The System for Spiroergometric Data Measuring and Evaluation

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Summary

Exercise testing today is used not only as a diagnostic tool, but also as a technique to determine the physical performance characteristic of a patient. Heart rate, pulmonary ventilation, breathing frequency and blood pressure are measured during the examination. Also amount of oxygen and carbon dioxide are measured in patient breath. From these data, many of other standard parameters are calculated by means of computer. In this paper, the systems for automatic measuring and evaluating are described. Application of these systems is possible in work medicine, sport medicine and rehabilitation.

Hardware

2 systems were developed for spiroergometric data measuring:

a) The **KARD** is a system for exercise testing which is used in laboratory.
b) The **TELEKARD** is a telemetric portable exercise testing system that allow to monitor cardiorespiratory function in laboratory as well as in the field (sport medicine, rehabilitation etc.).

For data evaluating, the program **KONSIL** was developed. The program is the same for booth system. In Fig. 1, the **KARD** system is shown. This is a "wire connected" system.

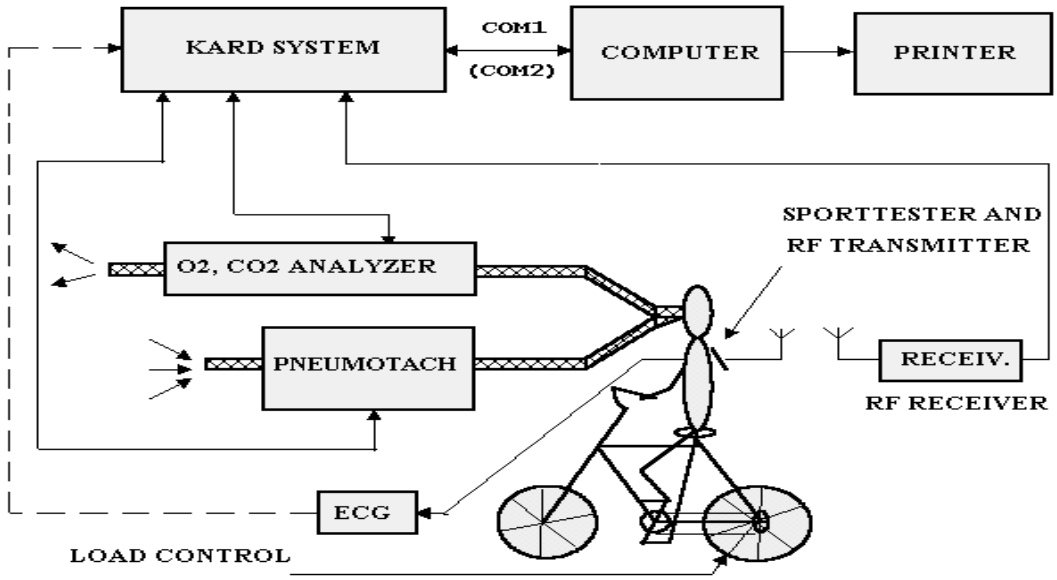

Figure 1. The laboratory **KARD** system for stress test. **KARD** system is based on MC68HC11 microcontroller. If needed ECG can be connected for heart rate measuring

In Fig. 2, the block diagram of the **TELEKARD** system is drawn. This is a "wireless" device. The equipment is composed of a unit (carried by the object) which transmits the measured data to a receiver in real time. The receiver is connected to personal computer (PC) which shows the information on the display, evaluates, memorizes and prints data.

The **KARD** system was designed to use different types of old gas analyzers (Spirolyt or Infralyt), but a new type of gas analyzers can be used also. The gas-meter with digital serial output was used for ventilation measuring. The heart rate meter SPORTTESTER is used For heart rate measuring [1] and information is wireless transmitted.

The following devices are used for **TELEKARD** system:

a) **Flow -** turbine flow meter, 26 mm, VE range 10 - 250 l/min.

b) **%O2 Expiratory** - Chemical oxygen sensor, range 0 to 100%.
c) **%CO2 Expiratory** - Infrared carbon dioxide sensor, 0 - 10 %CO2, dual detector technology, 45 x 60 x 35 mm).
d) **Heart pulse** - heart rate meter SPORTTESTER is used.
e) **Pressure sensor** - differential dual ports integrated silicon pressure sensor on chip signal conditioned, temperature compensated and calibrated MPX5010 [2] is used.
f) **Temperature sensor** - digital thermometer and termostat DS1620 [3] is used for temperature measuring.
g) **Pump** - micro diaphragm gas sampling pump is connected to a gas analyser.

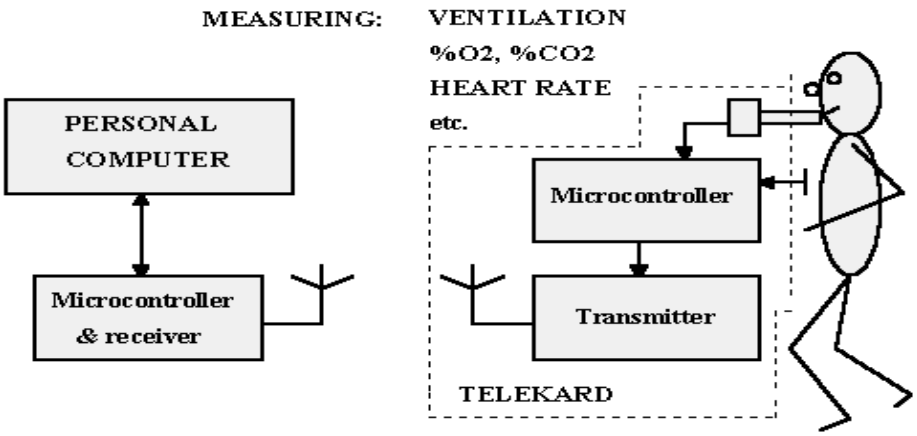

Figure 2. The **TELEKARD** system. The wireless data transmission (433 MHz) is used.

The signals a) - f) are processed in MC68HC711E9 microcontroller [4] and transmitted via a FM transmitter to a receiver, where they are being elaborated and presented to the user using PC. The blocks of 32 bytes are multiply transmitted for error removing. The sampling frequency is 5 sec. The FM transmitter which is used has dimensions 25 x 23 x 9 mm, working frequencies 433,0625 - 434,7875, 138 channels, 12,5 kHz spacing, RF output 10 mW. The receiver has dimensions 48 x 24 x 13 mm and the same working frequencies, 138 channels digitally adjustable. During the test, the data are also stored in serial EEPROM memory and they can be read at the end of the examination. This is important in case the connection between the transmitter and the receiver is lost during the examination. In Fig. 3 there is a block diagram of the **TELEKARD**.

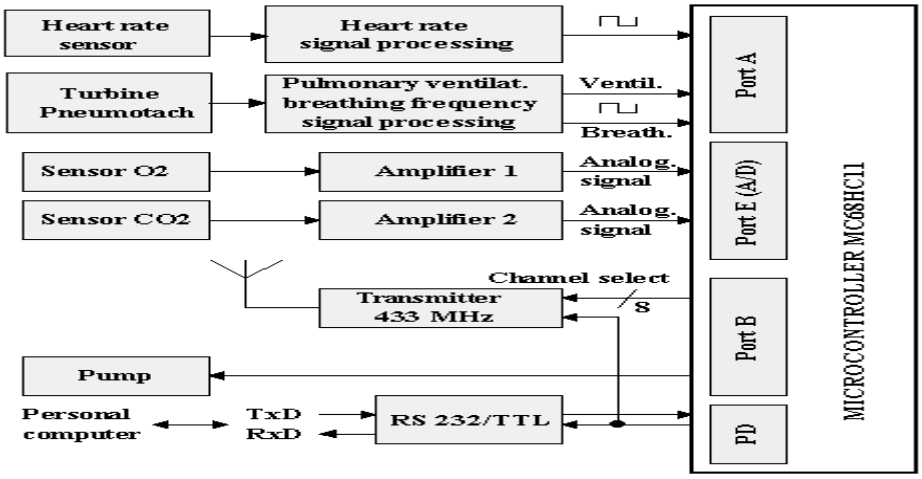

Figure 3. Block diagram of the **TELEKARD** system

Software

During the test the **TELEKARD** acquires the following main signals: Heart frequency, Flow, %O2 Expiratory, %CO2 Expiratory. These signals are processed in PC - **KONSIL** software [5].

The standard parameters calculated by the program are the following:

Symbol	Name	Units
VE	Ventilation	l/min, BTPS
RF	Respiratory frequency	1/min
Vt	Tidal volume	l, BTPS
VO2	Oxygen uptake	l/min, STPD
VCO2	Production of carbon dioxide	l/min, STPD
FeO2	mixed expired O2	%, dry
FeCO2	mixed expired CO2	%, dry
HR	Heart rate frequency	bpm
RQ	Respiratory quotient	---
VE/VO2	Ventilatory Equivalent for O2	---
VE/VCO2	Ventilatory Equivalent for CO2	---
VO2/HR	Oxygen pulse	ml/bpm
VO2/Kg	VO2 per Kg	ml/min*Kg
VO2peak	Maximum value VO2	ml/min, STPD
VEmax	Maximum value VE	l/min, BTPS
HRmax	Maximum value HR	bpm
VO2/HRmax	Max. value VO2/Max. value HR	ml/bpm
RFmax	Maximum value RF	1/min
VO2@LT	Lactate Threshold (Anaerobic Threshold)	l/min, STPD

In Fig. 4 the screen copy of real time stress test is shown. The measured data are stored in a table every 30 sec. The user can edit the data acquired during the test, or after the test.

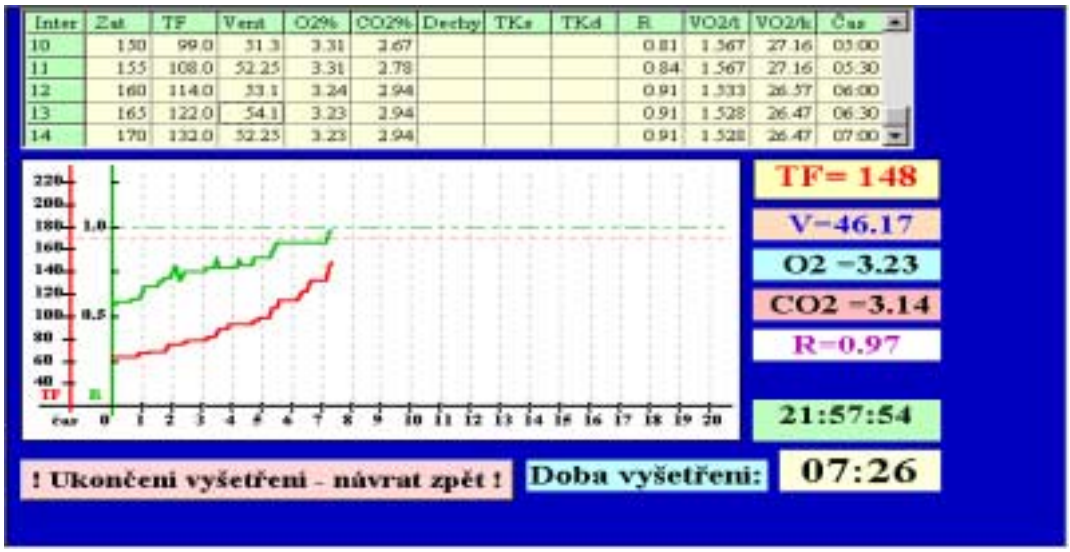

Figure 4. The screen during the real time measuring.
The graphs of heart rate and respiration quotient are displayed

All measured data and personal data of the patient are stored in Microsoft database (*.MDB). The program can display and print many graphs. The curve can be filtering by least-squares data smoothing. The program **KONSIL** enables to find automaticaly some important value from the data measured. In Fig. 5 there is an example of aerobic and anaerobic threshold finding. In some cases, the functional dependence finding is also important. In most of the graphs the functional dependence based on polynomial least-squares is used and coefficients are displayed. In Fig. 6 there is an example of polynomial least-squares approximation, heart rate frequency as a function of load. This function is useful mainly for sport testing (comparing different types of load) .

Conclusion

The **KARD** system and different versions of program **KONSIL** (old for DOS operating system, new for Windows 95 or higher operating system) are used in several function laboratories in the Czech

Republic. The programs and systems for automatic stress testing have been developed in cooperation with doctors for more then 15 years. They enable to test on bicycle or treadmill ergometer. Only a small part of the program **KONSIL** was shown in this contribution. The **TELEKARD** is the last developed part of this system and it is tested now.

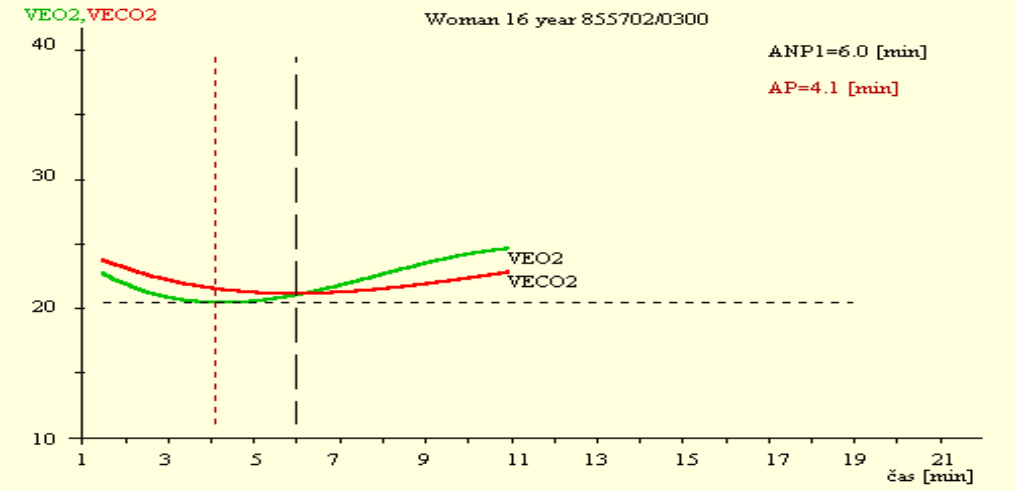

Figure 5. Automatic aerobic and anaerobic threshold detection based on least-squares data smoothing

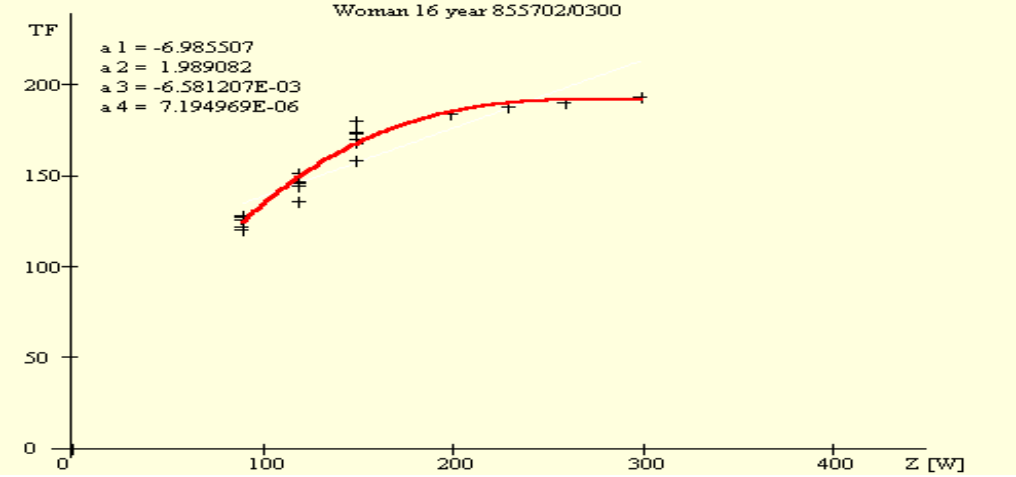

Figure 6. Example of polynomial least-squares approximation. Graph: heart rate frequency = f(load).
Herat rate = -6.9 + 1.989*L - 6.58E-3*L^2 + 7.19E-6*L^3 (L=Load [W])

Acknowledgment

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References

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