Short communication

A comparative study on different methods for the determination of energy expenditure

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Received August 5 / Accepted October 3, 1989

Summary. In order to determine energy expenditure, the Douglas Bag technique (DB) and Kofranyi-Michaelis respirometers (KM) have been widely used under field conditions for several decades. Some years ago the Oxylog (OX) method was developed, measuring simultaneously the difference of partial oxygen pressure in inspired and expired air (PO$_2$ diff.) by two polarographic oxygen sensors. In order to compare these three methods laboratory experiments (3 test subjects, 5 different bicycle ergometer work loads, 180 measurements per apparatus) were performed. Oxygen uptake (VO$_2$) varied between about 0.9 to 3.0 l/min. The VO$_2$ data obtained by the DB method, which were used as a reference, and those obtained by the KM method agreed fairly well. The recorded data of OX underestimated VO$_2$ up to 21%, with the deviation increasing with work intensity. A sufficient accuracy of recorded VO$_2$ was observed only up to moderate work intensity. OX data calculated from ventilation volume of inspired air per minute (VI) and PO$_2$ diff., measured by OX, were always about 19% higher than those recorded by OX. This means that the calculated VO$_2$ values of the OX corresponded fairly well with DB values at heavy work loads. The reason for the differences between recorded and calculated OX data is still unknown. Further research is urgently needed.

Key words: Energy expenditure – Douglas Bag – Kofranyi-Michaelis respirometer – Oxylog

Introduction

Different methods of indirect calorimetry are used to evaluate energy expenditure. The standard method, the Douglas Bag technique (DB) using a wet gas-meter needs a separate analysis of expired air by physical or chemical methods. The same applies to the portable Kofranyi-Michaelis respirometer (KM). Therefore the Oxylog (OX) was introduced [Humphrey and Wolff 1977] as a portable instrument, measuring ventilation volume of inspired air per minute (VI) as well as the difference of partial pressure of oxygen between inspired and expired air (PO$_2$ diff.) by means of two polarographic oxygen sensors. The manufacturer describes a measurement range of oxygen uptake (VO$_2$) from 0.25 to 3.00 l/min and for ventilation from 6 to 80 l/min. The purpose of the present laboratory study is to compare these three methods for measuring energy expenditure.

Subjects and methods

Three well trained sportsmen served as test subjects (aged 32, 28, and 22 years, weighing 67, 63, and 82 kg, with a height of 176, 178, and 186 cm). They worked on a Monark bicycle ergometer at work rates of 60, 90, 120, 150, and 180 W. Tests (n = 36) were performed at each working rate.

In order to counterbalance possible effects of fatigue and training respectively, we used a 3 × 3 Latin Square design with three tests for each subject in the morning and another three tests in the afternoon. Every experiment started with a working period of 4 min to reach steady-state conditions. After the fifth minute with mouthpiece and noseclip, measurements were made by using the three methods successively, each for 3 min (60, 90 W) or 2 min (120, 150, 180 W) at continuous work. The sequence of the gasmeters was determined by the Latin Square respectively.

Because a slack seat around the nose and chin of the original face mask of the Oxylog (Stimotron M.G., Type B, Serial No. 375) was observed, we used a respiratory valve with a mouthpiece manufactured in our institute. The OX-flowmeter was connected with the inspiratory side of the respiratory valve. The volume measurement of this system was calibrated by means of a modified 220-liter Tissot spirometer, described in detail elsewhere. The correction factor (CF) for the OX was found to be 1.03. This mechanical calibration was additionally checked by biological calibration: After connecting the OX-
flowmeter with the valve of the modified Tissot spirometer, the inspired air of the subject was taken from the spirometer. A slight overestimation of volume by OX between 1 and 4% was observed at work rates of 90, 120, and 150 W by using the CF of 1.03.

To calculating VO₂ by OX, a relative humidity (RH) of 50% and a respiratory quotient (RQ) of 1 were assumed. RH was measured during experiments in the range from 35 to 60%, corresponding to negligible mistakes in calculating VO₂ up to 0.5%. RQ varied from 0.76 to 1.00, causing a maximal underestimation of VO₂ of 4%. The oxygen sensors of OX were corrected to the actual barometric pressures every hour during experiments. The OX oxygen measurements were checked by test gases. Within a range from 14 to 21% oxygen concentration, the maximal relative mistake reached 1.5%, when using a paramagnetic oxygen analysator (Servomex) as reference method. The recorded VO₂ data of the OX were corrected to STPD conditions. Additionally we calculated the VO₂ by V₁, recorded by OX and corrected to STPD conditions, and oxygen difference, calculated by recorded PO₂ divided by the actual barometric pressure.

The KM (CF = 1.00) and the wet gasmeter (Elster and Co, A.-G.) of the DB system (CF = 0.98) were also calibrated by means of the modified Tissot spirometer. During all experiments each gasmeter was placed next to the subject or carried by an investigator. Expired air was analysed by Servomex and by UNOR (infrared carbon dioxide analysator), respectively. Both methods were regularly checked by the Scholander technique. In order to make sure that steady-state conditions existed during experiments, heart rate was continuously recorded from ECG by a Siemens telemetric system.

To compare arithmetical means Student's two-tailed t-test for not banded samples was used. A level of P < 0.05 was considered to be statistically significant.

Results

Figure 1 shows the relationship between VO₂ data measured by the three methods. The results obtained from KM non-significantly underestimated the DB values by 2.5 to 3% at 60 and 90 W. They resulted in a significant underestimation of 6 to 7% at 120 to 180 W. The recorded data obtained from OX were significantly smaller than those of DB. The deviations increased with work intensity from 7.6 to 21.0%. Contrary to this observation, calculated VO₂ always exceeded the recorded OX values significantly by about 19%.

Ventilation volume of expired air per minute (V̇ₑ) of KM was significantly lower (9–12%) than V̇ₑ from experiments with DB. Ventilation data of OX (V̇₁) were significantly lower (6–15%) than those of DB (V̇ₑ), with the difference depending on work intensity.

True oxygen derived from KM measurements was significantly higher (4–8% rel.) than those of DB. The oxygen difference, calculated from recorded PO₂ diff. of OX, was significantly higher (14–23% rel.) than true oxygen obtained from DB measurements.

Discussion

When using the KM, smaller V̇ₑ data were obtained, caused by a breathing resistance which exceeded the resistance of the DB-system [Hermansen et al. 1972]. True oxygen was higher for compensation. At V̇ₑ of more than 60 l/min, an increasing inaccuracy of KM was found [Consolatio 1971]. In field studies, however, KM might be considered as a suitable instrument even for studies at heavy physical work. The upper limit for measurements by KM amounts to about 100 l/min V̇ₑ [Montoye et al. 1958]. Such values were not reached in the present experiments.

![Fig.1. Comparison of oxygen uptake determined by the Douglas bag method, the Kofranyi-Michaelis respirometer and the Oxylog](image-url)