Lungtest System

Operating Instructions

User Manual

VO2max Tracker Ergospirometer

Version 19.8.28.1

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LUNGTEST
VO2max Tracker

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Contents:

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1. Introduction.

The *VO2max Tracker* ergospirometer is a stationary system designed to perform exercise tests of the respiratory and circulatory systems, and offering a comprehensive analysis of the measurements taken. The VO2max Tracker measuring system is designed based on a pneumotachographic head patented by MES and quick carbon dioxide and oxygen analysers that support measurements taken using the "breath by breath" method with an analysis of each exhalation phase. The system may be equipped with a mixing chamber as an option.

Due to the application of an advanced pneumotachographic head, the measuring system does not require any inhalation-exhalation valve nor any connections made e.g. from corrugated tubes. This ensures the full comfort during tests, because the examined patient breathes under natural conditions without any additional resistance to air flow. The integrated spirometric examination module with unique software offering reliability checks of completed tests, according to the recommendations of the ERS/ATS, enables the user to determine the FEV1, MEF50 and VC values, eventually used as a basis to automatically determine the normal values for HR, VO2 and VE measured in exercise tests.

VO2max Tracker supports continuous recording of the following signals as a function of time: tidal volume, respiratory flow, O2 and CO2 concentrations in the exhaled gas, 1 – 12 ECG leads. The system always archives the full examination procedure, enabling the user to reproduce each exhalation. The method of presentation of the procedure during its performance and the printout of measured changes and calculated values is defined by the operators.

Advantages of the *VO2max Tracker* system:

- works with the VO2 Viewer program
- examinations using the "breath by breath" method
- a light, low-resistance pneumotachographic head without movable components
- an automated ambient condition measuring system
- an automated gas analyser calibration system
- alternative methods available to measure the heart rate in a wireless system or with 12 ECG leads
- automated or manual determination of the anaerobic threshold
- possible VO2max determination
- measured quantities displayed as compared to normal values
- automated control of treadmills or bike ergometers
- the printout layout of the report on test results may be edited
- the report on an examination may be transferred to standard statistical programs
- software compatible with Microsoft Windows
- easy transport of the system mounted on a trolley
- the measuring system may be extended by additional options: pulse oximetry, minute cardiac output using a non-invasive method, measurements of systolic and diastolic pressure values.

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The *VO2max Tracker* system consists of the following components (Fig. 1a):

1. Carry case
2. 3-litre syringe for flow and volume calibration (in the optional carry case)
3. Wear belt system for main unit
4. *POLAR* heart rate sensor
5. Main VO2max Tracker deice
6. Telemetry radio receiver (optional)
7. Telemetry radio transmitter (optional)
8. A stand for the cylinder (optional)
9. A CD-ROM with the *VO2 Viewer* program

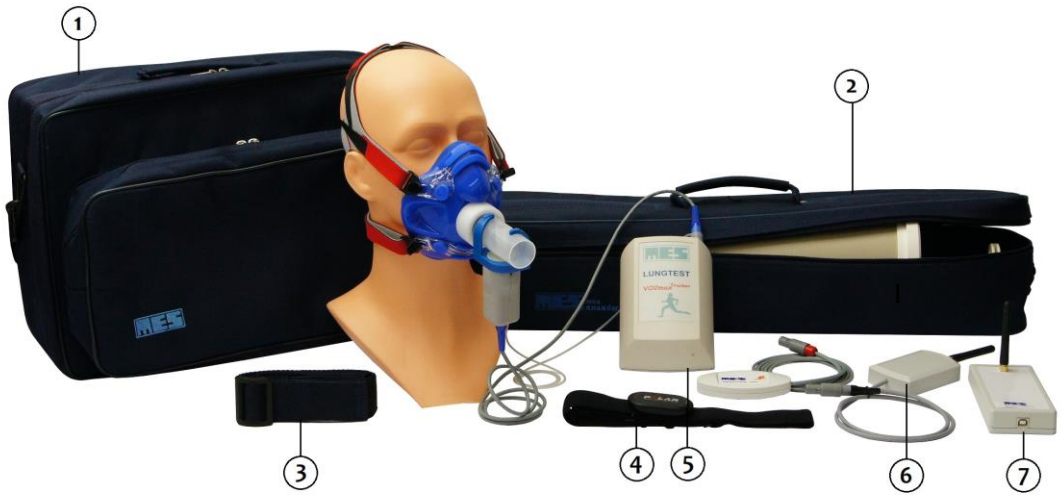

Fig. 1a. ***VO2max Tracker*** **Ergospirometer** ***with accessories***

Basic equipment necessary for performing of the examination consists of the following parts (Fig. 1b):

1. Headgear for the mask
2. Ergospirometry mask
3. Mask adapter
4. Pneumotachographic headpiece
5. Head coupler with built-in flow sensor
6. Polar HR transmitter
7. Gas tube with connectors
8. Main Tracker device
9. USB cable for PC connection
10. Rechargable batteries AA type – 4 pcs

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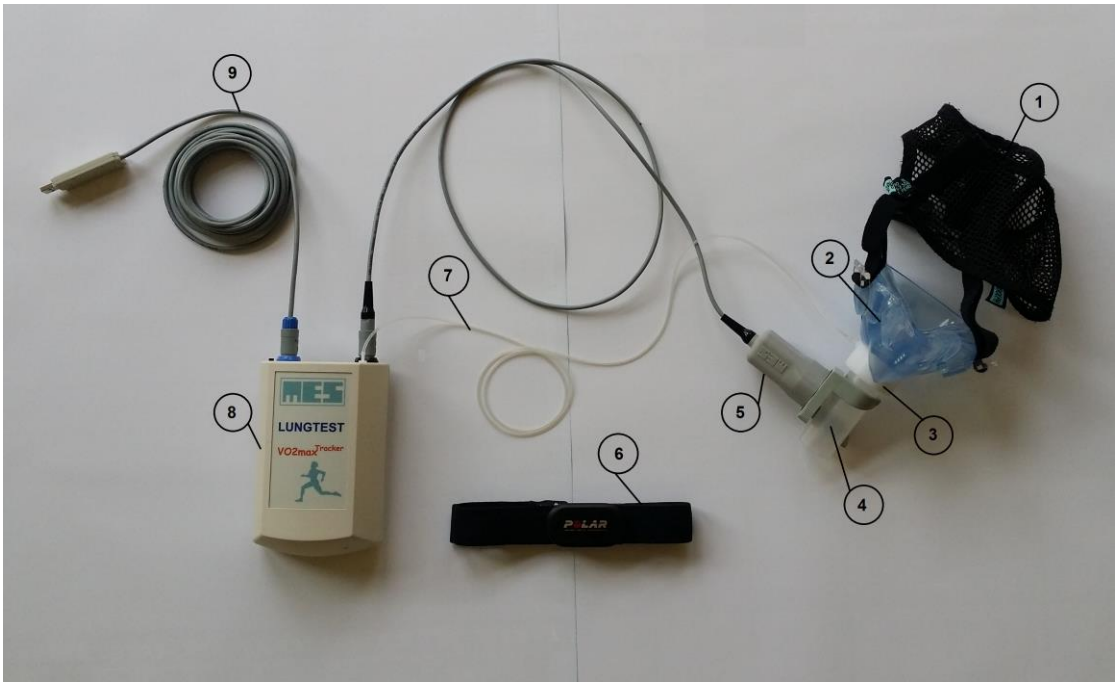

Fig. 2b. ***VO2max Tracker*** **Ergospirometer with basic equipment for examination**

The *VO2max Tracker* ergospirometer is equipped with the following sockets and components (Fig.1c):

1. **"Flow Port" Socket (blue)** connection with patient's cable and pneumotachgraphic headpiece
2. **"Main Port" Socket (black)** connection with PC Cable or the terminal Transmitter module
3. **Gas IN** Socket (Luer Type) for gas tube connection
4. **ON/OFF** button to switch on power supply. (Hold at least 3 seconds until all the leds turn off apart of the blue one (BT). To turn VO2max Tracker off hold the button again for at least 3 seconds.
   If the device is turned on at least 45 min. and no examination is performed, it will turn off automatically.

5. Three light diodes: ST, BT, BR and HR
   Diode ST-Status informs about the battry status:
   Continuous red colour- informs about low level of battery or no-battery
   Continuous Green colour – battry level is OK

Attention!
If the battery level is poor, the device will give the sound alarm (double-tone). Now the user has time to replace the batteries for fresh ones opening the battery compartment. VO2max Tracker has it own internal battery witch can hold the power up to 30 seconds. For safety it is better to replace batteries one by one instead of putting all of them out.

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Diode BT – Bluetooth status

Blinking blue (long ON/short OFF) – ready for connection
Blinking blue (short ON/long OFF) – patient cable disconnected
Continuous blue – connection is ON

Diode BR – Breath Rate is on during expiration phase of breathing patient

Diode HR – Heart Rate Status – starts to blink, when the connection with Polar belt transmitter is successful. .

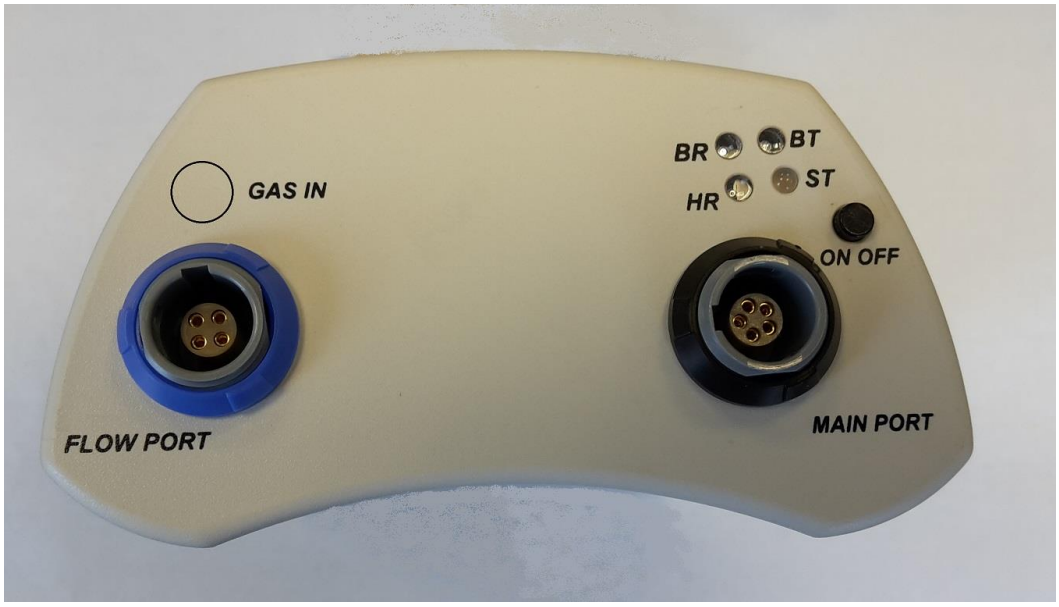

Fig. 3c. *VO2max Tracker* Ergospirometer – connection panel view

The *VO2 Viewer* program working with the *VO2max Tracker* ergospirometer enables the user to complete an ergospirometric examination. The interface view is shown on Fig. 4. The program enables its user to determine the following parameters:

BF [1/min] ⇒ breathing frequency;
HR [1/min] ⇒ heart rate per minute;
MET = VO2/kg/3.5 ⇒ a metabolism unit (1MET=3.5ml/min/kg);
VE [litre/min] ⇒ minute ventilation – the volume of air used by the patients to ventilate their lungs during 1 minute. The parameter is calculated as the product of the number of breaths (BF) and the volume of a single breath (TV) measured in the exhalation phase. BTPS conditions.
RER = VCO2/VO2 ⇒ respiratory exchange ratio;
TE [s] ⇒ exhalation time;
TI [s] ⇒ inhalation time;
TTOT [s] ⇒ duration time of the full breath cycle;
TV(VT) [litre] ⇒ volume of a single breath;
VO2 [litre/min] ⇒ oxygen consumption converted into the STPD conditions;
VCO2 [litre/min] ⇒ exhaled carbon dioxide converted into the STPD

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conditions;

FeO2 [%] ⇒ mean value of oxygen concentration in the exhaled air (the value is calculated as FeCO2);

FeCO2 [%] ⇒ mean value of carbon dioxide concentration in the exhaled air. The value is calculated for each exhalation phase, and when averaged for a selected time interval, it is computed as a mean value of all mean values of full exhalation phases in the selected time interval.

EQO2 = MV/VO2 ⇒ ventilation oxygen equivalent;

EQCO2 = MV/VCO2 ⇒ ventilation carbon dioxide equivalent;

TI/TE [%] ⇒ ratio of the inhalation time to the exhalation time;

TI/TTOT [%] ⇒ ratio of the inhalation time to the time of the entire cycle;

VO2/HR [ml] ⇒ oxygen consumption relative to heart rate per minute;

VO2/Kg [ml/kg/min] ⇒ oxygen consumption per 1 kg of patient's body weight

VO2/Kg/HR [ml/kg] ⇒ oxygen consumption per 1 kg of patient's body weight and unit of heart rate;

WATT [W] ⇒ workload;

SpO2 ⇒ saturation (blood saturation with oxygen);

VD/VT ⇒ ratio of the residual volume to the tidal volume

PEO2 [mmHg] ⇒ averaged partial pressure of oxygen in the exhaled gas;

PECO2 [mmHg] ⇒ averaged partial pressure of carbon dioxide in the exhaled gas;

BR [%] ⇒ breathing reserve;

VET_SUM [L] ⇒ ventilating air volume;

TV_TE [L/s] ⇒ ratio of the TV to the TE parameter;

Speed [km/h] ⇒ treadmill speed;

Slope [%] ⇒ treadmill slope;

SBP [mmHg] ⇒ value of systolic blood pressure;

DBP [mmHg] ⇒ value of diastolic blood pressure;

Borg ⇒ twenty-point Borg scale used by the patients to describe their perceived exertion;

Points	Exertion
6	Extremely light
7	
8	Very light
9	
10	Rather light
11	
12	Rather hard
13	
14	Hard
15	
16	Very hard
17	

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18	Extremely hard
19	
20	

Lactate [mmol/l] ⇒ the value of blood lactate concentration;

Quantities describing the oxygen debt (EPOC):

VE.B.SUM [L] ⇒ the total volume of breaths during the test calculated at the reference phase level (tare);
VE.T.SUM [L] ⇒ the total volume of breaths in the entire test;
VE.L.SUM [L] ⇒ the total volume of breaths in the exercise phases;
VE.R.SUM [L] ⇒ the total volume of breaths in the recovery phase;
VO2.T.SUM [L] ⇒ the total volume of oxygen consumed during the entire test;
VO2.OD.SUM [L] ⇒ the difference in the oxygen consumed during exercise phases between the consumption values rounded to the end-phase level and actual values;
VO2.L.SUM [L] ⇒ the total volume of oxygen consumed during the exercise phases;
VO2.R.SUM [L] ⇒ the volume of oxygen consumed in the recovery phase;
VO2.A.SUM [L] ⇒ **VO2.A.SUM = VO2.OD.SUM - VO2.R.SUM;**
VO2.B.SUM [L] ⇒ the volume of oxygen consumed during the test calculated at the volume of consumption from the reference phase;

Explanation of acronyms STPD, BTPS, ATP used:

STPD ⇒ Standard Temperature Pressure Dry (dry gas conditions at a temperature of 0 ^{o}C and a pressure of 760 mmHg);
BTPS ⇒ Body Temperature Pressure Saturated (human body temperature, atmospheric pressure and steam saturated air humidity);
ATP ⇒ Ambient Temperature Pressure (temperature, humidity and pressure conditions in the room where the test is performed).

1.1. Technical data.

General data:

Dimensions (length/width/height)	150/100/55 mm
Weight	280 g
Supply voltage	rechargeable batteries 4 x 1,2 V AA Ni-MH

Bettry Charger:

Supply voltage	230-240 V AC, 50Hz
Number of loaded batteries	4
Power consumption	1,5W

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Technical data of the measuring module:

Flow measurement:	
Measuring headpiece:	MES DV40 (or DV40e)
Dead space:	38 ml (or 20ml)
Flow range:	+/- 20 l/s
Flow resolutions:	1 ml/s
Usable flow resolutions:	10 ml/s
Volume measurement range:	0 - 10 l (0 – 20 l)
Usable volume resolution:	10 ml
Accuracy:	< 2%
Headpiece resistance:	< 0,9 cmH_2O/l/s (at 14 l/s flow rate)
Ventilation range:	300 l/min
Oxygen analyser:	electrochemical cell
CO2Meteor (UV flux sensor)	
Measurement range:	0 – 25 % (0 – 100 %)
Response time:	t90 < 100 ms
Accuracy:	0,01 %
Resolution:	0,01 %
Carbon dioxide analyser:	NDIR infrared absorption
CozIR SprintIR (infrared)	
Measurement range:	0 – 10%(0 – 15% expanded range)
Response time:	t 90 < 100 ms
Accuracy:	0,01 %
Resolution:	0,01 %

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2. Installation

The *VO2max Tracker* set must be correctly installed to successfully perform an examination. The installation process consists of the following steps:

To perform the examination properly, you need to install the *VO2max Tracker* software properly. Installation consists in the following steps:

1. From the attached CD-ROM install VO2 Viewer program on the computer:
   - Start the *setup.exe* file in order to launch the *VO2 Viewer* program installer. Install the program

2. Connect the USB cable with black plug to "Main Port" of the device. The other end of the cable with USB plug must be plugged to your PC.
3. Your system will ask You for drivers to the USB Adapter. If You are connected to the internet, You may try to allow automatic installation. If not, you have to find the drivers on installation PC*

4. Connect the patient cable with blue plug to the "Flow Port". The gas cable (transparent tube) has to be plugged to "gas in" plug.

5. Perform the examination according to the description from Chapter 7.
6. When there is a communication breakdown between the computer and the ergospirometer, one should check the cable connections to the ports (Chapter 5.3)

*Caution:
After installation and connecting the USB/COM adapter, it is necessary to check the COM number of the adapter. All You have to do, is to find a "Device Manager" in Your Windows system, find "COM/LPT ports". The title You are looking for is "USB-to-serial comm Port" Write down the COM number. You will need it to set up "The hardware configuration" of "Ergo2000M" software.

2.1. Connecting and disconnecting the cables

The device is equipped with smart and easy-to-use connections. However, please pay attention to proper and gentle handling of the "FLOW PORT" plug and "MAIN PORT" plug.

<u>Connecting:</u>
There is only one position, that you can plug the cable to the socket. There is a special notch on the end of the plug, also signed with additional arrows (see the pic below). It must fit to the similar notch inside the socket. After you match them, just push gently the plug into a socket, until you hear and feel the "click".

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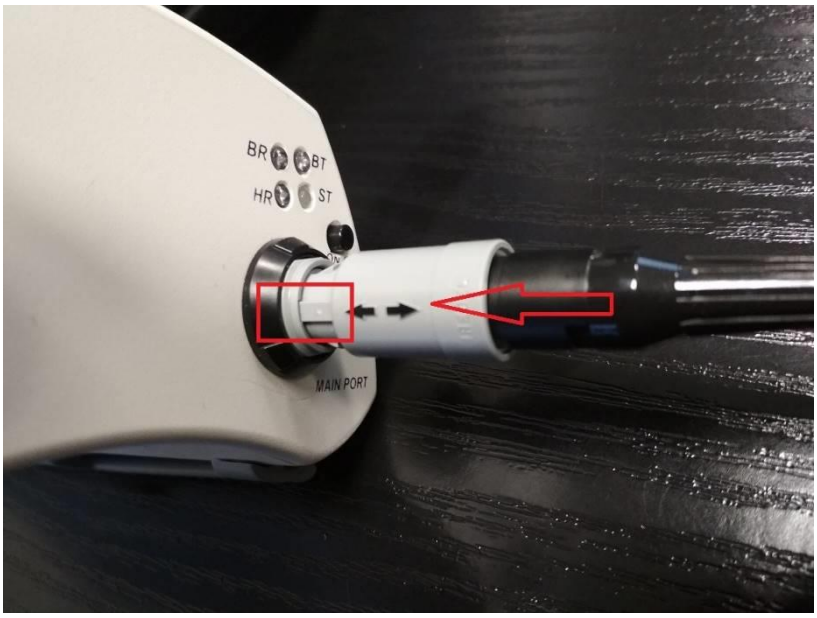

Fig 3d: Connecting the cable

Disconnecting:
Gently push the plug outside the socket in parallel to the cable.

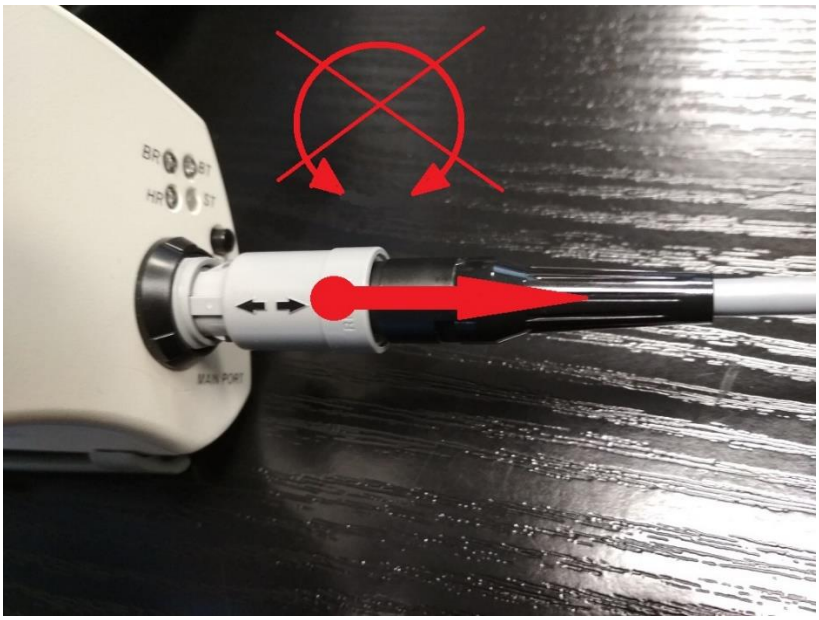

Fig 3e: Disconnecting the cable

WARNING! DO NOT TRY TO SCREW THE PLUG. Doing so may damage the plug or/and the socket.

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3. Program interface description

Fig. 4. Program interface view.

Sample program window view is shown on Fig. 4. It consists basically of several sections constituting separate windows. Each window may contain a chart, data table, digitally displayed parameter, or needle indicator. The dimensions of each window may be changed, and each window may be removed at any time.

The parameters, normal values displayed in each chart may be modified at any time, similarly the chart graphic properties (using additional settings). Selected chart fields may be enlarged or reduced during the examination using the scroll wheel (mouse wheel).

The table shows data collected during the examination in the “breath by breath” mode, i.e. each table row corresponds to one breath. The row values may averaged for any time interval. The table columns represent specific parameters during the examination time for each breath. The columns may be modified at any time, by adding or removing parameters and changing their order or sequence.

The displayed window and table configuration is permanently saved in the “View”. A dozen ready views are available. They may be modified and saved, and customized views may be created.

4. Patient's data

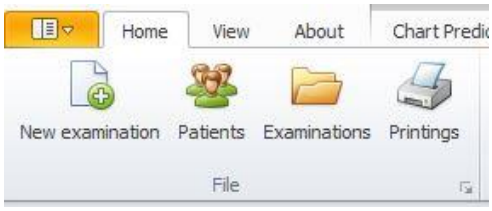
The patient's data is a set of information necessary to identify the patient. No test may be performed without this information. The patient's data may be entered using two methods:

1. Entering new patient's data (⇨ Section 4.1).
2. Selecting a previously entered patient from the list (⇨ Section 7.3).

Once patient's details are entered, the test is performed for this patient. To examine another patient, those patient's data must be entered in advance.

4.1. New data

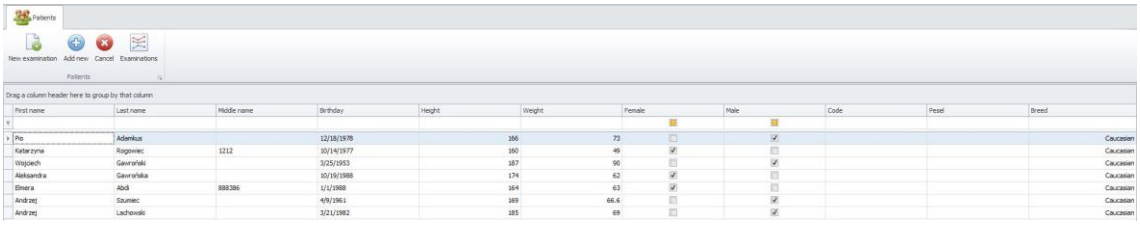
To enter new patient's details, display the patients' list (the “Patients” button) or use the “New examination” button.



If the first method is selected, the patient may be added to the list and the user may return to other tasks. If the second method is selected, the patient is entered or selected from the list and then the program automatically proceeds to performing the examination.

The “Examinations” button is used to display a list of all tests previously performed and to browse and edit the tests.

A series of options are available upon entry in the list of patients:



- New examination – beginning a test for the patient marked in the list
- Add new – adding a new patient to the list
- Cancel – exit from the patients' list
- Examinations – displaying tests performed only for the marked patient

If the “Add new” button is used, the *Patient* dialog box is displayed (⇨ Fig. 5). The box contains a set of fields where information is entered according to the labels

located next to each field. The BMI index is automatically calculated once the patient's height and weight are entered.

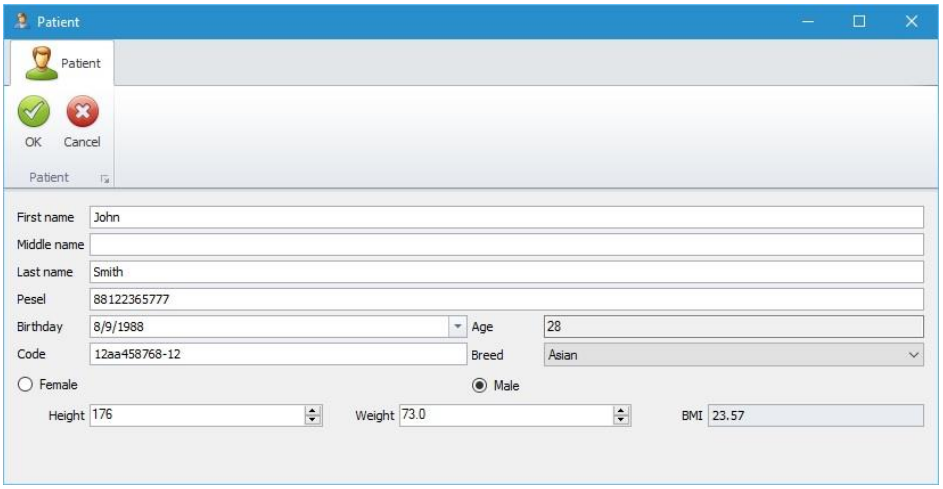


Fig. 5 The *Patient's data* dialog box.

4.2. Modifying

The patient's data may only be modified until the beginning of the examination. Erroneous details entered and approved may be corrected after starting the examination only if the examination is closed. Enter correct details then, following the procedure for entering a new patient (⇨ Section 4.1).

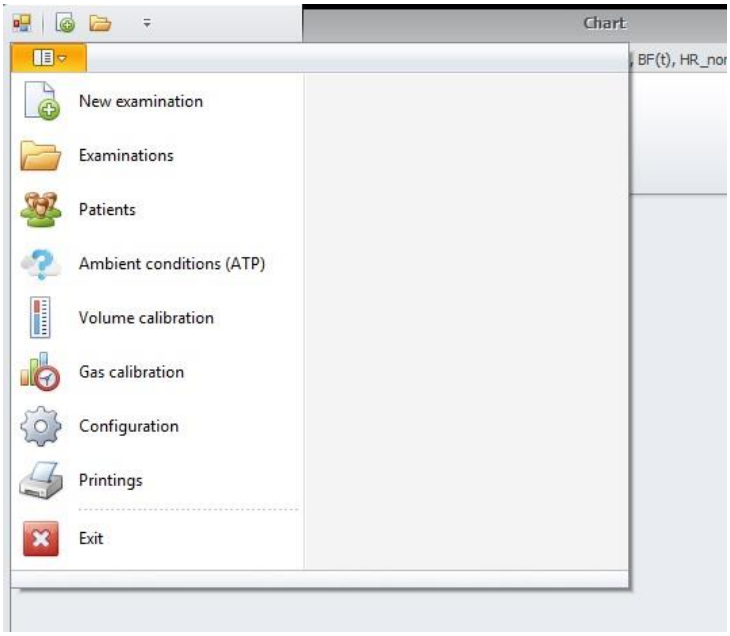
The patient's data may be modified prior to commencing an examination, using the *Patient* dialog box (⇨ Fig. 5), and selecting the desired item in the patients' list. Any detail may only be modified if it is previously entered (⇨ Section 4). All patient's details may be modified.

4.3. Data review

The patient's data may be reviewed when the patients' list is displayed and the patient is then selected in the list.

5. Program options

Program options represent information necessary to correctly perform an examination. This information describes parameters of data transmission between the ergospirometer and the computer, and the ergometer selected. The use of exercise protocols differs, depending on those settings. If a test with an ECG device is selected, the procedure of examination start and performance may change.



5.1. Ambient conditions

Once the *Ambient conditions* command is selected, the device will display a dialog box describing the external conditions prevailing during the examination (⇨ Fig. 6).

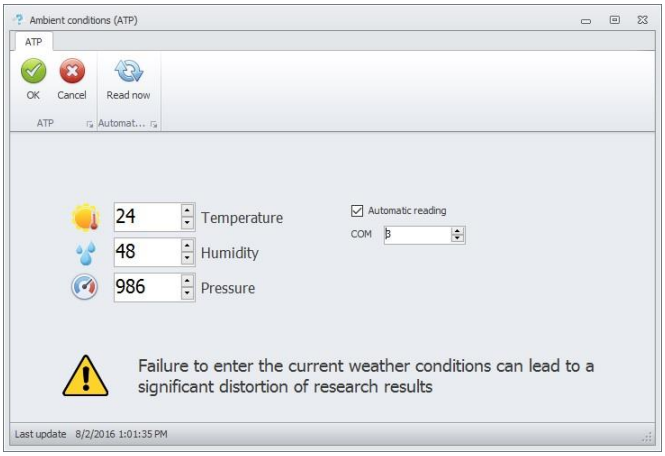


Fig. 6. Weather conditions.

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If no values or incorrect values of parameters representing the temperature, humidity and pressure are entered, the examination results may become inaccurate and unreliable. The values may be entered manually, as read from external devices (a thermometer, a barometer, a hygrometer) or may be read automatically. Connect to your computer a special extension module designed for weather condition reading, and (having executed the *VO2 Viewer* program) select the *Automated readings* field. The *COM serial port* window will be activated where the port number with the extension module connected should be selected. Click on the *Read now* button to have the current weather conditions read and their values entered in the dialog box. The values may be updated both prior to and after the selection of the examination type. They are valid for 4 hours. This means that the program will not request that the weather conditions be updated for 4 hours, regardless of the number of program starts in this period (be it one or more).

5.2. Calibration

When the *Calibration* command is selected in the *Program options*, you must select whether the calibration process applies to the gas or the volume. If the program is executed with outdated weather conditions, a dialog box will be displayed requesting their refreshment (⇨ Section 5.1). Enter current temperature, pressure and humidity values or select their automated reading (if the extension module for automated condition readings is available). Gas and volume calibrations are valid for 24 hours. The calibration process is completed under ATP conditions.

5.2.1. Volume calibration

When the *Volume calibration* command is selected in the *Program options* menu and the prevailing weather conditions updated, if required, the dialog box shown on figure Fig. 7 will be displayed.

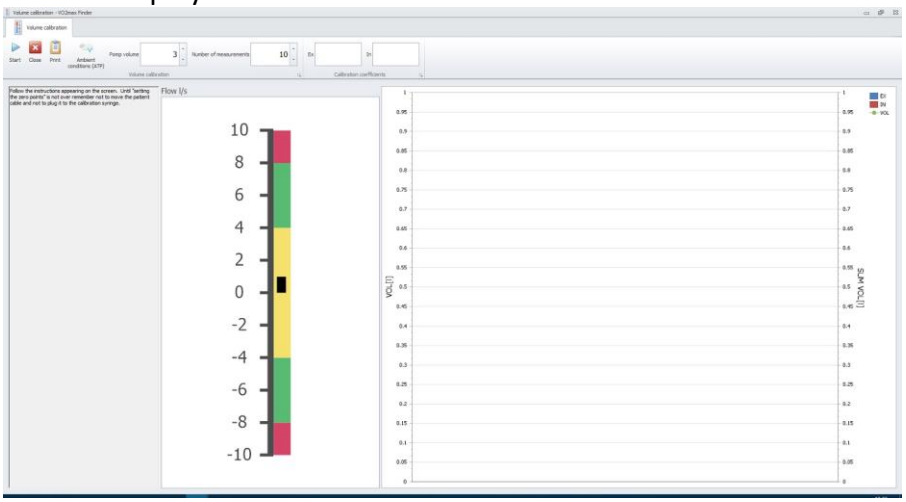

Fig. 7. Volume calibration.

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The *Calibration manoeuvres* window is used to enter the number of correct movements of the calibration pump piston necessary to finalize the calibration process. The irregularity of pump piston movement is checked in the calibration process. If the irregularity value is excessive, the program will reject the manoeuvre with the set percentage value of irregularity exceeded. A previously accepted manoeuvre may thus be rejected. The *Capacity* field is used to enter the capacity of the calibration pump used. Certainly, the calibration pump must be connected prior to the calibration process to the spirometric head that is correctly attached to the air conduit coupling. The calibration process is initiated using the *Start* button and producing uniform movements of the calibration pump piston. The *Calibration coefficient* field displays the most recent correct calibration coefficient and the *Number of uniform manoeuvres* shows the number of movements accepted by the program. The *manoeuvre volume* window displays bars with their heights corresponding to the volumes of manoeuvres completed. The number of bars is consistent with the number displayed in the *Number of uniform manoeuvres* field The bottom section of the window contains a field displaying "hint messages" facilitating the calibration process. If this field shows a message saying that the calibration process has been correctly completed, the volume calibration process is finalized.

5a. Plugging the headpiece to the air-tube connection

5b. Headpiece connected to the air-tube

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5.2.2. Gas calibration.

The gas calibration dialog box (⇨ Fig. 8) is displayed when the *Gas* command is selected in the *Calibration* sub-menu of the *Tools menu.*

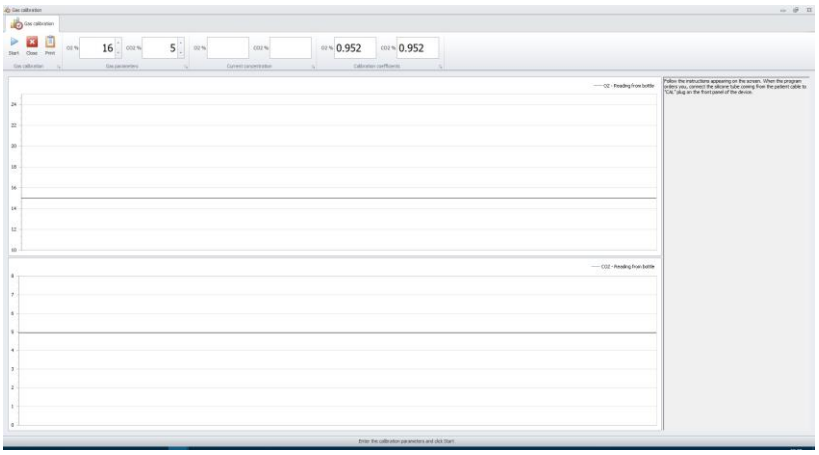

Fig. 8. Gas calibration.

This calibration process may be summarized by the following steps that must be taken in their precisely defined order:

Enter percentage concentrations of *O2* and *CO2* in the reference gas in the *Reference gas parameters* group (using the description on the cylinder with calibration gas). Any changes may only be entered following the connection of a new cylinder with a reference gas.

In the *Sample gas parameters* group one should enter the *O2* and *CO2* concentration percentage in the sample gas (description on the calibration gas cylinder). Changes can be made only after connecting a new sample gas cylinder.
After clicking the *Start* button there appears information that 'zero' will be read from the atmosphere. One should make sure that the end of the silicone gas cable (by the head connector) is 'let out' to the atmosphere. Then we confirm this with the *OK* button.
For the next 30 seconds 'zero' will be read from the atmosphere. In the meanwhile, you may prepare the bag with calibration gas:

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- Squeeze the bag to remove an atmospheric weather from the inside (see the photo below)

6a. Sqeezing the calibration bag

- connect the bag to the bottle, and gently open the valve. Fill the bag with small amount of the gas (see photo below)

6b. Filling the calibration bag with gas

- squeeze the bag again
- fill the bag with a gas (more than previous) but not as much as a “balloon”

After reading 'zero', the program will inform us that the sample gas calibration will be conducted. It is time to connect the bag with the calibration gas (if it is not already connected) to the “Luer” nut at the end of the transparent-blue gas cable.

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6c. Connecting the calibration bag to the air-tube

Let the device vacuum the gas from the bag. Do not squeeze a bag or silicone tube.

The connection is confirmed with *OK* button. The proper calibration process lasts also around 30 seconds. During the process the following information are displayed in the window:
In the *Currently read concentration* group there are displayed the currently read concentrations of the proper gases.
In the *O2 – cylinder reading* and *CO2 – cylinder reading* columns are drawn whose height corresponds to the values from the *Currently read concentration* windows.
At the bottom there is a field where the 'prompting messages' are displayed that facilitate the process of calibration. When in this field appears information that the calibration has been completed successfully, the process of gas calibration is finished.
In the *Calibration Factors* field the calculated calibration factors are displayed.

5.3. Configuration

When the *Configuration* command is selected in the *Options* menu of the program, a dialog box is displayed in the left section of the screen, with several tabs. They include (in sequence):

- General
- Devices
- Company
- Comments
- Parameters and norms
- Protocol
- Respiratory cycle examination

The following subsections describe each of the tabs. Any changes made must be confirmed using the "Save" or "Save and close" buttons, if not prompted in advance by the program.

5.3.1. The *General* tab

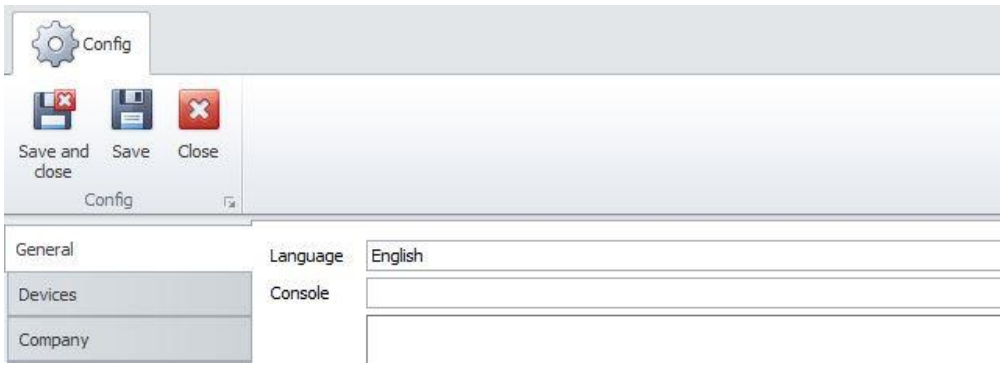

Fig. 9. The *General* tab

This tab is used to select the language (Polish or English). The language is changed in the entire program, excluding draft reports that must be set by the users, depending on their preferences.

The *Console* window is designed for authorised service staff. It has no functionality at the user level.

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5.3.2. The *Devices* tab

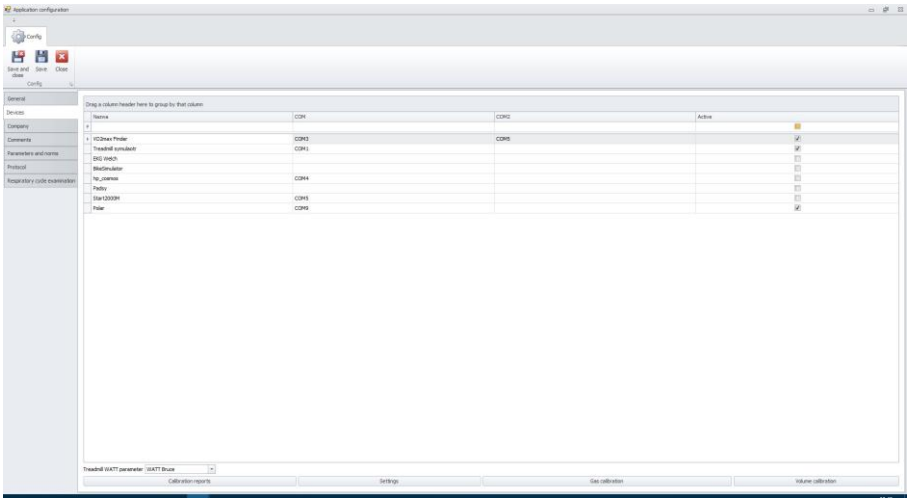

Fig. 10. The ***Devices*** **dialog box**

In this tab, the user may select from the list a device to be currently used in the test (the "Active" parameter), and assign the COM port number to the device. The number may be read in the system *Device manager*, in the "COM&LPT ports" branch. Each device has one number assigned, except VO2max Tracker that is supported by 2 COM ports.

In addition to the ergospirometer, the type of ergometer is set here (bike/treadmill) as well as work with an ECG system, if this additional option is available. If the "Polar" system receiver is used, it must be marked and an appropriate COM port must be assigned to the receiver.

The "Treadmill WATT parameter" can be seen in the bottom section of the screen. It is used to select the method for theoretical calculation of workload in watts, based on the treadmill speed and slope. 3 methods are available:

- JAEGER:
  - ✓ for running:
    W [Watt] = (V * BW * (2.11 + G * 0.25) + 2.2 * BW - 151) / 10.5
  - ✓ for walking:
    W [Watt]= (V * BW * (2.05 + G * 0.29) + 0.6 * BW - 151) / 10.5

- ATS:
  G = 100 * tan α
  W [Watt] = BW * V * sin α * 100 / 36.4

.

- BRUCE:

  $\tan \alpha \cong \sin \alpha$ for small ones α

  W [Watt] = BW * V * G / 36

The acronyms used in the above equations have the following meanings:
BW – weight of the examined patient [kg] (EN Body Weight)
V – treadmill speed [km / h]
G – slope [%]
W – workload [Watt]

5.3.3. The *Company* tab

Fig. 11. The *Company* tab

This tab is used to enter the parameters of your centre or another centre where the tests are performed. The details will be shown on report printouts. Completing all rows is not mandatory.

5.3.4. The *Comments* tab

This tab is used to enter standard comments that may be then used in examination report printouts.

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5.3.5. The *Parameters and norms* tab

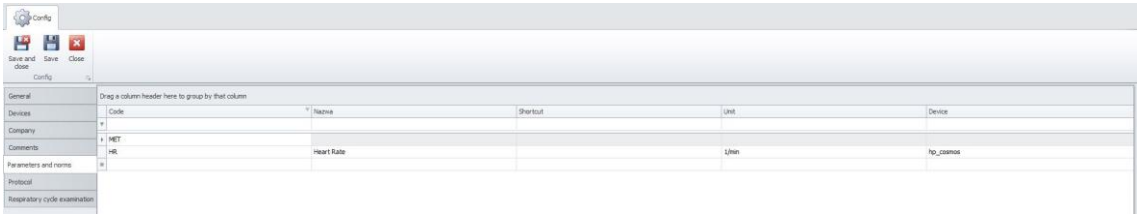

Fig. 12. The *Parameters and norms* tab

This space is used to define new parameters and norms for a test. Those changes may only be made by authorised service staff.

The source of heart rate reading (HR) in the “Devices” column may be changed from the user level, if this change is necessary. The program usually automatically identifies the source device of the HR parameter.

5.3.6. The *Protocol* tab

This tab is used to create and edit exercise protocols that are necessary to operate the ergometer with the aim of enforcing patient's physical workload as required to perform an exercise examination. The tab is irrelevant in the case of examinations with an ECG system that automatically defines a workload as a master program. It is also irrelevant if no ergometer is selected in the “Devices” tab.

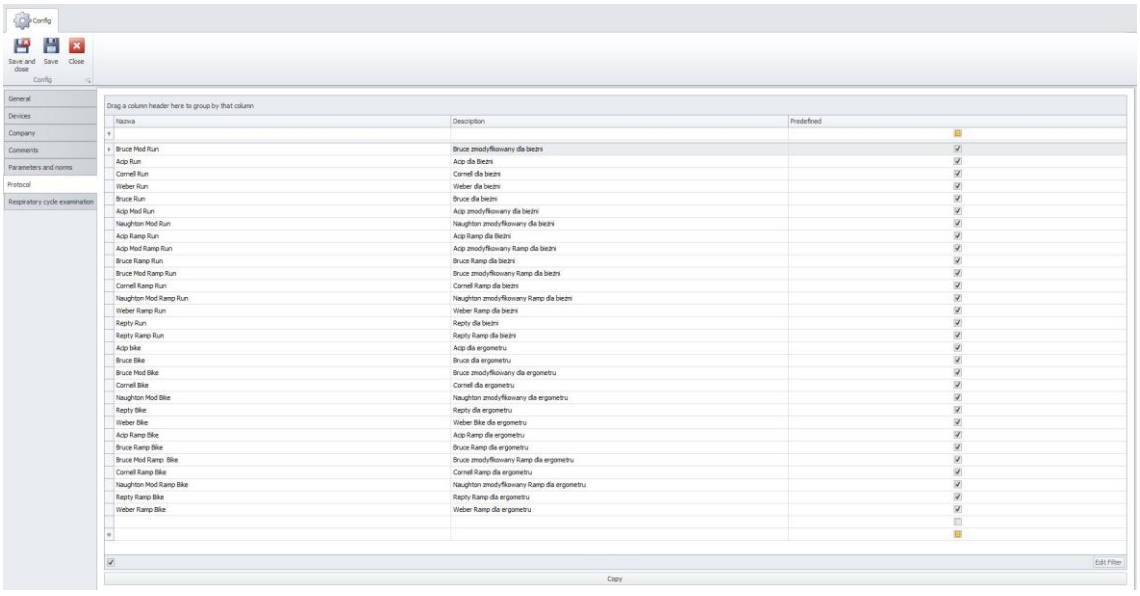

Fig. 13. The *Protocol* tab

The list displays default, standard protocols, used in exercise examinations. They include both treadmill protocols (with the "Run” extension) and bike ergometer

protocols (with the "Bike" extension). Also alternative protocol versions are available, such as "Ramp" with a linear increase in workload during the examination.
It should be emphasised that protocols designed for a treadmill only or a bike only may be selected prior to the examination.

To edit the selected protocol, click twice on the grey square located to the left of the protocol header. A window for editing and designing exercise phases will be displayed.

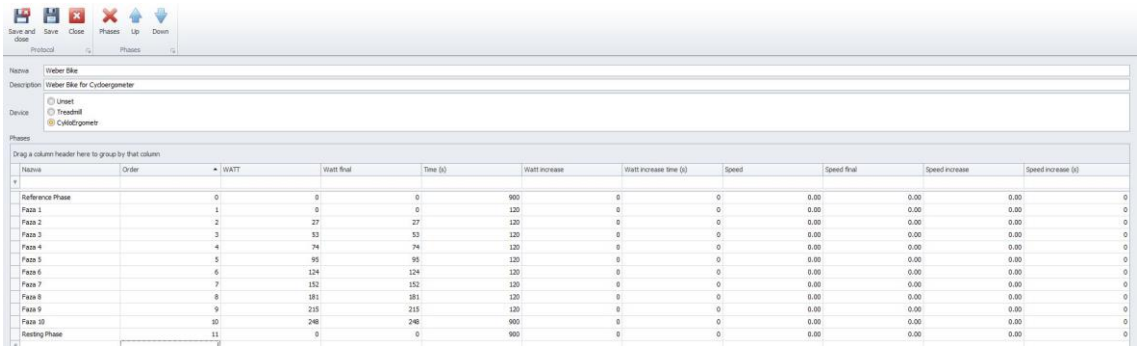

Fig. 14. Editing protocol phases

The following fields are to be completed:

- Name – the name of the protocol to be displayed during the examination
- Description – an auxiliary comment to the protocol name
- Device – define here whether the test phases are designed for a treadmill or a bike. Various column layouts are displayed in the table below and various workload calculation methods are used by the program during the test, depending on this setting. An exercise protocol is selected from the list displaying protocols for a treadmill only or for the bike only, depending on the device set in the program prior to commencing the examination.

Below you will also find a table where each row corresponds to one exercise phase. It contains the following columns:

- Name – the name of the phase displayed during the examination
- Order – a parameter of key importance. It enables the user to change the sequence of phases and define their meanings. Numbers **-1** and **0** represent special phases. Phase **-1** always represents an initial control phase when the patient is prepared for the test and the correct calculation of basic parameters is checked. Once the user proceeds to the next phase, the data from phase -1 is deleted and is not saved in the test results. Phase **0** always represents the rest phase. The examination begins with this phase. To correctly compute certain parameters (e.g. calorimetry), the phase should be set to at least 3 minutes (180 seconds). The phase is set to a longer time in most protocols, and the user is free to decide when to proceed to the exercise phases.
- Time – phase time given in seconds. If this time expires in the current phase, the program automatically proceeds to the next phase. The user is enabled to skip to the next phase or to the last phase at an earlier time.

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For a treadmill:

- Slope – the initial value of inclination for the defined phase in percent [%]
- Final slope – the final inclination value, computed automatically. If the workload is constant, it is equal to the value in the "Slope" column. If the "Slope increase" columns are used, the value is calculated based on those columns and the phase time. Selected treadmills
- Slope increase
- Slope increase (s)
- Speed
- Speed final
- Speed increase
- Speed increase (s)

For a bike ergometer:

- Workload
- Final workload
- Workload increase
- Workload increase (s)

5.4. Examination options

The system enables its user to perform two main types of examinations:

- An ergospirometric test
- A combined test (ergospirometry and exercise ECG)

The program operation depends on the devices selected in the *Devices* tab (Section 5.3.2). If the selected devices include an ECG, each commenced examination will automatically be set to the combined examination test. The ECG operating program takes then the functions of a master program managing exercise protocols, controlling ergometer parameters and reading the heart rate. The VO2 Viewer program is used to execute the "commands" from the ECG program.

5.4.1. An ergospirometric test

If only an ergospirometric test is to be performed (without ECG measurements), the "New examination" must be selected on the main screen. The program transfers us to the patients' list where a patient may be selected or a new patient added using the "Add new" button. A new patient may also be entered without initiating an examination, by entering the patients' list from the main screen.

Once a patient is selected, the program transfers us to the list of available exercise protocols. The list contains the protocols designed for the ergometer selected

from the devices list. Once the protocol is selected, the program proceeds to the main examination view.

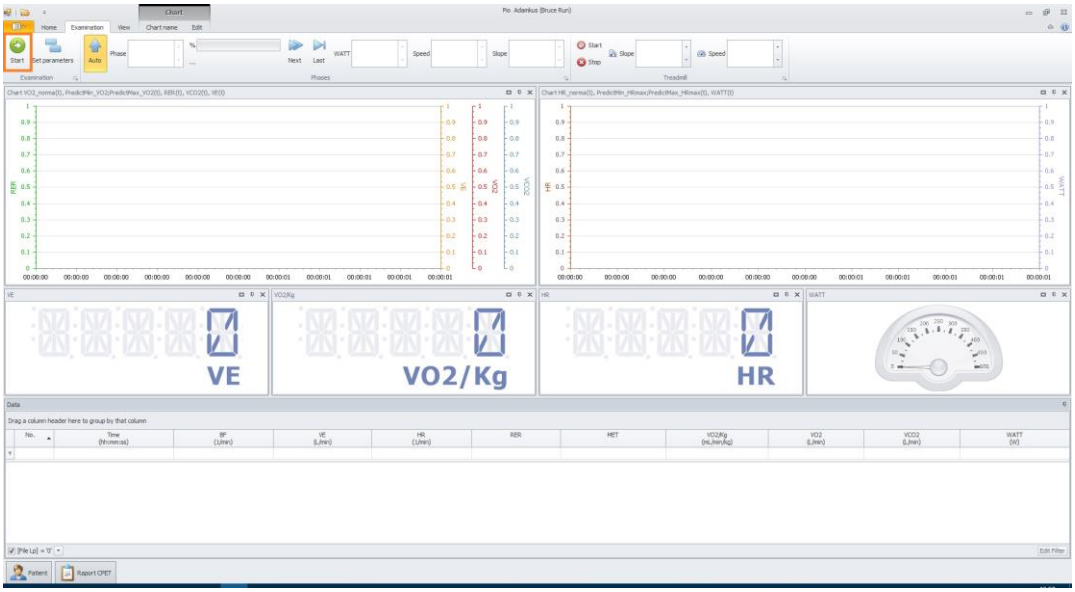

Fig. 15. Commencing an examination

The main view may be changed prior to commencing an examination, by expanding the “View” drop-down menu in the top screen ribbon, and confirming with the “Apply view” button. The examination is initiated using the green "Start” button.

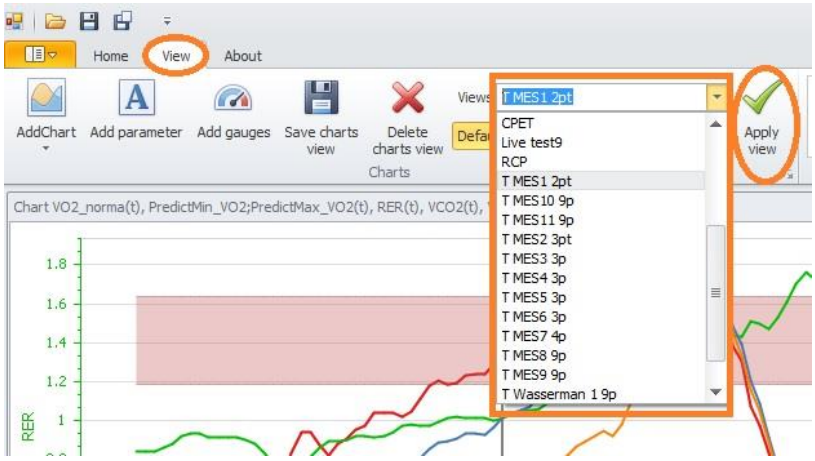

Fig. 16. The table with desirable values included.

The ergospirometry program resets the measuring device. Remember that the patient's conduit may not be moved and no air movement may be caused near the conduit until the reset process is finalized. The conduit must be detached from the mask and the patient.

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5.4.2. A combined test (ergospirometry and exercise ECG)

If an ergospirometric examination is to be performed combined with ECG measurements, the “New examination” must be selected on the main screen. The program transfers us to the patients' list where a patient may be selected or a new patient added using the “Add new” button. A new patient may also be entered without initiating an examination, by entering the patients' list from the main screen.

Once the patient is selected, the program proceeds to the main examination view.

The main view may be changed prior to the examination, by expanding the “View” drop-down menu in the top screen ribbon and confirming with the green “tick”. The examination is initiated using the green "Start” button. The ECG program is executed and current patient's data is transferred to the program only when the button is used.

The ergospirometry program resets the measuring device at the same time. Remember that the patient's conduit may not be moved and no air movement may be caused near the conduit until the reset process is finalized. The conduit must be detached from the mask and the patient.

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6. Options of the performed test.

6.1. Examination stages.

Each examination consists of two stages: a control stage marked as **phase "-1**" and the test stage (phases: 0, 1,2…). Operations necessary to prepare the spirometer for work are completed during the control stage. These include among others the memory reset, ventilation and the measuring system reset. Following these operations, the program proceeds to the analysis state in the control stage (with its measured values not saved in the memory). The user must ensure at this stage that the program behaviour is correct, i.e. charts are generated using the selected parameters and parameter rows are added to the bottom table. The proper examination procedure is performed at the test stage and is divided into the reference (rest), exercise and recovery phases.

NOTE!!!
1). The control stage (phase "-1") is crucial for ensuring the correct performance of the examination and obtaining reliable results at the proper examination stage, because the ventilation and measuring reset process is completed at the control stage. The connection conduit of the pneumotachographic head must be removed as far as possible from the mouth of the patient and the operating staff, because the high sensitivity of the systems used to measure ventilation and exhaled gas concentration may lead to a false zero being read and saved from the ventilation measuring module and CO2/ O2 gas analysers.
2). In the control phase of this stage, when the program already activates the analysis system, the triple connecting air conduit must be connected to the pneumotachographic head installed on the measuring mask previously put on the patient. The third conduit of the triple air conduit, marked with a blue ring, must be attached to the connector installed in the mask coupling.
3). The data displayed on the screen in the control phase is removed at the time of transition to the next stage, that is the reference phase (market with the "0" number). From this moment on, the examination is saved in the memory of your computer until the examination is stopped. The reference phase is usually set to 15 minutes, but the user is free to decide when to proceed to the next phase, i.e. the first exercise phase. It is recommended that the reference phase last for at least 3 minutes, to correctly compute reference calorimetry parameters.
4). Exercise phases (numbered: 1, 2, 3, 4…..) are changed automatically, according to the selected protocol. If the need to discontinue the examination occurs, the user is free to decide on the transition to the recovery phase. The phase is set to 15 minutes as a standard, but the decision to discontinue the phase and thus the entire examination, depends on the assessment and needs of the user.

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6.2. Examination phases.

The examination phases contain information about test parameters covering the entire examination time. This information includes: phase name, its duration, patient's workload, the speed and slope of the treadmill (if used in the examination procedure). The examination may consist of any number of phases.

Fig. 17. Examination phases.

The “Phases” segment displayed in the top ribbon of the screen is used to control exercise phases during examinations. The segment consists of the following components:

- The “Phase” window displaying the number of currently selected phase
- The progress bar – graphically showing the moment of examination phase. The time remaining until the end of the phase is displayed next to the progress bar in seconds. The name of the phase performed is displayed below the progress bar
- The “Next” button is used to skip to the next phase. Remember that the exercise phases change automatically with the lapse of their time
- The “Last” button is used to discontinue the exercise phases and proceed to the last (recovery) phase.

6.3. Chart view

Two types of chart views are available in the program. These include parameter chart views and *On Line* curve views. A sample chart view format is shown on figure 18.

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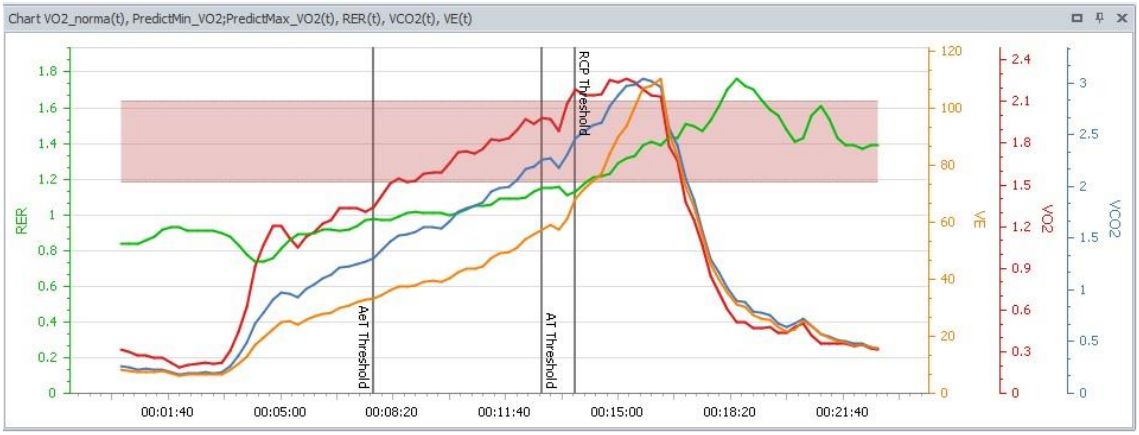

Fig. 18. Chart view

The view contains four parameter charts in this example. A separate vertical axis is assigned to each parameter. The vertical axis usually represents time, but may also represent another quantity. The parameter charts to be included in the view are selected in the "Edit" menu in the top screen ribbon. Additional options for the charts are made available by clicking on the chart with the right mouse button. The context menu of the chart view is then displayed.

6.3.1. Context menu of the chart view

The following options are defined here:

- Comment – enables the user to enter a comment in any point of the chart. The comment is associated in the data table with the corresponding breath and its time
- Chart wizard – activates a tool designed for advanced editing of chart properties
- Set AT / RCP / AeT– manual entry of AT, RCP and AeT thresholds
- Set as default – used to save the chart layout and use it to create customized views

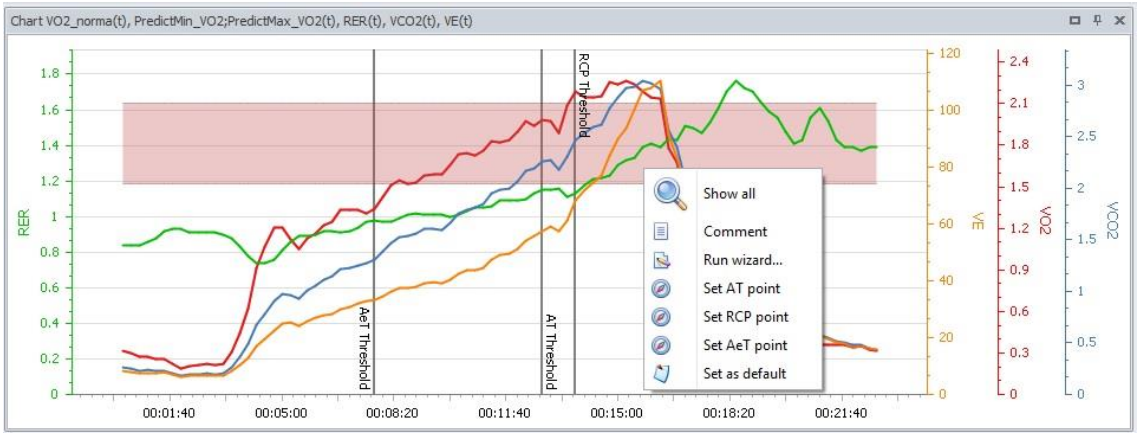

Fig. 19. Context menu of the *chart view*

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6.3.1.1. Comment

The *Comment* option marked in the context menu of the chart view enables the user to enter an individual comment displayed as a cursor on the examination chart.

Fig. 20. Dialog box for selecting parameters in the chart view.

6.3.1.2. Parameters

To define the parameters to be displayed in the selected view, click on the chart view to have its frame backlit as an active one, and then select the “Edit” tab in the top screen ribbon. Three drop-down menus will be displayed enabling the user to select: the Y axis, the X axis parameters and the norms.

When the "Axis X” menu is displayed, the user is enabled to select any number of parameters to be included in the chart and deselect undesirable parameters. The selection is confirmed using the “Apply” button next to the menu.

The “Norms” menu is used to select the norm bar for certain parameters and to display the bar on the chart.

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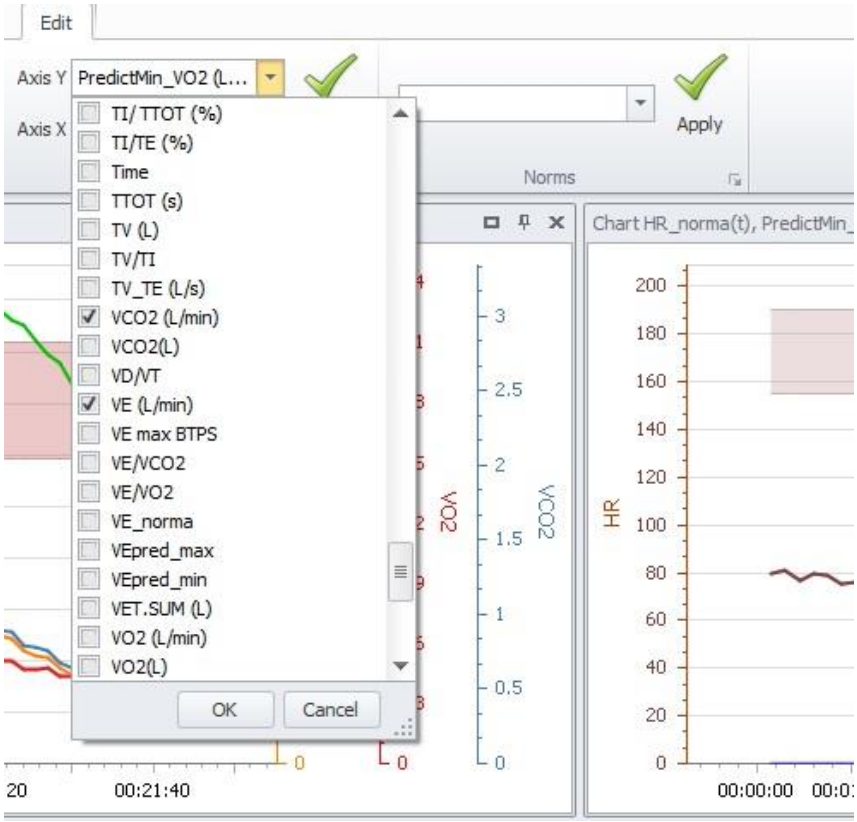

Fig. 21. Parameter selection menu

6.3.2. Chart options

6.3.2.1. Changing axis scale.

The scale on the chart may be easily changed using the mouse scroll. The chart is then enlarged, and scrollbars are displayed on the edges of the chart window, used to navigate in the previously enlarged chart.

6.3.2.2. Synchronizing the table with the chart (the "Follow" function)

The “Follow” function is used to view the data in detail. It is a binocular-shaped icon, displayed in the left top corner of the screen when the data table header is clicked on. Use the icon to select any point on the chart with the cursor, and only one row will be displayed in the table, corresponding to the point selected using the cursor. Click on the binocular icon again to deactivate the “Follow” function.

6.3.3. Table

A sample table view is shown on Fig. 22.

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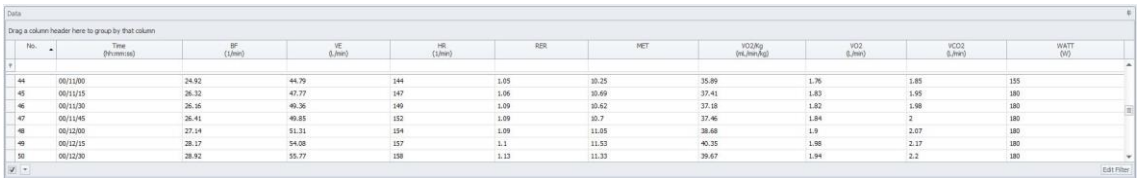

Fig. 22. Parameter table.

The table contains the values of selected parameters at individual time moments during the examination. Each row corresponds to the values of subsequent breaths taken, unless the option of averaging in time has been activated in the table. The user is enabled to edit the table view: to modify column widths, the order of columns displayed, add or remove the parameters displayed. To permanently save the changes in the table view, save the current view or save the table.

6.3.4. Table view options

The simplest operations during table view editing include: changing column widths and the order of columns. To change column widths, simply grasp, using the mouse button, the division line between the column headers, move it in the desired direction and release the mouse button.

To change the location of a column, grasp the header of the column using the mouse button, drag it to another location in the table and then drop.

6.3.4.1. Editing table parameters

To add or remove parameters in the table, go with the mouse pointer to any table header and click on it with the right mouse button. A context menu will be displayed, as shown on the figure below.

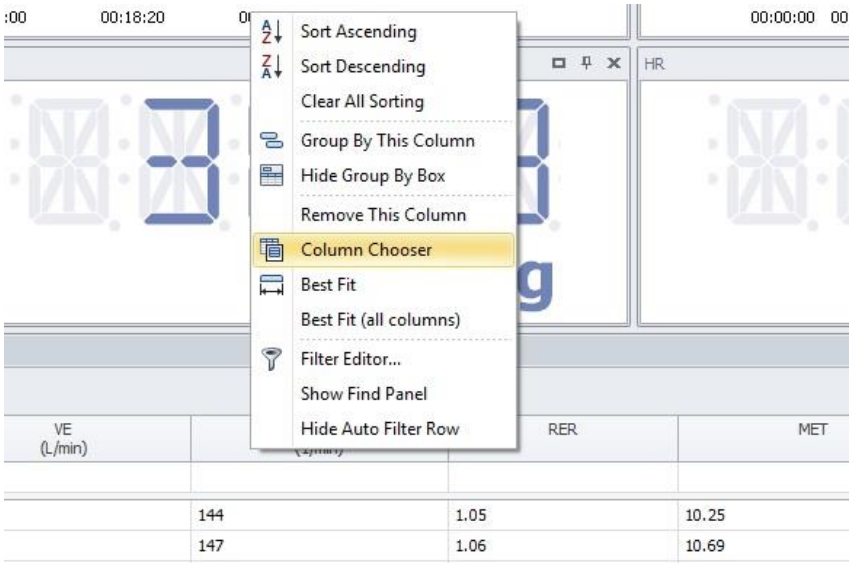

Fig. 23. The context menu of table options

The most important of these options include "Remove This Column", used to delete a parameter, depending on the header clicked on with the right mouse button, and the "Column Chooser" that opens an additional window where new parameters (columns) may be selected

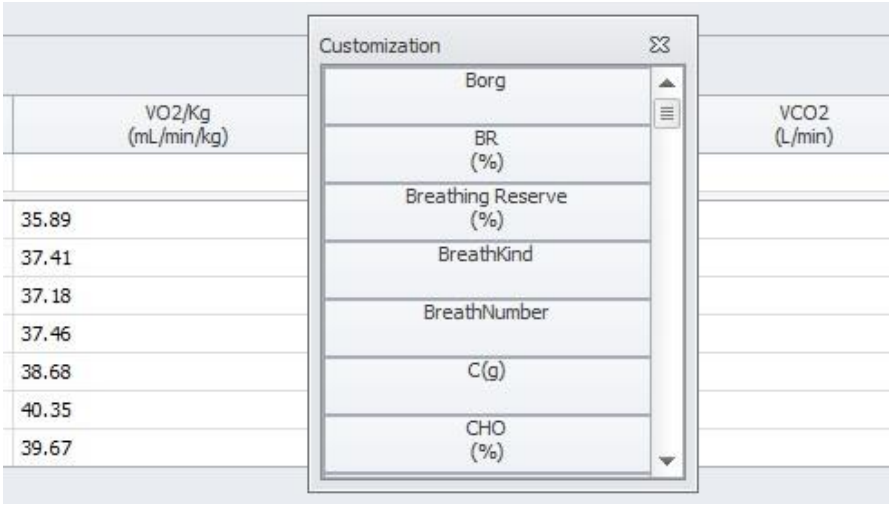

Fig. 24. Dialog box for selecting parameters in the table.

To add a new column to the table, firstly find the desired parameter on the list, then "grasp" it using the mouse button and drag to the appropriate location in the table. A similar step may be taken in the opposite direction when we wish to remove a column. To complete this task, grasp the column header and drag it to the parameter selection window.

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6.3.4.2. Averaging rows in tables and on charts

The program enables the user to display averaged results in the table and on charts to improve legibility and transparency of the examination saved. The averaging function may be set as follows:

- No averaging – the rows in the table are organized "breath by breath". This is the original and basic format of result presentation
- Averaging after time – the program computes a mean value for defined time intervals. The intervals are freely definable by the user
- Averaging for a phase – each row corresponds to the mean value from a single phase, i.e. the number of rows in the table is equal to the number of exercise phases in the protocol
- Averaging for measurement – averaging by the number of breaths. Unlike in the *averaging after time* function, here each row corresponds to a defined value of measurements, regardless of their time (remember that time intervals between breaths are never uniform)

To select the averaging method, click with the mouse button on the table header. Table editing icons will be displayed in the top screen ribbon.

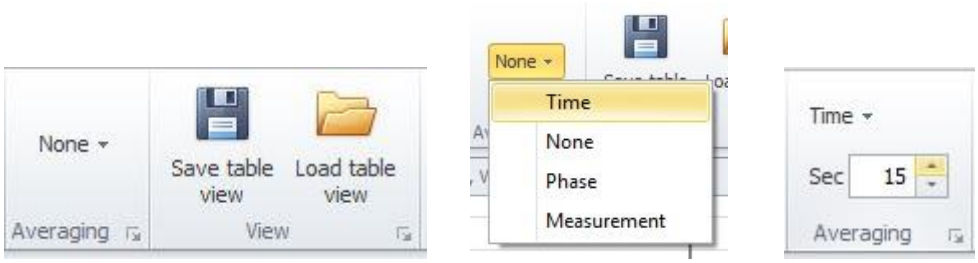

Fig. 25. Averaging a table and saving a table view

Expand the drop-down menu in the "Averaging" section and select the averaging method. If the "Time" option is selected, the user is enabled to freely select the time interval for averaging. Similarly, in the "Measurement" option, the user is enabled to select the number of consecutive breaths covered by the averaging operation.

6.3.4.3. Saving table view

Each table view may be saved for the future as a file. The icon "Save table view" is used for this purpose. The saved view may be used at any time, by clicking on the "Load table view" option. The table layout is saved with the complete screen view, so that the view saving option is also available.

6.3.4.4. Editing and deleting table data

Data may be edited in the table directly, by pointing to a selected cell and changing its value. Remember that not all changed details will be saved, but only those classified as "original" values. If a parameter is calculated as a function of other original parameters, the program will not accept the result of its editing.

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If data for a longer period is to be edited, e.g. heart rate (HR) for a time interval of several minutes, mark the entire range in the column, using the mouse button, and then activate the "Input new value" function available in the top screen ribbon.

Fig. 26. Editing and deleting data

Enter the desired value in the text box and press "Enter". The program will update data in the selected rows within seconds.

Selected rows (e.g. artefacts) may be removed from the table using a similar method. Mark the desired data range in any column and then click on the "Delete selected rows" icon.

6.3.4.5. Exporting a table to external applications

To export a table to another file format (e.g. spreadsheet), open the "File" tab in the top ribbon and click on the "Preview" icon.

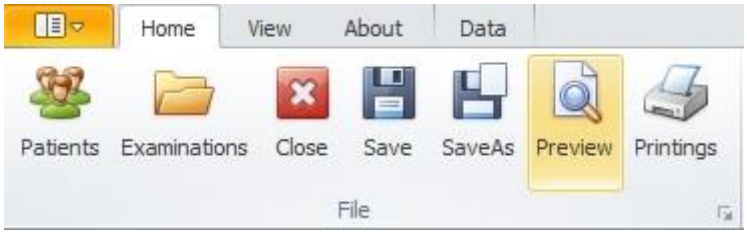

Fig. 27. Table preview

The table preview will be displayed where the user may print the table or use the export function. Click on the green floppy-disk icon for this purpose, as shown on the figure below:

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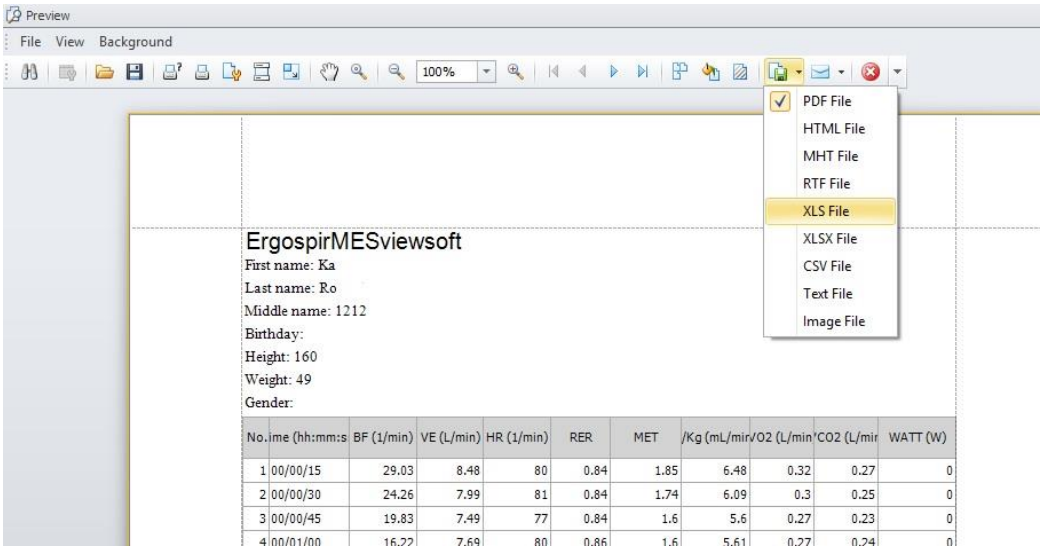

Fig. 28. ***Averaging results in the table*** **dialog box**

A menu will be displayed where the user may select the target file format to save the examination results.

6.4. Find AT / AeT / RCP threshold

The manual method or the automated mode may be used to find those thresholds. Using the first method, the thresholds may be determined in almost all charts in the program, by clicking on a location with the right mouse button and selecting the "Insert threshold..." option". (Fig 31).

The program is capable of automatically identifying the thresholds. Click on any chart or table. The tools for automated examination analysis will be displayed in the top screen section (Fig. 32)

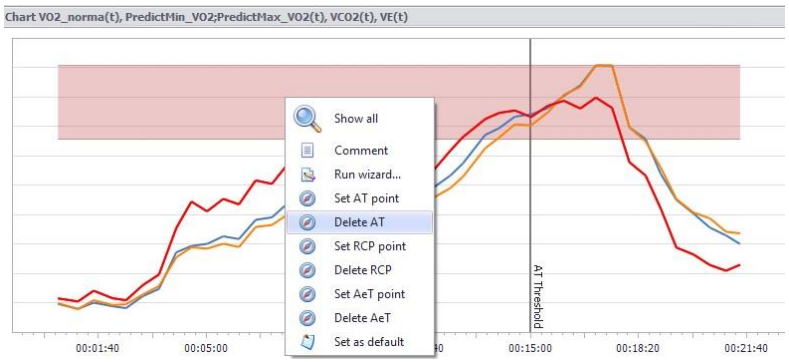

Fig. 31. Manual edition of AT / RCP / AeT thresholds

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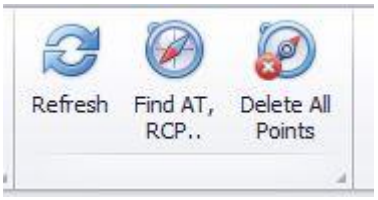

Fig. 32. Threshold and CPET report editing tools

Select the "Find" AT, RCP…. threshold button The program will automatically identify all 3 thresholds, if possible. Please pay attention to use “refresh” button after this action, if You want to have Your CPET report actual.

6.5. Delete the AT / AeT / RCP threshold

To delete the AT or other thresholds, You may use the manual tools (Fig. 31) in the same way as described in chapter 6.4. You may also delete all three thresholds using the tool from chapter 6.4. (fig. 32). To have all changes resulting from table and threshold editing included in the report and CPET calculations, use the "Refresh" icon.

6.6. CPET Report

One of the most popular formats of presentation of ergospirometric examination results is the CPET report. The report contains a set of the most important parameters, calculated based on the examination, defined for its individual stages, such as the rest phase, the moment of reaching the AT threshold or the VO2max.

The results are compared with desirable values calculated based on statistics.

The CPET may be obtained in the program using 2 methods:

- Select the CPET view in the view menu in the "View" tab
- Expand the "Report CPET" tab in the bottom section of the screen

NOTE! Remember to use the "Refresh" function, to have the data contained in the report updated taking into account the most recent changes.

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7. Performing the examination

7.1. Preparing the examination

Checking the device to ensure the correct functioning of all measuring components is a condition necessary to begin an examination. The check is made available as part of the calibration procedure of gas analysers and ventilation measurement system (Section 5.2). We recommend that the device be calibrated prior to beginning a cycle of examinations on each day.

The only command available during the examination is to discontinue the examination (the *Stop* command in the *Examination* menu). This prevents other, incorrect methods of discontinuing work with the program (e.g. closing the program during an examination). The entire examination procedure may be summarized as follows:

1. Complete a check of the device to ensure that people are protected against electric shock, by visually inspecting the condition of all electrical cables.
2. Complete daily service tasks following the instructions contained in Section "Maintenance and daily service".
3. Switch on the device using the mains switch located in the front panel of the device.
4. Leave the device switched on for at least 30 minutes, so that the measuring components can achieve their thermal stability.
5. Run the *VO2 Viewer* program.
6. Complete volume and gas calibrations.
7. Enter patient's data (⇨ Section 4).
8. Select a suitably sized measuring mask for the patient, ensuring tight contact between the mask and the patient's face skin.

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NOTE!

a.) Attach the pneumotachographic head to the mask before it is put on the patient;

b.) Remember that the connection conduit of the pneumotachographic head may not be connected to the head until the process of automated reset of the measuring system is complete;

9. Begin the examination by clicking on the "New examination" icon.
10. Perform the examination in accordance with the description applicable to the examination type.
11. Finalize the examination using the *Stop* button (the button with a red circle). Save the examination.
12. To begin another examination, the user must close the open examination. Proceed as above, starting with item 7. Patient's data refer to the last patient.

NOTE!

a.) The connection conduit of the pneumotachographic head may not be connected to the pneumotachographic head attached to the mask;

b.) The connection conduit of the pneumotachographic head must be removed as far as possible from the mouth of the patient and the operator of the ergospirometer!

c.) Once the reset process is complete, the measuring system proceeds to the control phase and now the connection conduit of the pneumotachographic head is to be connected to the head and the connector in the mask;

7.2. Entering parameters from the spirometry procedure

To enter the parameters from the spirometry procedure most recently performed for the patient, expand the “Patient” tab in the bottom section of the screen. Its contains 4 fields designed to enter values from the spirometry procedure: FVCEX, FEV1, MEF50 and MVV. The data is useful in calculating certain quantities contained in the CPET report.

7.3. Reading an examination from the database

To read and edit results saved in the database, select the "Examinations" button in the top screen ribbon. The program will display a list of all examinations organized by date and time of their performance. One of the columns contains patients' names and is used to easily sort the table by names, by clicking on the header of this column.

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Note: the database enables the user to filter examinations by a specified date range. Default filtering is set to the last 3 months. To view older examinations, activate the filtering function by clicking on the "Date" button and then using the "Refresh" function.

The list of examinations may also be displayed for a single patient, by starting from the “Patients” tab. Mark the patient's name and click on the examination button to obtain a list of examinations performed for this name only.

7.4. Printing the report on examination

The examination results may be printed upon its completion or once the examination has been loaded from the database. To print the report. select the *Printings* command in the *File* menu. The selection and configuration screen for report printouts will be displayed. Its left section contains a list of available report configurations. To print the report, mark one of them and click on the preview button in the bottom section of the screen. A printout preview will be displayed that can be printed using a selected printer.

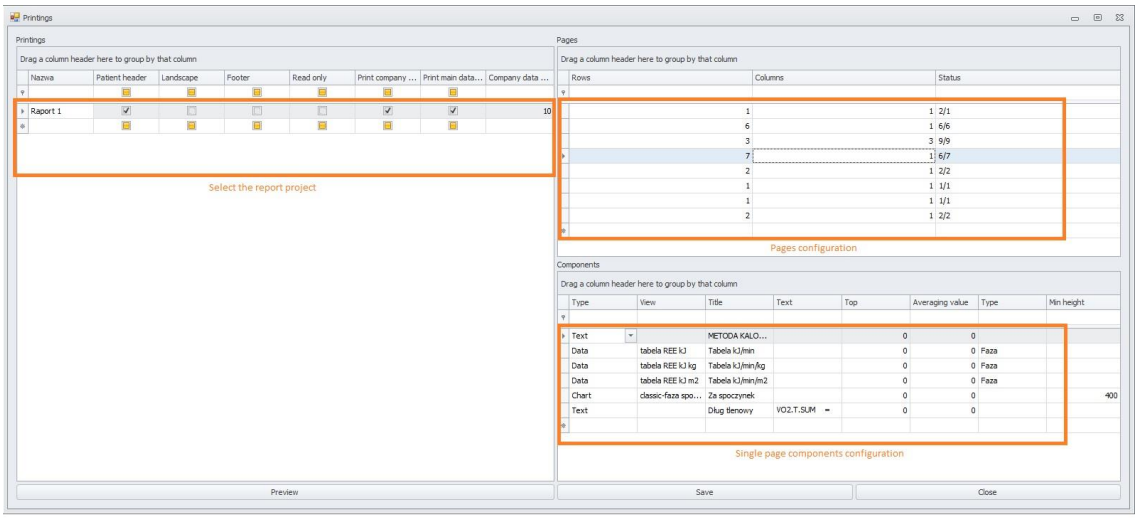

Fig. 34. The ***Printings*** **dialog box**

7.4.1. Printout settings

To add a page to the report, enter an additional row in the “Page” window, defining the division of the page into selected numbers of rows and columns. The number of rows must be selected so as to contain individual components within the page.

The next step is to define the components to be included in the page. Their list is created in the right bottom window of the configuration tool. The number of components must be consistent with the number of rows and columns declared in the "Page" window

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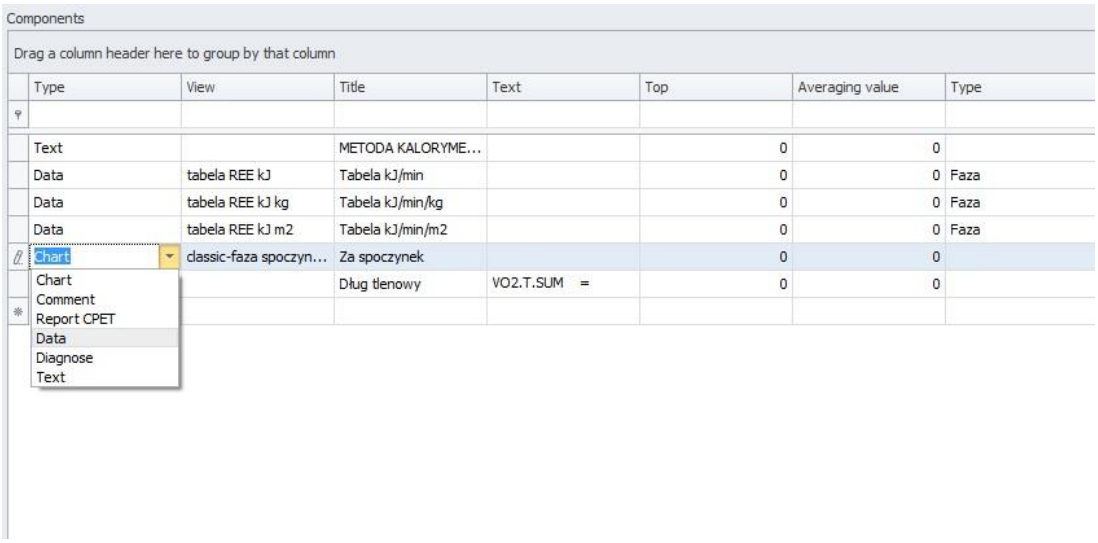

Fig. 35. Selecting printout components

The component type to be inserted must be defined in each consecutive row in the first place. It may include a chart from examination, a table saved as a file, the CPET report or an inserted text fragment.

If a chart is selected, indicate the source of the chart in the "View" column. The drop-down menu includes a list of views saved in the program and charts associated with them.

If "Data" is the selected component, i.e. a result table, the source file with the table must be indicated in the second column. An averaging value may also be defined for the table, other than the averaging value previously defined in the examination.

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8. AT threshold searching criteria

If the user wishes to define an AT threshold, a number of options facilitating this task is offered in the AT threshold determination mode. The first chart makes available an indicator (a vertical line) that may be moved horizontally (along the time axis) using the mouse pointer (the indicator becomes "attached" to the mouse pointer as soon as the pointer is moved to the area of the first window). When the indicator is moved within the exercise phases (two vertical orange lines – only if the grid is displayed), the two regression straight lines change their positions on the second chart. They refer to two data areas. The areas are created by dividing the entire data set in the point marked by the indicator in the first window. The regression lines facilitate the identification of the largest inflection point on the chart of VCO2 as a function of VO2 (a suspected point of the AT threshold). In addition to the regression lines, an indicator (a vertical line) is also drawn in the second window, indicating the point corresponding to the location indicated in the first window. A similar indicator is also drawn in the third window.

8.1. Non-invasive methods for determining the anaerobic threshold

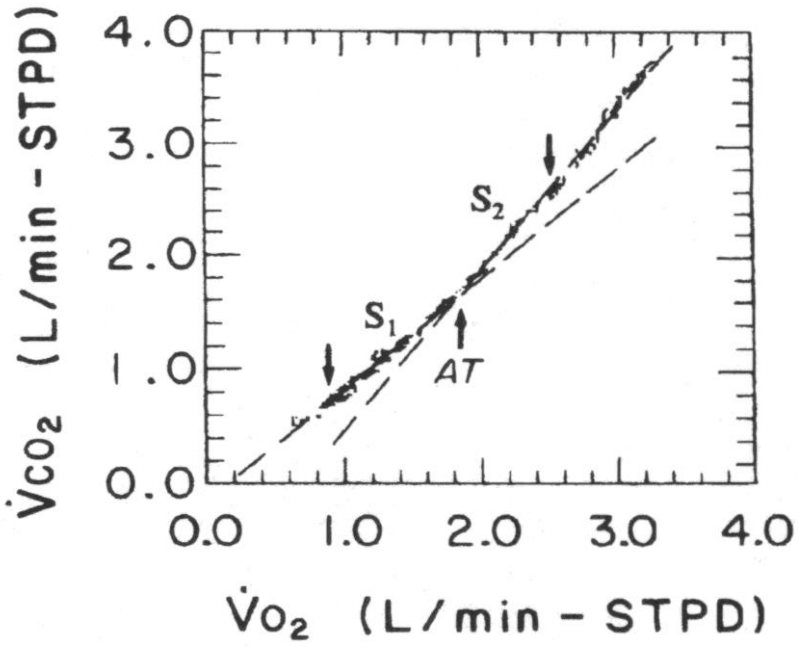
Equivalent method with an additional analysis of final-exhalation oxygen and carbon dioxide pressures

Slope method

VCO2/VO2

It consists in controlling the relation between VCO2 and VO2.

AT is the event of occurrence of such a VO2 value at which the slope increases in the relation curve between VCO2 and VO2 that is relatively linear, and previously, during a graded examination protocol, its slope is indicated by the S1 line (Fig. 2). The examination intensity increases, and consequently the slope also increases in the curve representing the relation between VCO2 and VO2, as marked with the S2 line on Fig. 2.



The double method

To minimize the error in determining AT, use both methods at the same time (the double method), at RQ approximated to 1.

To confirm that the slope change is not accidentally caused by hyperventilation, it is necessary to monitor O2 and CO2 equivalents. Consequently, the ventilation equivalent EQO2 reach their lowest values and then begin to increase in the S1-S2 transition point without any increase in the EQCO2 equivalent. The slope method proposed by Beaver is complex (correlation for CO2 transport changes, at a distance from the lungs, data filtering, mathematical calculations required by a computer analysis), and has been replaced with a simplified method in more conventional systems, The modified slope method defines, consecutively, the point of slope change in the relation between VCO2 and VO2 and determines the VO2 value above which the increase in VCO2 is faster than in VO2, without hyperventilation.

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9. Maintenance and daily service.

1. The masks must always be clean and the mask duct connected to the air conduit must be unobstructed.
2. The masks and pneumotachographic heads should be changed following each examination, so that the patient obtains a sterile mask and head.
3. The masks and mouthpieces may be sterilized using a gas sterilizer or fluids (CIDEX or ALDESAN).
4. The sterilization process in fluids is carried out by immersing the masks for 2 hours, and then carefully rinsing them with distilled water and drying. The drying temperature may not exceed 65 °C
5. Following the sterilization and drying processes, the masks and heads must be checked to ensure that the air ducts are not obstructed.
6. **Earthing and equipotential connections:** VO2max Tracker is an apparatus conforming to the B2 class of electric shock protection. Consequently, no earthing of the apparatus is required, but it may be useful in preventing disturbances originating from the power supply system. The power supply cable is equipped with a neutral conductor (the central terminal in the supply cable socket and plug). If grounding in the power supply system is uncertain, the apparatus may be connected to an earthing system conforming to the IEC standard, using an earthing cable. The earthing cable must be connected to the device using the earthing socket located in the rear panel of the apparatus. **Attention. Earthing cables are not equipotential cables.**
7. **Replacing the fuse.** A 1A 220V 50Hz fuse is located in the drawer socket of the power supply switch in the rear panel of the apparatus. To replace the fuse, disconnect the power supply cable, and then pull out the drawer with the fuse. **Attention. Only fuses with parameters consistent with those given in these instructions may be used.**

NOTE!!!

The recommendations contained above must unconditionally be followed!

A failure to follow the foregoing recommendations may cause damages to the apparatus, lead to erroneous results of performed tests and to infections in the examined patients.

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10. Appendix A

10.1. O2 kinetics analysis

VO2 kinetics, the O2 deficit, O2 debt represent important indicators of tolerance to exercise and of sports achievements. Under "normal" O2 convection and diffusion conditions, supply of oxygen to skeletal muscle fibres does not provide important VO2 kinetics indicators.

Consequently, under "normal" conditions (e.g. normoxia, no obstacles in oxygen supply, no pathological conditions), the factors limiting VO2 kinetics seem to be those located in muscle fibres. Important VO2 kinetics indicators in skeletal muscle fibres probably lay in interactions between various mechanism of energy supply during increasing exertion.

The varying "locations" of the main factors limiting the VO2 kinetics and the VO2max value offer the physiologists of exertion the opportunity to complete non-invasive, functional assessments of the oxidation metabolism at two various levels of paths securing O2 supply, from the atmospheric air to the mitochondria of exercise muscles. In other words, by measuring the VO2max, we assess principally the functional capacity of the cardiac circulatory system in term of supplying O2 to the muscles involved in exercise while the determined VO2 kinetics refer, through a functional assessment, principally to the oxidation mechanism of skeletal muscles. In pathological conditions, the circumstances may be less clear.

It has been confirmed that pulmonary VO2 kinetics are slower (than normal) in patients with documented pathological conditions, such as chronic obstructive pulmonary disease, cardiac embolism, peripheral vascular diseases, type II diabetes, etc. Does it mean that the reduced capability of the lungs, heart, blood vessels of supplying O2 to the muscle involved in exercise may be responsible for O2 kinetics being slower than normal? The answers to those questions are not simple. The proposition that a limited capability of supplying muscles involved in exercise with O2 entails slower VO2 kinetics is confirmed by experiments on patients with acute hypoxia, on patients performing arm exercises, on patients performing leg exercises in a supine position, on patients treated using blockers and others. Under all those conditions, slower pulmonary VO2 kinetics were recorded with an accompanying (or resultant) reduction in O2 supply to the muscles involved in exercise. On the other hand, there is a growing body of evidence that in patients with chronic diseases of the heart, lungs or blood vessels as well as in patients with diabetes, the metabolism in skeletal muscles is changed and plays a key role in determining a reduced tolerance to exercise. All patients with transplanted hearts demonstrate slower pulmonary VO2 kinetics which results from a reduced innervation of the transplanted organ and an accompanying reduced systole frequency and slower cardiac output kinetics.

10.1.1. O2 kinetics in the stress phase

The oxygen consumption in the period from rest to exercise in a steady state may be defined by three phases or states (Figure 1).
Phase 1 may be defined as a metabolic response during the first twenty seconds of an exercise test.
Gaesser and Poole define Phase I as an increase in VO2 caused principally by an augmented cardiac output and pulmonary blood flow. In Phase II, the kinetics is described by the τ time constant that is the time necessary to achieve 63% of Δ VO2 increase in a steady state and is characterized by an exponential rise in VO2 just after the beginning of Phase I. Increased venous return from the exercising muscle as well as continued pulmonary blood flow denote Phase II kinetics. Gaesser and Poole (1996) also suggest that the Phase II kinetic response is relatively constant in the transition from rest to steady state during exercise of light to moderate intensity (below the LT lactate threshold).
Moreover, increased levels of physical fitness (VO2 max) may lead to a faster τ. τ may also be delayed as a result of increased exercise intensity and probably facilitates an oxygen drift.

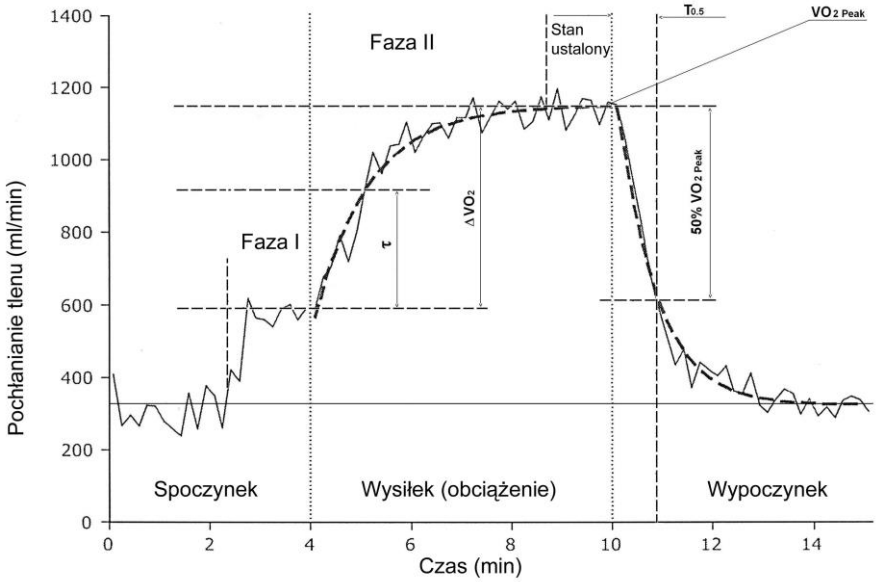

Figure 1.
VO2 response to exercise with a constant workload; the curve in dotted line, generated by the computer, is a representative, best matching, strongly exponential VO2 response model; the first dotted vertical line (t=4min) shows an increase in exertion, the second (t=10min) – the end of exercise and the beginning of the recovery phase

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The response in the second phase (τ) is determined using the following formula:

$$VO2(t) = \Delta VO2 \times (1 - e^{-t/\tau})$$

where VO2(t) represents the VO2 value above the base line increasing at each moment (t);
Δ VO2 represents the difference between the VO2 value in Phase I with a sign in the 20th second and the VO2 value in a steady state (Phase III);
e is a natural logarithm;
τ is the time to achieve 63% of ΔVO2.

The value describing O2 increase kinetics:

τ(63% ΔVO2) - τ is the time to reach 63% of ΔVO2

10.1.2. O2 recovery kinetics

In the recovery phase, VO2 decreases exponentially after gradually increased workload. The half time for VO2 in the recovery phase (T0.5) is 60-80s for normal patients after gradually increased exercise. VO2 kinetics becomes longer with increasing heart disease severity. The patients with a value h a VO2peak< 10-12 ml/kg/min may need 3 minutes to reach VO2 value reduction to 50%. This probably reflects the reconstruction of energy reserve after exercise. The advantage of post-exercise VO2 kinetics results from the fact that the results depend to a limited extent on the intensity level of exercise, and thus a kinetics analysis may also be useful if the test was sub-maximal, i.e. VO2>50% VO2max. VO2 kinetics may be used to analyse and assess the degree of circulation disorders. The normal value of VO2 at a low VO2 peak value suggests sub-maximal exercise. The half time for VO2 in the recovery phase is important for medical prognoses.

Values describing recovery O2 kinetics:

T0,5VO2peak	(s)	time to reach 50% VO2peak in the recovery phase
τ(63% ΔVO2)	(s)	a time constant of the oxygen consumption increase curve during exercise with a constant workload, for which the increase in VO2 value reached 63% of the VO2max value

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10.1.3. Calculating O2 deficit and debt

The oxygen deficit is defined as the difference between the total energy costs of work, understood as required during the exercise period in a steady state, and the measured portion of total energy output that took place during the exercise period at aerobic energy production. The deficit may be directly associated with the VO2 steady state. Therefore, if the steady state is reached sooner, the identified oxygen deficit is lower.

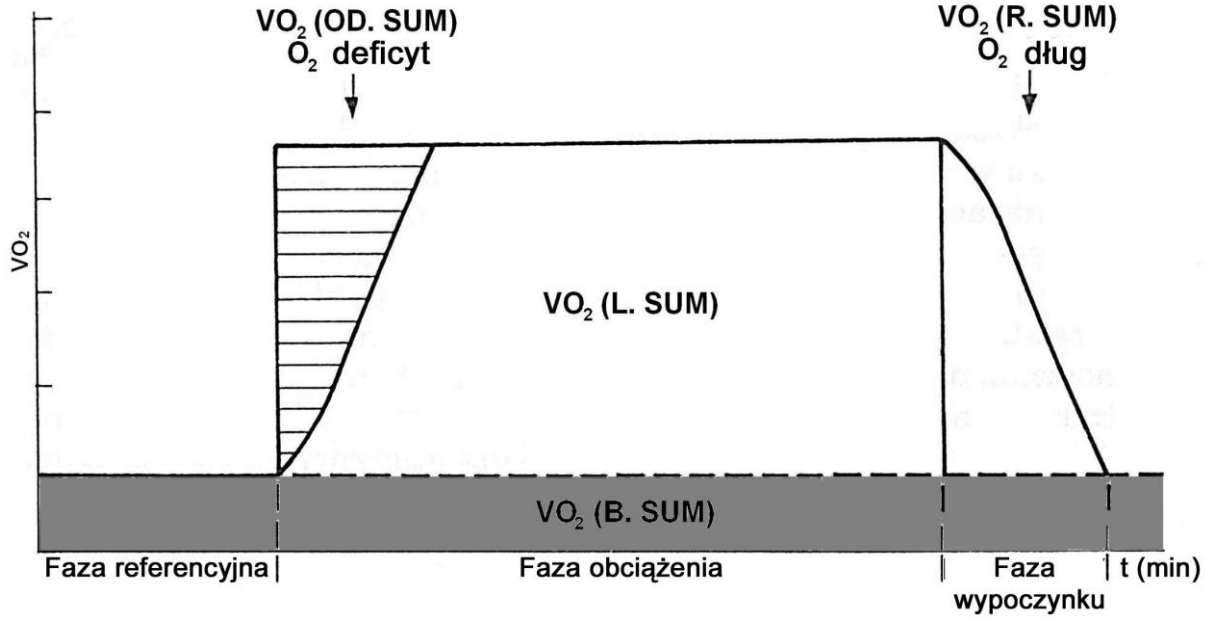

Figure II

Oxygen deficit and debt during exercise with a constant workload below the anaerobic threshold (AT)

VO2.T.SUM [L] ⇒ the total volume of oxygen during the entire test (gross);

VO2.OD.SUM [L] ⇒ the total of accumulated oxygen deficits: the difference between the O2 consumption product in a steady state during exercise and the total current oxygen uptake by the body during exercise

VO2.L.SUM [L] ⇒ the total volume of oxygen consumed during the exercise phases (net);

VO2.R.SUM [L] ⇒ the volume of oxygen used in the recovery phase (net);

VO2.A.SUM [L] ⇒ **VO2.A.SUM = VO2.OD.SUM - VO2.R.SUM** – the total of anaerobic oxygen consumption**;**

VO2.B.SUM [L] ⇒ the volume of oxygen consumed in the test, calculated at the level of consumption from the reference phase (tare);

VE.B.SUM [L] ⇒ the total volume of breaths during the test calculated at the reference phase level (tare);

VE.T.SUM [L] ⇒ the total volume of breaths in the entire test (gross);

VE.L.SUM [L] ⇒ the total volume of breaths in the exercise phases (net);

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VE.R.SUM [L] $\Rightarrow$ the total volume of breaths in the recovery phase (net);

10.2. Basic recommendations for the optimum selection and preparation of rooms for ergospirometric examinations

- minimum room area 16 m2
- a well ventilated room with a stable temperature throughout the year (air conditioning)
- floor finished with an anti-static material, easy to clean and not slippery
- power supply with a good earthing system or secure equipotential bonding, suitable for installing loads of 3-8kW (such as treadmills, bike ergometers)
- the best solution is to equip the room with a three-phase wiring system 3 x 400V/20A (but only if equipment that requires this type of power supply is to be purchased)
- a room with a defibrillator and a couch (may be located in an adjacent room)
- a good practice is to use 2-3 communicated rooms (a small cloakroom with a shower, or at least a washing basin and a toilet, and a room with a couch)
- door width even up to 140 cm to facilitate equipment transportation to the room
- room location at the lowest level possible, preferably at the ”0” level to ensure easy transport from the outside, in particular for disabled people, and to facilitate equipment supplies for exercise examinations
- minimum room height 300 cm