Reliability and Validity of the Maximal Anaerobic Running Test

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Physically active men (n = 13) twice performed the Maximal Anaerobic Running Test (MART) on a treadmill and once the Wingate Anaerobic Test (WAnT) on a cycle ergometer. The MART consisted of n · 20-s runs with 100-s recovery between the runs. The speed of the first run was 14.6 km · h^{-1} and the inclination 4°. Thereafter, the speed was increased by 1.37 km · h^{-1} every run until exhaustion. During all tests oxygen uptake was measured breath-by-breath and blood samples were taken from the fingertip 40 s after each run to determine the lactate concentration (BLa). Power at submaximal BLa levels and maximal power (P_{5mM}, P_{10mM} and P_{max}, respectively) were calculated and P was expressed as the oxygen demand of running according to the American College of Sports Medicine equation. In the MART the P_{max} was 108 ml · kg^{-1} · min^{-1} and peak BLa was 15.6 mM. The reliability for the power indices in the MART were as follows: $r = 0.92$ ($p < 0.001$) for P_{max}, $r = 0.80$ ($p < 0.001$) for P_{10mM} and $r = 0.67$ ($p = 0.01$) for P_{5mM}. The average contribution of anaerobic energy expenditure was calculated to be 68 % but it ranged from 64 % to 72 % during the MART. Although four out of seven of the correlations between the corresponding variables of the MART and WAnT were significant ($0.52 < r < 0.59$) they were not high. It is concluded that the anaerobic energy production is high in the MART, the test is reliable, and that the treadmill and cycle ergometer test measure slightly different qualities.

Key words: Anaerobic capacity, anaerobic power, Wingate, blood lactate, reliability, validity, O_2 deficit

Introduction

There are many kinds of anaerobic tests which measure the anaerobic power and capacity: the Margaria staircase running test (17), vertical jump tests (6,14), treadmill tests (11,19,24, 25), cycle ergometer tests (3,4,7,8,9,15,26), standing long jump and isokinetic tests (5,15,16,26). The reliability indices of these tests are quite satisfying with coefficients ranging for the power tests from 0.85 to 0.98 (3,26), for the constant load test around 0.77 (26) and for the Wingate Anaerobic Test (WAnT) from 0.89 to 0.98 (9,21). Concerning the validity different authors have concluded that no single best test exists which measures all determinants of anaerobic performance (5,16, 26).

A new Maximal Anaerobic Running Test (MART) was developed (22) to give a more comprehensive description of the energetic and neuromuscular determinants of maximal anaerobic performance. The MART consists of n · 20-s runs with a 100-s recovery on a treadmill. The speed of the treadmill is increased progressively until volitional exhaustion. In the MART the power at exhaustion, expressed as oxygen demand, describes the anaerobic work capacity of an athlete. On the other hand the power at submaximal lactate levels, also expressed as oxygen demand, was suggested to describe the sprinting economy of an athlete. In addition, the peak blood lactate concentration in the MART is used as an index of anaerobic capacity.

The reason for the development of the MART was that previous anaerobic tests do not determine all the important components of anaerobic performance (22,26). The results of the MART include information on the anaerobic work capacity, sprinting economy as well as power and fatigue of the force generation of the leg muscles. Furthermore, the submaximal power indices are expected to be useful in the prescription of training for sprint athletes such as the so-called aerobic-anaerobic thresholds used in endurance sports.

The purpose of this study was to establish the reliability and validity of the variables in the MART. The research hypotheses in the study were as follows:
(1) first and second trials of the MART give similar results on all variables;
(2) energy during the MART is primarily yielded by anaerobic processes;
(3) there are high correlations between the corresponding variables of the MART and the WAnT.

Material and Methods

Thirteen healthy physically active men with a wide range of sport activities (e.g. soccer, tennis, squash, badminton, karate, track and field, orienteering, basketball and weight lifting) were studied during 3 weeks. Their age, height and weight

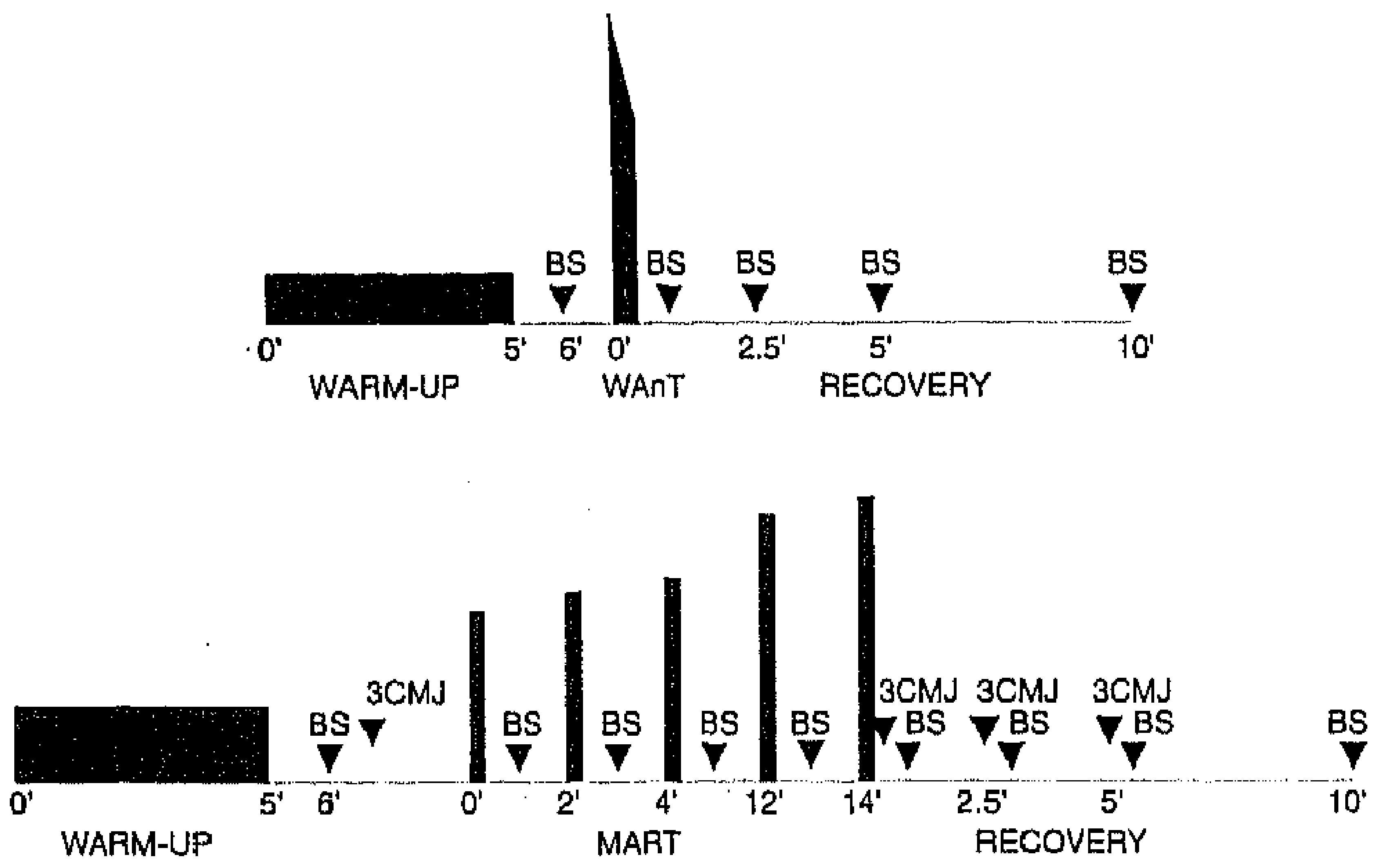

Fig. 1 Schematic presentation of the Wingate test (WAnT) and the MART protocol. Abbreviations: BS = blood sample; CMJ = counter-movement jump

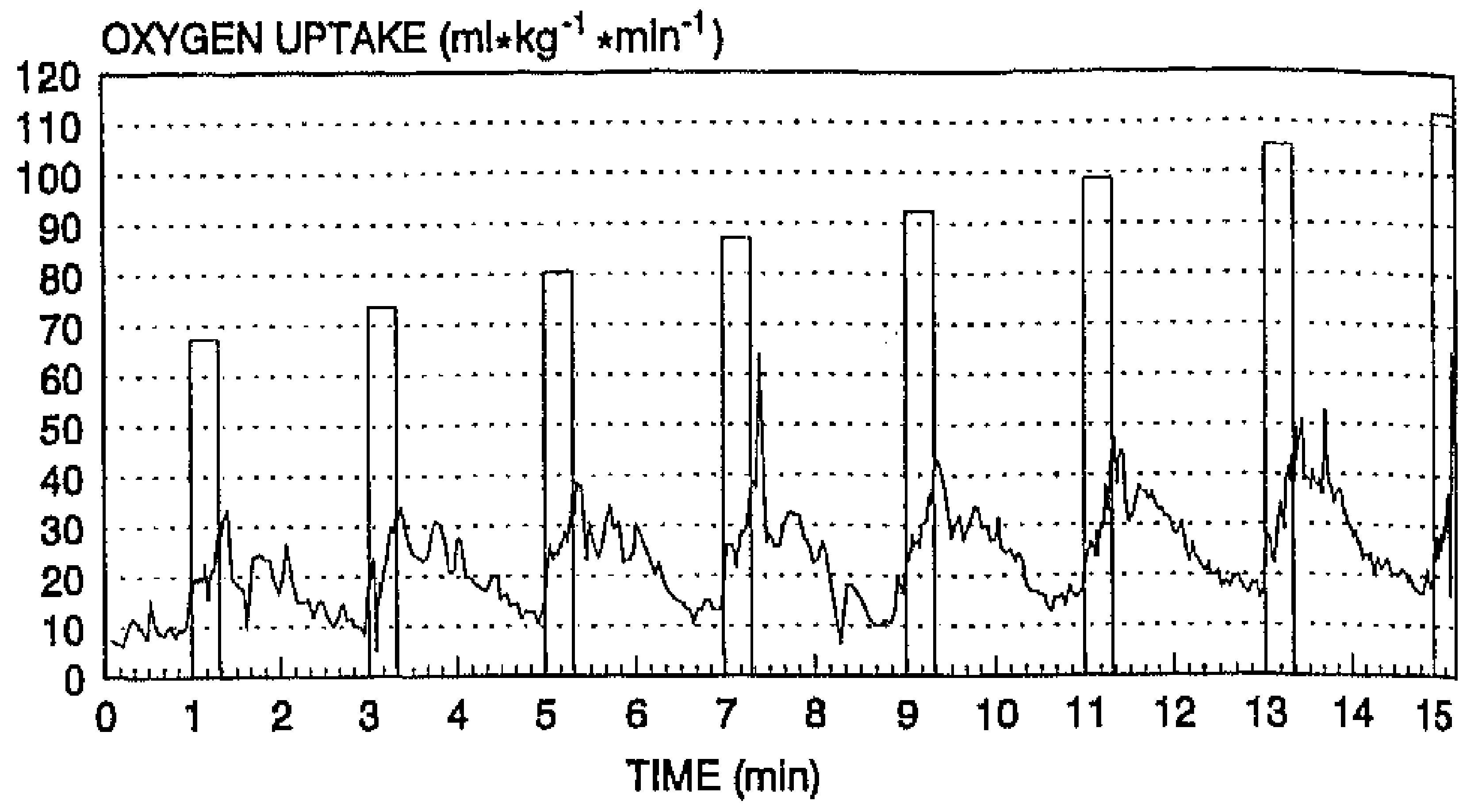

Fig. 2 Oxygen uptake curve of one subject during the MART. The bars in the figure describe oxygen demand of the runs.

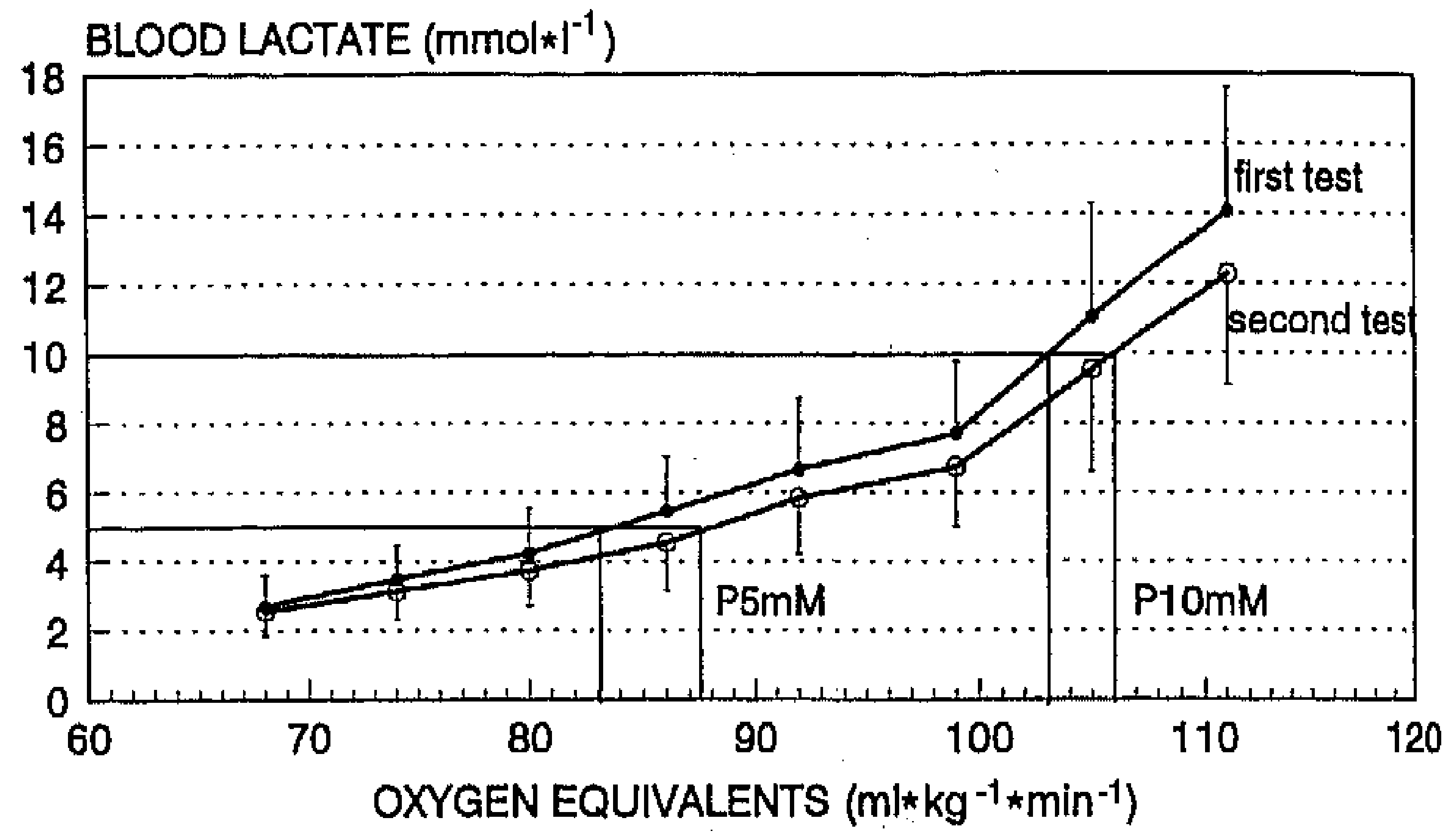

Fig. 3 Average blood lactate curve of the first and the second MART. The determination of P_{5mM} and P_{10mM} is also shown in the figure.

were 24.9±3.4 years, 177.3±4.1 cm, 70.7±5.8 kg, respectively. The subjects gave their informed consent before the tests were started. They all performed the MART twice and the WAnT once. In addition, two subjects performed the third MART trial without oxygen uptake measurements to find out the influence of the O_2 uptake measurements on the test results, because the MART is usually done without O_2 uptake measurements. The tests were done in a random order with at least 48 h between each test.

Protocol MART (Fig. 1)

Before the test, counter-movement jumps (CMJ) were practiced. The subjects performed a standardized warming up of 5 min running on the treadmill with a speed of 8.1 km · h^{-1} and at 0° inclination followed by a 2-min rest period (18). After a 1-min rest period, a blood sample was taken and resting blood lactate concentration was analyzed (Boehringer Mannheim). After the rest period the subject performed three maximal vertical jumps with a preparatory counter-movement with a 10-s interval on a contact mat (14). The flight time was recorded automatically.

Each run lasted 20 s, excluding a 5-s acceleration phase, and was followed by a 100-s rest period, during which after the 40th s a blood sample was taken. The initial speed was 14.6 km · h^{-1} and was increased by 1.37 km · h^{-1} every run until exhaustion. The inclination was 4° during the whole procedure. A harness connected to an emergency break was used to ensure the safety of the subjects. Strong vocal encouragement was given during the last few runs. The treadmill and the stopwatch were stopped when the subject could no longer run at the speed of the treadmill. Immediately after exhaustion, at 2.5 min and at 5 min three CMJs were performed and a blood sample was taken. The last blood sample was taken at 10 min after exhaustion.

Oxygen uptake ($\dot{V}O_2$) was measured breath-by-breath starting 1 min before the first run and continuing during the whole test (Fig. 2). Respiratory parameters were measured using an open system (Sensormedics 2900Z). Pulmonary ventilation expressed at standard temperature, pressure and saturation (STPD) was measured using a mass flow sensor calibrated every new test day by a mechanical pump. Oxygen concentration was measured by a thermal analyzer (zircon cell) and CO_2 concentration by an infrared analyzer and the analyzers were checked before and after every test by calibration gas mixture of known concentration. Before each series of measurements, the linearity of both analyzers was checked.

Running power, in oxygen equivalents, was calculated according to the ACSM formula for inclined treadmill running: $\dot{V}O_2 = 0.2 \cdot v + \text{grade} \cdot 0.9 \cdot v + 3.5$, where $\dot{V}O_2$ = oxygen demand (ml · kg^{-1} · min^{-1}); v = speed of the treadmill (m · min^{-1}); grade = inclination of the treadmill (fraction) and 3.5 = oxygen uptake at rest (ml · kg^{-1} · min^{-1}) (1). Although the formula only applies to submaximal intensities it was assumed that a linear extrapolation to higher intensities was justified.

P_{max} was calculated from the power of the last completed 20-s run and from the exhaustion time of the following faster run (22). P_{10mM} and P_{5mM} were calculated from the lactate-power curve as shown in Fig. 3. The height of rise of the center of gravity in the CMJ was calculated in meters by the formula: $H = g \cdot t^2 \cdot 8^{-1}$, where t is the recorded flight time in seconds. The average of the two highest CMJs was chosen for further calculations. The CMJ decrease was calculated as the percentage decrease of the CMJ during the MART. Oxygen deficit was calculated as net oxygen demand minus net oxygen uptake. The last completed run of each subject was used for the oxygen deficit calculation. The net oxygen demand and net oxygen uptake were determined for each individual assuming a resting oxygen uptake of 3.5 ml · kg^{-1} · min^{-1} (1). The percentages of aerobic and anaerobic contributions were calculated from the net oxygen uptake and the net oxygen demand values.

Protocol Wingate Anaerobic Test (Fig. 1)

Monark ergometer and sensor optical system connected to the computer program (SMI Power Version 1.02, St. Cloud, USA) was the basic equipment used for all the bicycle tests. The precision of the sensor in measuring revolutions per minute (rpm) as a function of 16 markers and a flywheel speed of 400 rpm was ±0.5 %.

A 5-min warm-up procedure adjusted for body weight (150 W or 2.2 kp at 70 rpm for 75 kg) was followed by a 2-min resting period (18). After 1 min rest a blood sample was taken. The load was set on 0.0872 kp · kg^{-1}, and equalled 5.13 J · rev^{-1} · kg^{-1} (9, 21). The subjects were told to start pedalling as fast as possible from the first second on. A flying start was used so that the acceleration phase (3 s) was not used in the calculations. Strong vocal encouragement was given throughout the test. For their own convenience the subjects were allowed to pedal for a few minutes at a low intensity after the test, the oxygen mask was taken off and blood samples were taken at 0 s, 2.5 min, 5 min and 10 min. The SMI Power Version 1.02 calculated three indices: peak power, highest power (W · kg^{-1}) during a 5-s period; total work, work (J · kg^{-1}) performed during the 30-s period; and fatigue index, percentage decreases of power from the highest 5-s power output to the lowest 5-s power output. Oxygen demand was calculated according to the ACSM formula for leg ergometer: $VO_2 = load \cdot 6 \cdot n \cdot 2 \cdot BW^{-1} + 3.5$, where VO_2 = oxygen demand (ml · kg^{-1} · min^{-1}); load = frictional load of the ergometer (kg); 6 = one revolution on the Monark ergometer (m · rev^{-1}); n = revolutions per minute (rev · min^{-1}); BW = body weight (kg) and 3.5 = oxygen uptake at rest (ml · kg^{-1} · min^{-1}) (1). Oxygen uptake measurements were done breath-by-breath using the same equipment and procedure as described previously. Oxygen deficit and anaerobic contributions were calculated from the net values likewise in the MART.

To evaluate the validity of the MART, the second trial of the MART was compared with the WAnT. Certain variables, which were thought to measure similar qualities, were chosen for comparison. P_{max} (MART) and total work (WAnT) reflect the speed endurance of leg muscles, i.e. their ability to sustain extremely high power. The highest CMJ (MART) and peak power (WAnT) are reflections of the ability of the limb muscles to produce high mechanical power in a short time. The fatigue index (WAnT) is a measure for the degree of power drop-off during the test. The corresponding variable in the MART is the CMJ decrease. Peak blood lactate in both tests is an indirect indication for the amount of anaerobic energy produced by the glycolytic pathway. Oxygen deficit in both tests is the measure of the amount of energy drawn by the working muscles from sources other than the oxygen uptake through the mouth (19). Finally, the percentage anaerobic contribution in both tests is a general indication for the energy sources of the tests.

Table 1 Test results of Wingate anaerobic test (WAnT) and Maximal Anaerobic Running Test (MART).

	Mean	SD
WAnT		
Peak power (W · kg^{-1})	12.23	1.33
Total work (J · kg^{-1})	304.4	28.6
Fatigue index (%)	33.2	10.6
Peak blood lactate (mmol · l^{-1})	13.2	2.4
Oxygen deficit (ml · kg^{-1})	51.9	9.2
Anaerobic contribution (%)	80.7	8.7
1. MART		
P_{max} (ml · kg^{-1} · min^{-1})	108	5
P_{10mM} (ml · kg^{-1} · min^{-1})[1]	102	6
P_{5mM} (ml · kg^{-1} · min^{-1})	85	9
CMJ_{before} (cm)	43.6	5.9
CMJ_{after} (cm)	37.6	5.1
CMJ decrease (%)	13.7	6.5
Peak blood lactate (mmol · l^{-1})	15.6	3.2
Oxygen deficit (ml · kg^{-1})	23.5	1.8
Anaerobic contribution (%)	68.1	2.3
2. MART		
P_{max} (ml · kg^{-1} · min^{-1})	111	5
P_{10mM} (ml · kg^{-1} · min^{-1})[1]	106	5
P_{5mM} (ml · kg^{-1} · min^{-1})	89	9
CMJ_{before} (cm)	43.2	5.8
CMJ_{after} (cm)	38.5	5.2
CMJ decrease (%)	10.8	3.8
Peak blood lactate (mmol · l^{-1})	14.1	2.0
Oxygen deficit (ml · kg^{-1})	23.8	2.3
Anaerobic contribution (%)	67.7	4.9

[1] one subject did not reach the 10 mM level during the test, the value of 9.7 mM was used for this single case.

Abbreviations: P_{max} = maximal power in oxygen equivalents, P_{10mM} = power in oxygen equivalents at 10 mM lactate level, P_{5mM} = power in oxygen equivalents at 5 mM lactate level, CMJ_{before}, CMJ_{after} = counter-movement jump before and after the MART.

Ordinary statistical methods including mean, standard deviation and correlation coefficient were used in this study. In addition, standard error of estimate and coefficient of variation were used for reliability purposes. Differences between the two MARTs were tested for significance by employing an analysis of variance. Significance was accepted for all analyses at the alpha < 0.05 level.

Results

In the MART P_{max} ranged from 101 to 116 and 101 to 119 ml · kg^{-1} · min^{-1} in the first and the second MART, respectively. In the WAnT the total work values ranged from 260.0 to 357.0 J · kg^{-1}. The results of the three tests are shown in Table **1**.

The reliability of the variables between the first and second MART ranged from 0.56 to 0.96 ($p < 0.01$; Table **2**). There were small but significant differences in P_{max} ($p < 0.01$) between the first and the second trial. Although the peak blood lactate was lower after the second test, the difference was not statistically significant. The CMJ, O_2 deficit and anaerobic contribution values were about the same for both tests. The oxygen demand, oxygen uptake, oxygen deficit, aerobic and anaerobic contribution of the first and the second MART are shown in Table **3**.

Table 2 Reliability values of the Maximal Anaerobic Running Test.

	P_{max}	P_{10mM}	P_{5mM}	CMJ	CMJdec	pBLa	O_2def	Anaer %
r	0.92^c	0.80^c	0.67^b	0.96^c	0.56^a	0.60^b	0.47	0.50^a
A	17.47	-4.23	24.38	1.38	3.42	2.05	14.36	52.15
B	0.82	1.01	0.68	0.98	0.96	0.96	0.38	0.24
SE	1.87	3.94	7.31	1.72	5.66	2.63	1.68	2.07
CV	2.75	4.86	9.67	3.80	48.68	19.21	8.69	5.98

^{a}p <c0.05; ^{b}p < 0.01; ^{c}p <0.001. **Abbreviations:** A = constant in the linear regression equation, B = the slope of the linear regression, SE = standard error of estimate, CV = coefficient of variation, P_{max} = maximal power in oxygen equivalents, P_{10mM} = power in oxygen equivalents at 10 mM lactate level, P_{5mM} = power in oxygen equivalents at 5 mM lactate level, CMJ = counter-movement jump before the MART, CMJdec = decrease of the counter-movement jump, pBLa = peak blood lactate concentration, O_2def = oxygen deficit, Anaer% = contribution of anaerobic energy yield

Table 3 Mean oxygen demand (O_2-dem), oxygen uptake ($\dot{V}O_2$), oxygen deficit (O_2-def) and aerobic (Aer%) and anaerobic (Anaer%) contribution in each run during the first and second Maximal Anaerobic Running Test (MART).

RUN	O_2-dem $ml \cdot kg^{-1} \cdot min^{-1}$	$\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$	O_2-def $ml \cdot kg^{-1}$	Aer% %	Anaer% %
1. MART					
1	68	24.03	14.48	32.1	67.9
2	74	26.52	15.70	32.8	67.2
3	80	27.97	17.41	31.9	68.1
4	86	29.59	18.91	31.5	68.5
5	92	32.03	20.14	32.1	67.9
6	99	32.93	21.89	31.0	69.0
7	105	34.34	22.39	30.5	69.5
8	111	35.77	24.01	30.0	70.0
2. MART					
1	68	23.67	14.60	31.5	68.5
2	74	27.04	15.52	33.6	66.4
3	80	30.89	16.42	35.7	64.3
4	86	29.93	18.81	31.9	68.1
5	92	32.21	20.08	32.3	67.7
6	99	32.58	22.00	30.6	69.4
7	105	34.83	22.50	30.9	69.1
8	111	33.45	22.92	27.9	72.1

Table 4 Correlations between Maximal Anaerobic Running Test (MART) and Wingate Anaerobic test variables.

	r
P_{max} vs. Total work	0.52^a
P_{max} vs. Peak power	0.45
pBLa vs. pBLa	0.53^a
O_2 deficit vs. O_2 deficit	0.59^a
Anaerobic% vs. Anaerobic%	0.43
CMJ vs. Peak power	0.58^a
CMJdec vs. Fatigue-index	– 0.04

^{a}p < 0.05. **Abbreviations:** P_{max} = maximal power in the MART, pBLa = peak blood lactate concentration, Anaerobic% = contribution of anaerobic energy expenditure, CMJ = the height of the counter-movement jump before the MART, CMJdec = the percentage decrease of the counter-movement jump during the MART

The correlations between the corresponding variables of the MART and WAnT are shown in Table **4**. Although four out of seven of the correlations were significant ($0.52 < r < 0.59$) they were not high. The correlations between the P_{max} and O_2 deficit were not significant in the first ($r = 0.18$) and second ($r = 0.34$) MART.

There were slight differences between the P_{10mM} and P_{5mM} of the second and third trial performed by two subjects but they were smaller than those between the first and second trial. The P_{max} was almost the same (±1.0 $ml \cdot kg^{-1} \cdot min^{-1}$) suggesting that the oxygen measurements did not infuence the reliability or the validity of the MART.

Discussion

Reliability

The calculations of the correlations between the first and second MART as well as the coefficients of variations were quite promising. The P_{max} was higher in the second test than in the first one (Table **1**) suggesting probably a learning process since most of the subjects were not familiar with any kind of anaerobic testing. A similar change between two trials has also been found in a cycle ergometer test, where the author indicates that the increase was due to the fact that the subjects were not familiar with the test (23). No differences in the results of the third trial compared with the second one also support the idea that the low values of the first trial were due to unfamiliarity with the MART. In addition, even higher retest correlations for P_{max} ($r = 0.93$, $p < 0.001$) and P_{10mM} ($r = 0.85$, $p < 0.001$) have been calculated for sprinters ($n = 34$) who were familiar with anaerobic exercise and performed the MART before and after a 10-week intensive training period (unpublished results). According to Vandewalle et al. (26) these reliability indices are high since for constant load tests they normally range around 0.77.

The reliability of the peak lactate measurements was low but significant. Vandewalle et al. (26) revealed indices of 0.87 to 0.91. The coefficient of variation of peak blood lactate was high suggesting that the reproducibility of peak blood lactate measurements was not high. Another possible explanation for the differences in the peak blood lactate between the first and the second test could be motivation, but it is a very difficult variable to control. There was, however, no real pattern: some subjects had lower peak blood lactate values and higher P_{max} at the second test compared to the first one and vice versa.

The reliability figures calculated for the CMJ agree with values found in the literature, ranging from 0.92 to 0.98 (26). The reason for this is probably the simplicity of the test and the heterogeneous subjects. The reliability of the CMJ decrease was low but significant (Table **2**). The test-retest reliability of the fatigue index in the Wingate test has also been reported to be low ($0.43 < r < 0.74$; 26) suggesting that the fatigue indices cannot give a reliable estimate of the fatiguability of subjects. The reason for this might be that not only numerous physiological but also motivational, methodological and tactical factors affect the fatigue indices calculated as the relative decrease of force or power.

Validity

The validity of the MART was verified by evaluating the anaerobic energy production, calculating the maximal power of the test, and comparing the results of the test with the results of the Wingate test, which is most frequently used by many authors since its first description (3) and is supposed to be valid (4). The duration of the runs is critical when measuring the anaerobic capacity. To ensure the high degree of specificity, the runs should be long enough to exhaust the anaerobic process and short enough to keep the proportion of the aerobic energy yield as small as possible (26). Anaerobic contribution in the 20-s runs ranged from 64% to 72% during both the first and the second test (Table **3**). The anaerobic contribution corresponds to the values reported earlier in the maximal exercises of 60 s (2,25) suggesting that the MART is highly anaerobic by nature. The anaerobic contribution for WAnT has been determined to be between 71% and 87% (4,12, present study).

The P_{max} did not correlate with the O_2 deficit in the MART suggesting that either O_2 deficit is not an accurate method for determining anaerobic energy yield in the short lasting exercises or some other determinants are more important than anaerobic energy production influencing P_{max} in the MART. There are some factors which must be considered when using O_2 deficit values in the calculation of anaerobic contribution in the MART and in the WAnT. One of the main assumptions of the oxygen deficit calculation is that the oxygen uptake at the mouth level is equal to oxygen consumption at the muscular level. This assumption might be a source of error for short lasting exercises like the MART and the WAnT, because there is a delay between oxygen consumption and oxygen uptake at the mouth, which is probably not negligible for 20- and 30-s exercises.

Another assumption, which might cause an error, is the determination of energy demand in the MART and in the WAnT. In the present study the O_2 demands were derived from the ACSM formula (1) assuming that running and cycling economy remain the same at different intensities. However, Hermansen and Medbø (1984) have reported that running economy decreases at higher speeds resulting in the O_2 deficit being underestimated. In addition, they have stressed the necessity for establishing individual relationships between oxygen uptake and treadmill speed at submaximal intensities to determine O_2 demand for supramaximal exhausting bouts (11,19).

It is difficult to compare the O_2 deficit values in the MART and in the WAnT, because the durations of the exercises were different. O_2 deficit in the WAnT was higher than in the MART, which could be explained at least partly by the oxygen stores. Using a theoretical $6\,ml \cdot kg^{-1}$ value (19) the oxygen stores contributed for 25% of the O_2 deficit in the MART and 12% in the WAnT. On the other hand, the repetitive nature and short recovery periods in the MART elevated the O_2 uptake in the beginning of the runs (Fig. **2**) and accumulated O_2 deficit during the whole test. It is, however, impossible to calculate the total accumulated O_2 deficit in the MART, because myoglobin oxygen stores were used in the beginning of each run. Similarly, creatine phosphate stores were partly replenished before each run. Consequently, the accumulated O_2 deficit in the first and second MART ($155\,ml \cdot kg^{-1}$ and $153\,ml \cdot kg^{-1}$, respectively) clearly overestimates the O_2 deficit and the anaerobic capacity of the subjects. That is why we have used the O_2 deficit of the last completed 20-s run in the MART when describing anaerobic energy yield in Table **1**.

Peak blood lactate concentrations of about $20\,mmol \cdot l^{-1}$ after races of 400 m and 800 m have been mentioned, whereas in individual cases, values as high as $25\,mmol \cdot l^{-1}$ are possible (13). In non-athletic subjects the exercise comes to an end when the blood lactate has reached the concentration of 15–$20\,mmol \cdot l^{-1}$ (25). In the present study, the peak blood lactate concentration was $15.6 \pm 3.2\,mmol \cdot l^{-1}$ and $14.1 \pm 2.0\,mmol \cdot l^{-1}$ after the first and the second MART, respectively, and $13.2 \pm 2.4\,mmol \cdot l^{-1}$ in the WAnT. These values suggest that it is possible to attain a high level of lactic acidosis in the MART. In the previous study on trained athletes there was only a slight difference in peak blood lactate concentrations between the MART and the 400-m run (22). The validity of blood lactate as an indicator of muscle lactate concentration and anaerobic capacity, however, is limited, because there is not a simple causal relationship between glycolytic energy production and blood lactate concentration. Significant negative correlations between peak blood lactate concentration and running times for 400 m (10,20) suggest, however, that blood lactate can be used as a rough estimate of anaerobic capacity.

The anaerobic nature of the MART is also shown in the P_{max} values. According to the ACSM formula the mean power of $118.5\,ml \cdot kg^{-1} \cdot min^{-1}$ has to be generated for running 400 m in 45 s. In the above calculation it is supposed that air resistance corresponds to the inclination of 1° on a treadmill. The results of the present and the previous study (22) showed that non-athletic and athletic subjects were able to attain the oxygen demand of 111 ± 5 and $118 \pm 5\,ml \cdot kg^{-1} \cdot min^{-1}$, respectively, in the MART. The above example demonstrates that the P_{max} is at the same level as the power demand during the 400-m run and 400 m is known to be a highly anaerobic distance of running.

Because of the repetitive nature of the MART and relatively short recovery periods between the runs the P_{max} is influenced by the anaerobic power and capacity as well as the ability to recover between the runs and the sprinting economy. The relative contributions of these components, however, cannot be estimated. The high correlation ($r = 0.89$) between the P_{max} and the speed in the 400-m run (22) demonstrated that the maximal performance in the MART and in the 400-m run were determined by the same metabolic and neuromuscular components. The constant speed during the last run suggests that anaerobic capacity could not be totally depleted at the end of the test and the subjects could have been able to continue the test at lower supramaximal speed. This is the problem with all constant load tests. Psychological factors also affect P_{max} as in all maximal anaerobic tests.

In order to validate the MART its results were also compared with the corresponding variables of the WAnT (Table **4**). Four variables in the MART (P_{max}, peak blood lactate, height of the CMJ and O_2 deficit) correlated significantly with the corresponding variables of WAnT suggesting that MART at least partly measures the same anaerobic properties as the WAnT. Low correlations between the corresponding variables in the MART and WAnT in the present study could be explained by the differences between the two tests. First, MART is a running test and WAnT a cycling test and different muscle groups are involved in running compared with cycling. Second, running is a stretch-shortening cycle exercise but in cycling concentric work dominates. Third, the total duration of the MART may be over 15 min while the WAnT is a standard 30-s test. The comparison of the tests is difficult because the way to do them is different: submaximal workloads are included in the MART and it is an interval test while the WAnT is a short-term all-out test.

It is concluded that the MART is a reliable anaerobic running test. The values describing anaerobic energy production and the contribution of anaerobic energy expenditure during the MART as well as the correlation coefficients between the corresponding variables of the MART and the WAnT suggest that the MART is also a valid test to determine combined lactacid and alactacid anaerobic work capacity during treadmill running.

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