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# COMPUTER ASSISTED ERGOSPIROMETRY IN EVALUATING LIMITING FACTORS OF PHYSICAL PERFORMANCE

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Reliable informations about the functional capacity of the cardiopulmonary system can only be obtained from quantified stress testing. In sportsmedicine the diagnostic considerations will be confronted with challenging problems: we need not quantify the physical performance of the diseased patient (coronary heart disease, chronic obstructive lung disease, hypertension ect.), but we have to rule out any limitation of physical performance in healthy and trained people at various stages of physical fitness and age. Methodological aspects of stress testing must vary with regard to the problem and question raised for solution. The cardiologist will be more interested in the exercise ECG and in data concerning the pump function of the heart and the pre- and afterload. The pulmonary internist will put more emphasis on investigating the work of breathing (ventilation) and the efficacy of gas exchange (respiration).

## METHODS

We have designed a comprehensive diagnostic system for non-steady-state-exercise to quantify limiting factors of physical performance by a single test procedure: rectangular-triangular bicycle ergometry (2-min increment test). Besides ordinary parameters such as heart rate, blood pressure, ECG, work load and subjective symptoms (perceived exertion rate, angina pectoris rate score, dyspnea) non-invasive ergospirometric parameters of ventilation (tidal volume, respiratory frequency, minute ventilation volume, exspiratory flow rate) and respiration (oxygen uptake, alveolar ventilation, functional dead space ventilation ratio) and blood gas analysis (gas tension, base excess) will contribute in quantifying the physical performance in health and diseased states (cardiopulmonary-metabolic capacity).

By means of a computer system (Ergopneumotest mit EDV, Jäger, Wûrzburg, BRD) we compare selected parameters (heart rate, minute

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ventilation volume, oxygen-uptake at 1st and 2nd minute per load, expiratory flow rate) with reference data. Derived parameters of aerobic and anaerobic power (adaptation to increasing work rates, anaerobic power, anaerobic threshold, alveolar ventilation) are calculated on-line and documented graphically and (or) via key-board printer. The method of computer assisted ergospirometric stress testing has been fully described elsewhere [3, 4].

In Fig. 1 is given the computer plot of ergospirometric data available every 30 second and the graphical display of derived parameters, which are assessed intermittendly: analysis of end-expiratory gas tension of oxygen and carbon dioxide to calculate alveolar ventilation ($\dot{V}_A$; crosses below the $\dot{V}_E$-line) and the on-line calculated index of anaerobic power (crosses below the Watt-line; concerning the columnar diagram the anaerobic power is represented by the black part of columns indicating the total amount of energy (aerobic and anaerobic power) to perform the work. Any parameter is stored on a magnetic disc during the test to enable off-line analysis of correlation between variables such as $\dot{V}_E$ versus $\dot{V}_{O_2}$ (code 3), $\dot{V}_E$ versus $\dot{V}_{CO_2}$ (code 2), heart rate (fh) versus $\dot{V}_{O_2}$ (code 4), exspiratory flow rate ($\dot{V}$) versus tidal volume (VT) and minute ventilation volume (code 5 and 6).

## DIAGNOSTIC IMPLICATIONS

### 1. Cardiological aspects in ergospirometric stress testing.

The (maximal) oxygen uptake (aerobic power) is related directly to the cardiac output and the oxygen transport capacity of the blood. When assessed during short time intervals (15, 30 seconds) of non-steady-state-exercise the analysis of oxygen uptake leads to the calculation of derived parameters.

The *adaptation* to increasing work rates — in other words the adjustement of cardiac output — will be assessed semiquantitatively by rating the oxygen uptake at the first minute per load with regard to the deviation from the reference values [1, 3].

The *anaerobic power* of the working muscle is assessed by rating the energy supply provided for by oxygen uptake with regard to the work output (= energy that is not accounted for by reactions involving the $\dot{V}_{O_2}$ measured is computed by substracting the caloric equivalent of oxygen uptake during work exceeeding the steady-state level during rest from the energy demand to sustain a given load aerobically). This index of anaerobic power is defined in kcal, cal/kg b.w., and as a percentage of the total amount of energy required: moderately trained athletes 350-500 cal/kg; sedentary people 200-300 cal/kg) [3]. A graphical display of the distribution of aerobic-anaerobic power compartments is presented by the columnal diagram (s. Fig. 1).

This on-line calculated index leads to quantifying the anaerobic power by means of ergospirometric stress testing. Besides a known quantity of the anaerobic compartment exceeding 30 % is indicating a low output syndrom (hypodynamic circulation). Therefore the findings of an adequate adaptation and of an anaerobic compartment normally related to the work performed will rule out any abnormal myocardial pumpfunction, if the symptom of dyspnea is absent [4].

The *anaerobic threshold* (defined in l/min $\dot{V}_{O_2}$ and in percentage of $\dot{V}_{O_2}$ max) represents the most important parameters of endurance performance indicating the highest achievable oxydative rate of the working muscle [4, 6]. This threshold is assessed routinely by plotting the paired $\dot{V}_{O_2}$ - $\dot{V}_E$ — data in a rectangular coordinate system (s. Fig. 1, code 3). The anaerobic threshold is indicated by a changing of the linear relationship of delta $\dot{V}_{O_2}/\dot{V}_E$ caused by the onset of hyperventilation due to acidemia (lactate, metabolic acidosis). In defining the anaerobic threshold the data obtained by this procedure correlate very well with data obtained from relating $\dot{V}_{O_2}$ to the onset of metabolic acidosis (base excess, lactate) [2]. See Fig. 2.

## 2. Pulmonary aspects in ergospirometric stress testing.

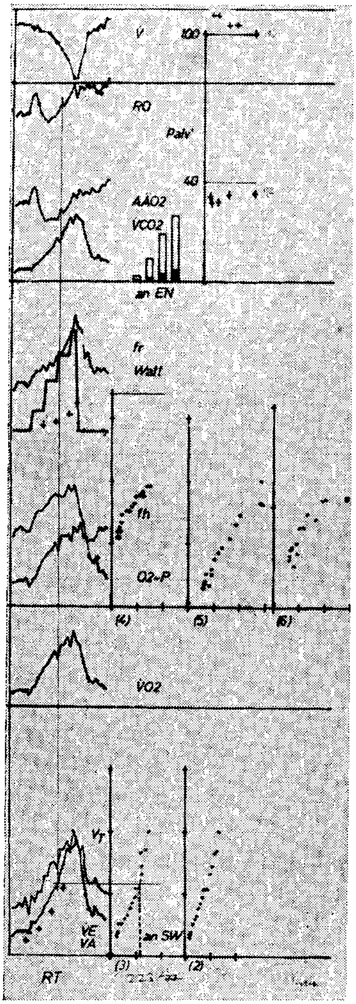
The lungs are never a limiting factor of physical performance, unless symptoms of disordered lung function still exist [5]. Discussing pulmonic aspects the ergospirometric data (tital volume, minute ventilation volume, espiratory flow rate) shoud be compared with findings in standard tests of lung function analysis, such as spirometry, flow-volume-curve and bodyplethysmography.

We compare the exspiratory flow rates during exercise to the flow data at 50 % of the forced exspired vital capacity to realize, whether there is any reduced flow reserve (= difference less than 1 l/sec).

As we have found a linear relationship between expiratory flow rates and minute ventilation volume during work (s. Fig. 3), it is likely to estimate the maximally tolerable $\dot{V}_E$ from flow-rates of the flow-volume-curve in diseaded states (small airways disease, obstructive lungs disease, emphysema).

Endexspiratory gas samples are assessed intermittendly (Alveo-test, Jäger) to calculate alveolar gas tensions (palv' $O_2$, $CO_2$), the alveolar ventilation ($\dot{V}_A$, s. Fig. 1) and the functional dead-space ventilation ratio (VD/VT). As the minute ventilation is rated by the computer (comparison to reference data) any hyperventilation will be assessed quantitatively. The calculation of the $V_D/V_T$ ratio will contribute in differentiating between dead-space and alveolar hyperventilation.

FIG. 1. - On-line and off-line analysis of ergospirometric parameters.



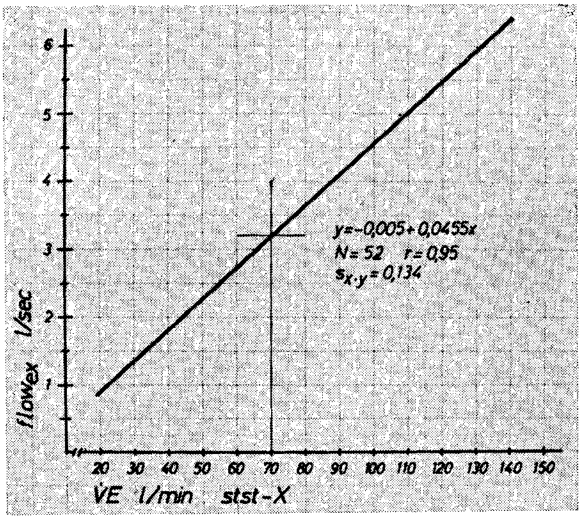




FIG. 3. - Relationship between expiratory flow rate and minute ventilation volume in healthy young men.

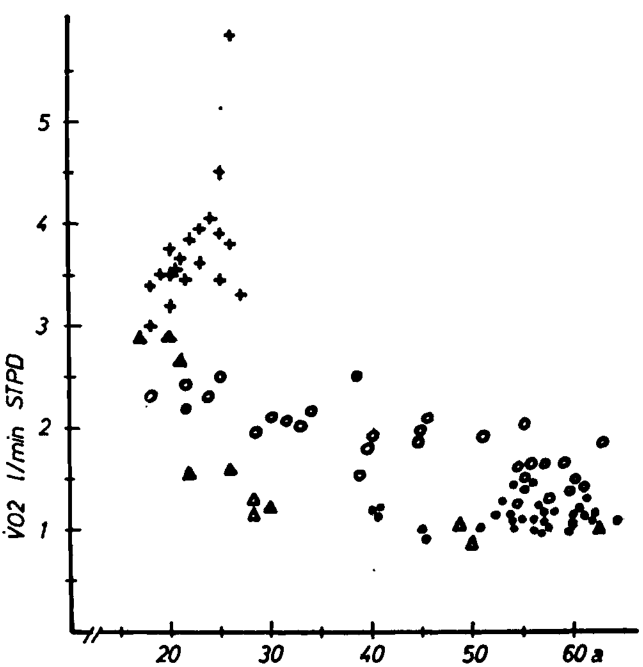



FIG. 2. - Anaerobic threshold in normal person (○ = male; △ = female), athlete (+ = long distance skiing, male; ▲ = = rowing, female) and patients with coronary heart disease (●, male) defined in l/min oxygen uptake (graphical analysis of paired $\dot{V}_{O_2}$-VE date during non-steady-state-exercise). (Lit. 4).

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