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MEDICAL TEACHING INNOVATION: CREATION OF THE COMPUTER PROGRAM FOR OPTIMAL PHYSICAL ACTIVITY PRESCRIPTION

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Abstract

The aim of our project was to create suitable applications of physical activities to individual subjects - diseased and/or healthy – according to their level of fitness and exercise test results with the help of a computer program. It is an educational tool that contributes to the improvement of medical students in our medical school. The program could also be used by physicians as a tool for setting up a physical activity plan for both healthy and diseased individuals.

Key words: *computer program, physical activity prescription, exercise test, maximal oxygen consumption, anaerobic threshold*

Introduction

It was sufficiently proven, that physical activity is an important primary and secondary preventive factor of the onset of many diseases and their complications. Frequently, physicians in internal medicine, sports medicine, and in general practice are asked for advice concerning adequate physical activity for either a sick or a healthy but untrained man, who would like to improve his/her physical fitness level. It is necessary to prepare our medical students for these situations. Till now our students have been instructed with common recommendations concerning physical activities. The aim of our project, however, was to create suitable applications of physical activities to individual subjects - diseased or healthy – according to their level of fitness and exercise test results with the help of a computer program. We have introduced a program called KONSIL.

Methods

Anamneses, anthropology, spirometry, clinical investigation and electrocardiogram (ECG) of each subject are saved in a computer. Those tests are followed by an exercise test on a bicycle or treadmill ergometer that permits controlled and reproducible results. Blood pressure (BP) and heart rate (HR) are obtained repeatedly, and continuously monitored 12 leads ECG is used. Expiratory minute ventilation is determined using a pneumotachograph or other type of in-line flow or volume measurement device. Expired gas is passed into mixing chamber from which gas is sampled and analyzed for O_2 and CO_2 concentrations. Differences in O_2 and CO_2 concentrations from the beginning to the end of each breath are smoothed, and resultant O_2 and CO_2 concentrations are equaled to the volume-weighted average concentrations or „mixed expired" O_2 and CO_2 concentrations.

Electronic system for data acquisition

The KARD system (Figure 1) collects physiological data and transfers them every second to a personal computer. BP sampling frequency is 60 sec during submaximal load and 30 sec during maximal load. ECG is also registered. The most expensive parts in the KARD are O_2 and CO_2 gas sensors. These sensors measure partial pressure of the gas and therefore are affected by water vapor, pressure in the sampling gas systems, and changes in barometric pressure. The effect of temperature and pressure can be eliminated by applying corrections using the ideal gas law. The measured data are stored in a table every 5 or 30 sec. The user can edit the acquired data both during and after the test. All measured data and personal data of the patient are stored in Microsoft database. The program can display and print many types of protocols and graphs. The curves can be filtered by least-squares data smoothing. Our program enables an automatic delivery of important values from the data measured. In some cases, models of different functional dependencies are needed. In most of the graphs the functional dependencies based on polynomial least-squares are used and coefficients are displayed. This function is useful mainly for testing of athletes (comparing different types of load).

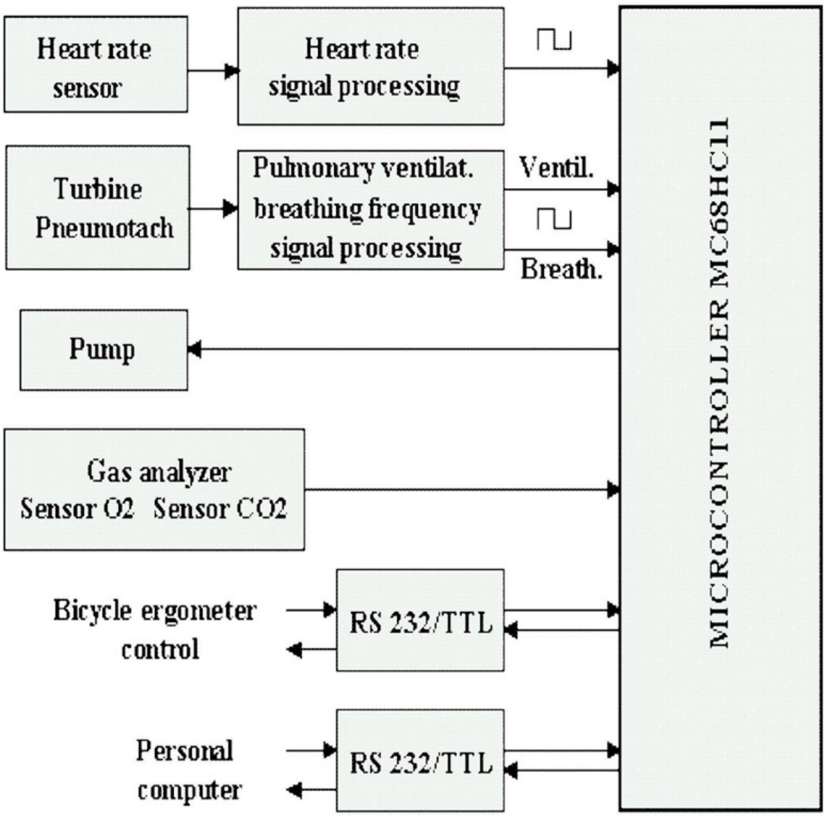

Figure 1. *Simplified block diagram of the KARD system. RS 232/TTL – Convertors for changes of the signal level.*

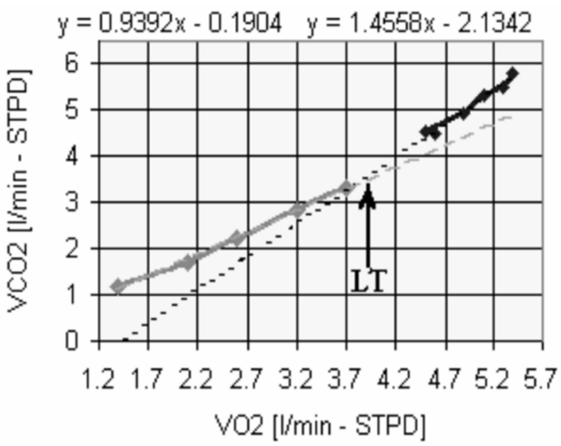

Figure 2. *Example of V slope method for the anaerobic threshold (LT) estimation*
VO_2 (l/min- STPD) – Oxygen consumption in liter per minute corrected to standard barometric pressure, air temperature and air humidity
VCO_2 (l/min- STPD) – Carbon dioxide expenditure in liter per minute corrected to standard barometric pressure, air temperature and air humidity

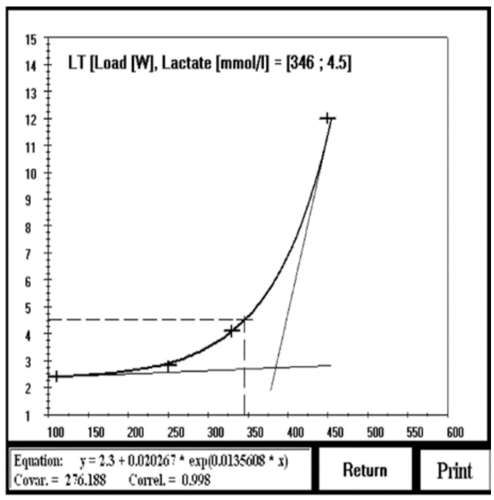

Figure 3. *Example of the screen showing the lactate threshold (LT) determined by exponential approximation based on the blood lactate measuring*
X axis = load [W], Y axis = blood lactate concentration [mmol/l]. Equation, covariance and correlation are also shown.

Maximal oxygen consumption ($\dot{V}O_2$max) is the highest amount of oxygen a person can use from inspired air while performing dynamic exercise involving a large part of total muscle mass. $\dot{V}O_2$max·kg^{-1} is considered the most predictive value of cardiovascular fitness and exercise capacity. It is convenient to express oxygen uptake in multiples of sitting/resting requirements (1). One metabolic equivalent (MET) is a unit of sitting/resting oxygen uptake = 3.5 ml of O_2 per kilogram of body weight per minute [ml·kg^{-1}·min^{-1}].

Another important value is the anaerobic threshold (lactate threshold). The anaerobic threshold (LT) is defined as the level of exercise above which aerobic energy production is supplemented by anaerobic mechanisms and is reflected by increase in lactate concentration in the blood (2). Our program has offers the option to detect the LT based on V-slope method. Above LT, the increase in lactic acid production results in an increase VCO_2 to $\dot{V}O_2$ ratio (respiratory exchange ratio). When these variables are plotted against each other, the relationship is composed of two apparently linear components, the lower of which has a slope of slightly less than 1.0, whereas the upper component has a slope steeper than 1.0 (3). The intercept of these two slopes is lactate threshold (LT), shown in Figure 2. More exact method for LT estimation used in program KONSIL is based on blood lactate samples taken during the examination and lactate curve construction (3). From 3 or 4 lactate samples, the LT is determined by the exponential approximation (Figure 3).

Results and Discussion

Procedures for setting up a suitable training level

Directly from the results of the exercise test the program takes over $\dot{V}O_2max{\cdot}kg^{-1}$, HR max and LT values (with corresponding values of HR, $\dot{V}O_2{\cdot}kg^{-1}$, $\dot{V}O_2max{\cdot}HR^{-1}$ on the level of LT). The program is also able to display the values from each step of the exercise test, which are marked by the physician. Calculation of corresponding MET and kJ values follow – according to the already published equations (4, 5, 6) cited below in the paragraph Healthy persons. In the next step the user chooses between the healthy and diseased subjects.

Healthy persons

In case of a healthy person it is necessary to insert the type of his/her present physical output (none, or minimal activities, recreational or sports activities). It is followed by the question: Do you want to improve your physical performance? In case of the positive answer the program calculates the recommended training value $\dot{V}O_2{\cdot}kg^{-1}{}_{train}$ and HR_{train} according to the formula:

$$\dot{V}O_2{\cdot}kg^{-1}{}_{train} = [(\dot{V}O_2max{\cdot}kg^{-1}/350) + 0.6]{\cdot}100 \quad (\%)$$

$$HR_{train} = [(\dot{V}O_2max{\cdot}kg^{-1}/350) + 0.6]{\cdot}(HR_{max} - HR_{rest}) + HR_{rest} \quad (HR/min)$$

When no expired gas was analyzed during exercise test, HR_{train} is calculated according to this simple formula:

$$HR_{train} = (HR_{max} - HR_{rest}){\cdot}0.6 + HR_{rest}$$

The program permits value corrections by the user (e.g. physician). Obtained or corrected values are introduced in formulas (7) for running and walking velocities (v):

$$v_{running} = (\dot{V}O_2{\cdot}kg^{-1}{}_{train} + 3.91) / 3.58 \quad (km/h)$$

$$v_{walking} = [(\dot{V}O_2{\cdot}kg^{-1}{}_{train} - 4.2) / 0.389]^{0.5} \quad (km/h)$$

In the next step the program offers suitable activities according to corresponding MET values (1,8).

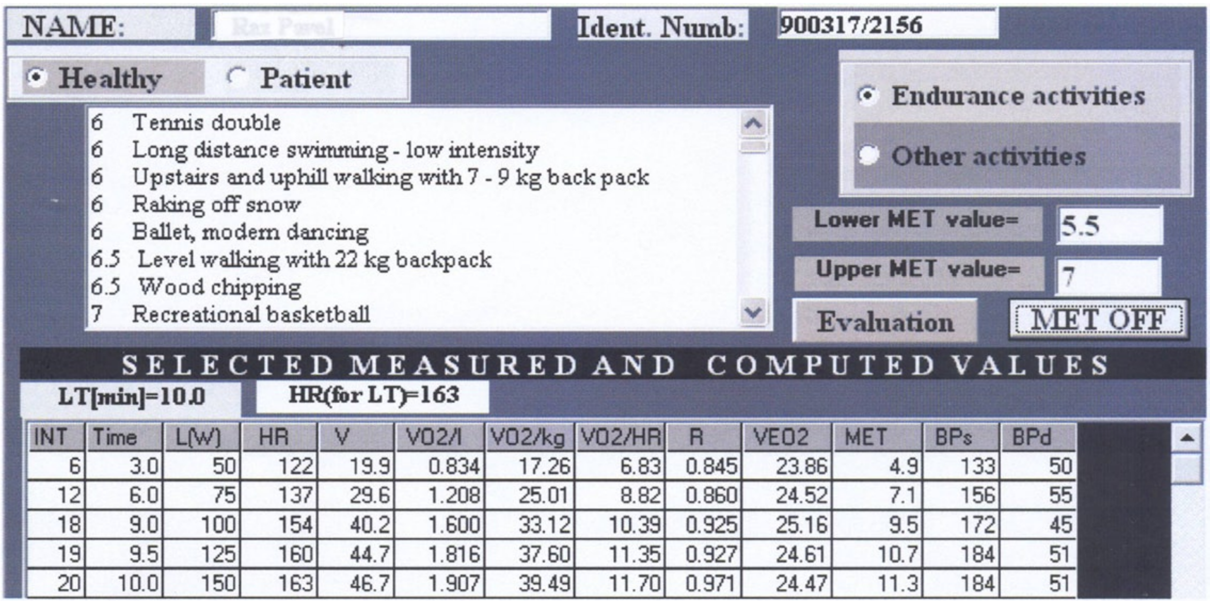

Figure 4. *Example of the screen showing a selection of suitable activities according to metabolic equivalents (MET values)*
LT (min) - Time at which the lactate threshold was reached
HR (for LT) –Heart rate corresponding to LT
INT –Interval (The measured data is stored every 30 seconds)
L (W) – Load in watts
HR – Heart rate
V – Ventilation per minute
VO_2/l – Oxygen consumption in liter per minute
VO_2/kg - Oxygen consumption /kg of body weight (in ml per minute)
VO_2/HR - Oxygen consumption / HR (in ml)
R - Respiratory exchange ratio (VCO2 / VO2)
VEO_2 - V / VO_2 (in liters)
BPs, BPd – Blood pressure systolic and diastolic

Upper and lower MET values are estimated as the training MET value ± 10%. Also these values can be corrected by the physician. The program suggests possible kinds of activities in the rated MET range. From these the user can choose suitable activities for a specific person. An example of possible screen display is shown in Figure 4.

For improvement of physical performance in recreational activities the program recommends the training frequency 3 times 30 minutes per week as a minimum. The program sets no special procedures for highly trained athletes because it can not involve various practices of a wide range of sport events. However also top athletes obtain $\dot{V}O_2 max \cdot kg^{-1}$, HR max and LT value with corresponding values of HR, $\dot{V}O_2 \cdot kg^{-1}$ and $\dot{V}O_2 \cdot HR^{-1}$ on LT level.

Diseased persons

Procedures mentioned above are not quite valid for diseased persons. Nevertheless many forms and stages of some diseases are also compatible with definite types and levels of physical activities. Coronary heart disease (CHD) and hypertension (HD) are the most frequent diseases that come into question. In patients with CHD and HD it is very important to interrupt the exercise test prior to $\dot{V}O_2 max$ is reached. The interruption must be made if warning symptoms like dyspnoea, stenocardia, dangerous BP values, arrhythmias and ischemic signs in ECG appear. The last step of the exercise test without warning symptoms is usually called symptoms limited load. This level must be determined by a physician. Thus he/she orders $\dot{V}O_2 max \cdot kg^{-1}$, $\dot{V}O_2 max \cdot HR^{-1}$, MET and HRmax - each of them symptoms limited values. According to MET value the program includes the CHD patient in a corresponding stage of NYHA classification (9,10) and sets him/her the physical activity level that can be corrected also by the physician. From the recommended range of MET intensity (MET *train* ± 10%) the program proposes mainly dynamic, cyclic and mild endurance activities for CHD and HD patients. Besides, there is a safety precaution in form of patients' LT. It is generally accepted, that the physical activity in patients with CHD and HD should be realized in the aerobic zone (10). Hence if the recommended activity were set above LT, the program would ask: Do you really wish to set the physical activity above LT? Each patient obtains 2 HR values: HR for training should be reached for the optimal level of physical activity and maximal HR should not be exceeded.

An example of the recommended weekly training program for the leisure athlete X.Y. according to the computer choice of suitable activities (see fig. 4)

Workout 1: Freestyle swimming for 3x 10 min non-stop or

10 min freestyle + 10 min breaststroke + 10 min freestyle.

Velocity of swimming: 2:00-2:30 min per 100m

Workout 2: Forest hiking with 7 kg backpack for 1 hour, slower pace uphill, faster pace downhill. (In case of bad weather upstairs and downstairs walking possible)

Workout 3: Recreational basketball or tennis double

Any combination of the workouts three times per week is possible. The intensity of physical activity should correspond to 50-60 % of V02max, which in subject X.Y. was equal to 12 MET.

Before starting any of those leisure activities warming up including selected stretching exercises is recommended, similarly warming down afterwards.

Conclusion

The demonstrated program contributes to the education progress of medical students in our faculty. They can compare their own proposals with the results of the program. It could also be used by physicians as a recommendation for physical activity both in healthy and diseased persons.

Practice points

- The computer program takes over results from the exercise test directly
- Program can be applied both in healthy and in diseased persons.
- Physical activities, HR for training and maximal HR suggested by the program can be changed by the user (physician) at each level.
- Medical students can compare their own proposals with the results of the program.

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Authors' contribution
A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection