stress that is produced during exercise and its formation appears to be related to the intensity of exercise [11,12]. Scientific evidence supports the ability of the organism to increase the antioxidant protections with well-conducted exercise training. On the basis of known physiological responses to exercise we designed the Bicycle Redox Test (BRT) under the hypothesis that the alterations of determined physiological parameters during exercise happen in concordance with alterations in the redox status. BRT is based on measured heart rate during a constant load-incremental pedaling frequency with the aim to assess antioxidant capacity and blood redox status in order to evaluate the improvement of user physical status.

Methdology of the test: it is an incremental exercise test (IET), based on power increases and Heart Rate (HR) continuous measurement, following a simple protocol:

a) First time: determination of MaxHR = 208-0.7*age; HR1 = 0.65*MaxHR; HR2 = 0.8*MaxHR

b) During exercise:

- pedaling during 3’ increasing power to get HR1.
- pedaling 3’ at HR1 and then stop and rest during 3’
- pedaling during 3’ increasing power to get HR2.
- Pedaling during 3’ at HR2 and then stop and rest

The BTR is based on the quantification of the recovery of HR after a sub-maximal effort. The HR recovery curve kinetic can be characterized by the following parameters:

- τ = time of recovery
- A_{max} = Maximum amplitude of recovery
- A_0 = Minimum value of HR

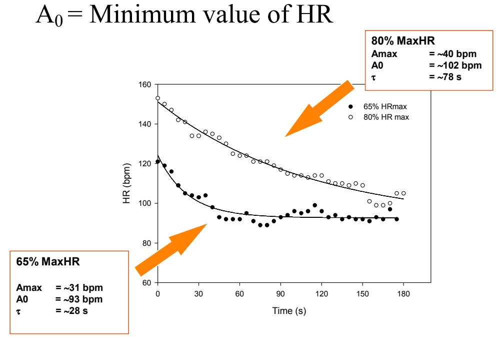

Fig. 2. Example of HR recovery kinetics

III. RESULTS

A. The Virtual Trainer technological platform

According with the software realization plan of the project, the following modules were implemented and tested:

a) Virtual Trainer Repository and Data Manager: the repository is composed of the different databases: User Profile DB, Multimedia Content DB, Virtual Trainer Support DB, Sport Knowledge DB and Health Knowledge DB. The data structure designed is based on the characterization of session-exercises and all their relations with the rest of components like the user profile, motivation and alarm definitions, media files, etc.. This structure stores all measurements acquired and data generated during the exercise in order to be processed afterwards, and recorded as historical backup for futures analysis. Thanks to the database design, any exercise can be reproduced at any moment in the same way that it was made by the user.

b) Communication Module: for the first prototype, while the actual biomedical sensor was available, an On-body Electronics Simulator has been developed in order to generate the needed biomedical signals for the VT application. Its main features are:

HR simulation producing HR values within the range 60 - 250 bpm following increase-recovery patterns

Parameter adjustments through GUI interface

Communication over RS232 and Bluetooth

c) RPM sensor: It is a speed sensor for the bike that consists of a Bluetooth enabled optical detector that counts the revolutions of the wheel and sends the data to the application. It's installed in the chassis of the bike near the edge of the wheel.

d) Training Session Module: software application that controls the execution of the exercise session. The main components are:

- Graph component
- N-polygon interpolation/regression for summary graph estimation.
- Handling of error and alert states.
- Status indicators during session (calories, velocity, respiration animation.)
- Summary report of completed exercise
- Questionnaire for feedback evaluation
- VTControls: Auxiliary components to manage the application, such as *VTPlayer* to reproduce simultaneously different music files during the session; *VTSpitch* to show the rhythm of the user's heart rate; *VTDisplay* can reproduce videos or show photos randomly or under control of the motivation & alarm module; *VTGraph* to draw in real time the measurements of the sensors.

e) User Interface: One of the main objectives of this interface is to catch the attention of the user, in order to guide him through the process of training. To achieve this goal, an attractive layout has been designed to fit graphical information on: real time HR and respiration, multimedia motivation contents (sound and video), system messages (voice and text), and exercise statistics. The user may browses through different screens during his training sessions.

f) Motivation & Alarm Algorithm: It consist of two main components:

- *Evaluation component*: real time feedback of user performance according to given objective. This is based on the BRT algorithm
- *Candidate selection algorithm*: Rule based selection algorithm for determining which motivation events are triggered during the different moments of the exercise.

The objective of the *alert algorithm* is to inform the user on both, the system's status (i.e. connection loss, transaction error…) and the user's real-time measurements (i.e. when the user leaves recommended training zones).

The *motivation algorithm* objectives are:

- Advise and inform users about things he/she ought to be aware of or might find useful during the excise session.
- Inspire the user to keep up even when he/she gets exhausted.
- Entertain the user and give him/her a unique training experience.
- Motivate user to continuous use of the VT so that his/her physical condition improves.

Evaluation

A first prototype of the VT concept was built integrating all the components described above. All the software of the platform is now running on a PC-based system (Fixed configuration) and using the on-body electronics simulator to test its functionality. Laboratory tests where conducted for most of the applications running on the prototype:

- Downloading of exercise session form the server.
- User Interface presenting the information both, real time and motivational multimedia contents
- Data link communication between biomedical sensor (using the on-body electronics simulator) and data processing unit
- Evaluation of the alarms and motivational algorithms could not yet been finalized because of the late reception of the wearable biomedical sensor. This is nowadays under progress.

B. The fitness condition assessment

Previous of the software implementation of the algorithm for fitness condition assessment and its inclusion within the VT system, a test was conducted to verify that the HR recovery kinetics after sub-maximum exercise may represent a parameter for the control of the fitness level and this parameter is sensitive to variations in the cardiovascular fitness. 30 people (female n=15; male n=15), average age 31.3 SD 5.9 (range 23-46); mass: 69.2 kg SD 8.1 (range 50-98); height: 170.9 cm SD 1.2 (range 154-182); Vo2max 2581.2 ml/min SD 184.1; followed a protocol of training during 8 weeks and the BRT and the Test Incremental Maximal (TIM) based on the direct measurement of the VO_2 and concentration of lactate in blood during the exercise were applied at the end of week 4 and week 8.

The results of the BRT during the control condition and the end of week 4 (Fig. 3) are similar to the results of the TIM. The HR have decreased 7% and the concentration of lactate in 13% for a similar effort demand equivalent to 4 MET which represents the aerobic capacity needed to step a stair or ride a bicycle. This represents an increment in the cardiovascular fitness capacity produced by the training program designed for the VT concept. In the same period of time, the A_{max} value have increased a 69% respect to the control condition for HR1, and have increased 30% for HR2 after 3 minutes of recovery. This preliminary results shows that the BRT indicators may be suitable for implementation within the VT concept.

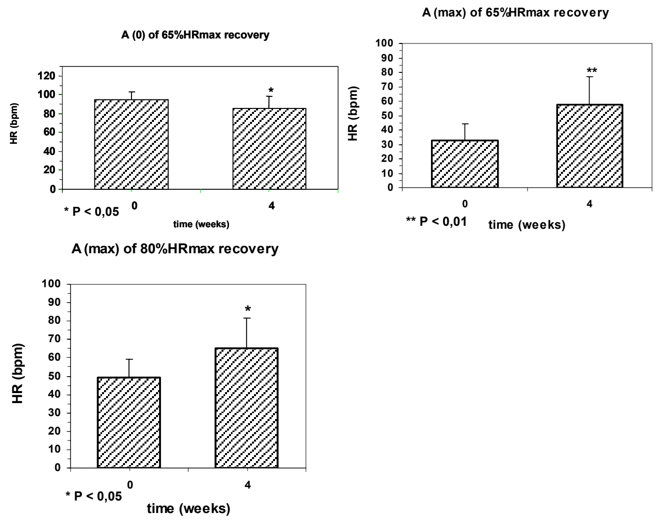

Fig. 3. Results of BRT at the end of week 4

IV. CONCLUSIONS

Physical training is considered the best non-pharmacological approach to reduce the incidence of heart diseases and maintain an independent life-stile even in old age. The most helpful approach to improve cardiovascular function is aerobic training, independently of exercise mode. Oxidative stress is a metabolic status in which an equilibrium between pro-oxidants and anti-oxidants is broken. Oxidative stress is present in most of diseases, including hepatitis, lung dysfunction and cancer. Ox radicals are produced during exercise and their formation appears to be related to the intensity of exercise. When the organism is unable to transform the reactive oxygen species produced by the organism itself to an inactive form an oxidative stress occurs. *Training paradox tells that exercise is beneficial to health but exercise itself produces harmful molecules to the organism. Scientific evidence supports the ability of the organism to increase the antioxidant defences with a well conduct exercise training*. VT concept within project My Heart is an environment for the methodological practice of aerobic exercise addressed to healthy people to fight against sedentary and to reduce CVD risk factors. VT strategy is oriented in two objective lines: for one part, to create a tool that motivate the user to perform regular practice of physical activity throughout a long term training program, to achieve better fitness results within a fun and motivational experience. The sense of achievement is a strong value for the VT users. They need to feel that they are progressing; they need to see real results in the medium and long term. VT provides an intelligent feedback of objective data that helps them to understand their performance and a sense of working with reliable information. Motivation was also high lined as a strong value that helps users to perform better the routine exercise and commit them in a continuous active life. VT aims at creating a friendly and motivating exercise environment tailored to the user special preferences and fitness goals.

The second strategic objective line is the coaching. This is based on the design of personalised training programs adapted to user's characteristics and preferences, and of a continuous assessment of the actual fitness status and the intelligent feedback through the motivational environment created for this purpose.

In the first year of the project we have built the first prototype of the concept and designed a method for the assessment of the cardiovascular fitness status of the user. The evaluation of this method is under way but the first results show that it may be suitable the VT concept. This period is now ending with the first evaluation of the stakeholders feelings: users, professional trainers and fitness club owners. The second phase in years 2005-2006 will be devoted to the consolidation and stabilisation of the technical platform, the validation of the algorithms and the evaluation in real use conditions.

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