Reproducibility of Determining Anaerobic Capacity Using Treadmill Ergometry

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Abstract: To implement a method measuring anaerobic capacity within the field of training control, the reproducibility of the results is of deciding significance.

In this study, we examined the test-retest-reliability of the most commonly used method for measuring anaerobic capacity to date, modified according to Monod and Scherrer, on a motorized treadmill. Ten healthy, athletically active, male participants carried out two defined test series of each three sprint tests with an interval of one week. The work output of each participant and test series was calculated from this data. These results, as well as the running time of the sprint tests were graphically plotted using a work-exhaustion-time-diagram. After calculating a linear regression, the point of intersection of the regression line with the y-axis (y-intercept) was defined as the measure of anaerobic capacity (AC).

The mean AC determined from the first sprint test series was 1.4 ± 0.8KJ and from the second sprint test series 1.2 ± 0.06KJ. The AC shows a mean difference of 18.4% (95% CI: 10.5 - 26.4), which is statistically significantly higher (p=0.004) than a tolerable mean difference level of 5%.

Based on this difference, the described method does not seem suitable as a training control in competitive sport. This method, however, could be implemented for talent sighting.

Keywords: Anaerobic capacity, y-intercept, anaerobic power, exercise testing, treadmill ergometry, training.

INTRODUCTION

The anaerobic metabolism plays an extremely important part in the success of competitions with a performance of 30 seconds to 10 minutes [1, 2]. Therefore, not only determining aerobic performance, but also determining anaerobic components is the aim of total performance diagnostics, since deficits can be detected or examined in the course of training. Ultimately, it could be possible to verify the athletes' suitability for a specific discipline.

In contrast to aerobic performance, quantifying anaerobic performance and capacity seems to be impossible by estimating the oxygen uptake or by determining lactate metabolism [3]. Another approach is to determine the anaerobic capacity through repeated high-intensity tests. This approach stems from the critical power-concept, which was first described by Monod and Scherrer [4]. This concept assumes a hyperbolic relationship between power and time to exhaustion [4-6]. In the past few years, an entire series of test procedures has been developed on this basis [5, 7-10]. The methods of testing are mostly based on cycle ergometry or sports specific field tests [9, 11].

The repeatability of results is of significant importance to increase the objectivity of a procedure for determining anaerobic capacity, and therewith its application as a training control [3]. Previous studies with correlation coefficients of r=0.62-0.97 had no consistent results [10, 12, 13]. Moreover, we must question whether a test-retest difference of less than 5% can be achieved despite high correlation coefficients, which seems to be vital as a training control. In the present study therefore, we examined the test-retest-reproducibility of a method for measuring anaerobic capacity on the treadmill, based on the critical-power-concept.

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SUBJECTS AND METHODS

Test Subjects

In the present study we examined ten healthy, athletically active, male subjects between the ages of 19 and 27. The subjects were familiarized with the treadmill several times before the tests were carried out. According to the guidelines of the University's Ethics Committee, the subjects were thoroughly briefed about the stress of the exercise tests. All subjects signed an informed consent to participate in this study. The anthropometric data are presented in Table **1**.

Table 1. Anthropometric Data of the Participating Subjects

Age (years)	23.9 ± 2.1
Weight (kg)	71.5 ± 24.0
Height (cm)	175.5 ± 7.4
VO_2max (ml/kg/min)	62.6 ±4.2

Exercise Protocol

On the first test day, all subjects completed a speed test consisting of three 30-meter sprints on the track to determine their maximum running speed (V_{max}). The speeds for the last 10-meters of the 30-meter sprint test were measured using a light barrier [14]. The fastest time was assessed for each subject.

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Based on the individually determined maximal running speed, all participants carried out a defined test series of three sprint tests on a motorized treadmill ergometer (HP Cosmos, Saturn, Traunstein, Germany). The speed at V_{max} - $2km \cdot h^{-1}$ was chosen as the intensity for the first sprint test. For the second and the third sprint tests, the speed was decreased by $2km \cdot h^{-1}$ (V_{max} - $4km \cdot h^{-1}$ and V_{max} - $6km \cdot h^{-1}$), respectively. The slope remained constant at 1.5%. In each test, subjects ran until subjective exhaustion, and were encouraged to give a maximum effort. The time to exhaustion for each test speed was determined and recorded during the sprint series. There was a 90 min break between each sprint test for recovery. The room temperature was air-conditioned to a constant 20°C and 50% humidity. All participants took part in an identical sprint test series one week later.

Determination of the Anaerobic Capacity

For every sprint test, the treadmill speed (v), time to exhaustion (t_{lim}), slope of the treadmill (S), and body weight (kg) were used to define the work output (W_{lim}) in kilojoule (kJ) according to the following formula [15]:

$$W_{lim} = [(v \times kg \times (2.11 + S \times 0.25) + 2.2 \times kg - 151) : (10.5 \times 1000)] \times t_{lim}$$

The work output (W_{lim}) was shown graphically using the running velocities in each sprint test (t_{lim}) in a work-output-duration-diagram according to Monod and Scherrer [16]. After calculating a linear regression, the point of intersection of the regression line with the y-axis (y-intercept) was defined as the measure of anaerobic capacity (AC) [8, 13, 15]. A single example for determining AC was presented in Fig. (**1**).

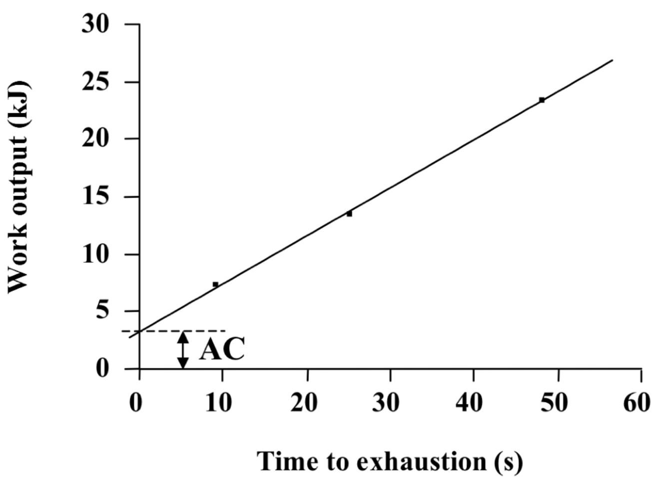

Fig. (1). Individual presentation of the determination of anaerobic capacity (AC) in a work-exhaustion-time-diagram through linear regression of the work output from the sprint tests. AC corresponds with the distance of the y-axis at time t=0.

Statistical Analysis

The raw data were analyzed using the statistics program JMP (SAS Institute, Cary, USA) and tested for standard distribution according to Shapiro-Wilk. Mean values and standards of deviation (SD) were calculated for all parameters. Test-retest reproducibility for the determination of AC was estimated by Pearsons Product Moment Correlation Analysis. A value of $p < 0.05$ was considered statistically significant. In addition, differences between test series 1 and 2 were presented in percent. Shapiro-Wilk W-testing of the individual absolute mean differences in relation to the first test values indicated normal distribution. We therefore tested the actual value against a tolerable value of 5% mean difference with a two-sided T-test.

RESULTS

Sprint Test Series 1

The mean value of time to exhaustion of the first sprint test was 11.7 ± 6.0s, and 22.5 ± 5.6s and 35.8 ± 6.3s for the second and third tests, respectively. The mean anaerobic capacity determined from this sprint test series was 1.4 ± 0.8 KJ (Fig. **2**).

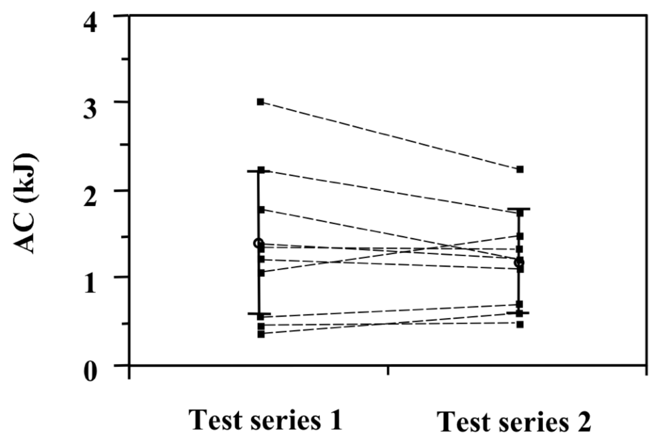

Fig. (2). Means, standard deviation and individual values of determination of anaerobic capacity (AC) of sprint test series 1 and 2.

Sprint Test Series 2

In the second sprint test series, the times to exhaustion were 11.2 ± 4.2s for the first test, and 22.3 ± 4.1s and 38.3 ± 4.9s for the second and third tests, respectively. The mean anaerobic capacity calculated from these data was 1.2 ± 0.6 KJ (Fig. **2**).

Differences and Test-Retest Reproducibility of AC

The mean value of the difference of time to exhaustion between sprint test series 1 and 2 was 13.8 ± 12.5% for the first set of tests, and 15.1 ± 9.0% and 17.1 ± 10.9% for the second and third set of tests, respectively. A comparison of sprint test series 1 and sprint test series 2 shows a good reproducibility for AC with r=0.95 (p<0.001) (Fig. **3**). The AC shows a mean difference of 18.4% (95% CI: 10.5 - 26.4), which is statistically significantly higher (p=0.004) than a tolerable mean difference level of 5%.

DISCUSSION

To determine anaerobic capacity, aside from determining the maximal accumulated deficit [16-19], methods are favored which are based on the critical-power-concept first described by Monod and Scherrer [4]. This concept assumes a hyperbolic relationship between power and time to exhaustion [3, 10, 20, 21]. Previous approaches using test procedures for bicycle and treadmill ergometery have not been analyzed as to whether they could be applied as a performance diagnostics tool to supervise training. This is because it is an absolute necessity for the method to have a very high degree of reliability, but also a small test-retest difference of less than 5 %. Previous studies only indicate test-retest reliability, but not test-retest difference in percent [12, 10, 22].

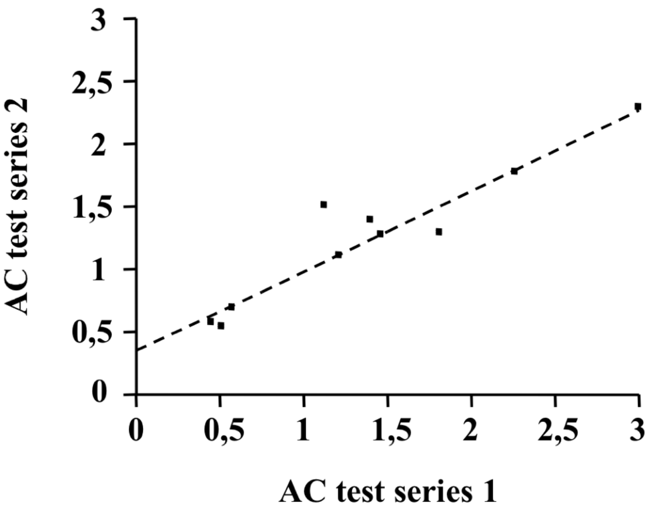

Fig. (3). Correlation of anaerobic capacity (AC) between test series 1 and test series 2 ($r = 0.95$; $p < 0.001$).

We show for the first time that this commonly used procedure to determine AC could not fulfill the necessary test-retest criteria for intra-individual performance diagnostics. As in other studies [10, 22], we observed a very high correlation of r=0.95. However the intra-individual difference was 18.4%, which is considerably higher than 5%. It is questionable whether other measuring strategies based on the central assumption of a hyperbolic relationship between power and time to exhaustion fulfill sufficient criteria of test-retest-reliability on treadmill ergometers at all.

First of all, the high test speeds on the treadmill are problematic yet necessary, since the aerobic metabolism increases continually during longer periods of exercise. The results are a composite presentation, since the aerobic and anaerobic energy phases overlap [9]. With exercise duration of 45 seconds, the relative contribution of anaerobic to aerobic energy is already about 80% to 20% [23].

The dependence of the results on the subjective exhaustion of the participants is still problematic [11]. The subjective condition of the subject on each test day directly affects the time to exhaustion for each test, which is then entered directly into the formula to calculate anaerobic capacity. As an indication of the influence these subjective components have, the present study shows that increased running duration in the individual tests results in a continually higher mean difference between test days.

In addition, it appears that there is no exact linear relationship between work done (W_{lim}) and time to exhaustion (t_{lim}). Several studies showed that the y-intercept, as a measure for AC, shows a dependency on the duration of the individual sprint tests [5, 7]. Selecting shorter periods of exercise with higher intensities for the individual tests to avoid measurement errors by keeping the aerobic to anaerobic composite presentation as low as possible results in a much steeper regression line with a consecutively lower y-intercept. However, if longer periods of exercise with lowered intensities are selected, then it results in a flatter regression line and a higher y-intercept [5, 7]. Physiologically, this can be explained in that the maximal oxidative flow rate is not achieved due to the delayed increase of oxygen uptake at the beginning of an exercise with short periods of high intensity exercise less than 60 to 90 seconds [7, 24].

CONCLUSION

In conclusion, it appears that the use of this procedure based on the critical-power-concept to determine anaerobic capacity for performance diagnostics cannot be realized due to the existing test-retest deviations in connection with the presented problems with treadmill ergometry. It is feasible that this procedure be used by talent scouts, at best. Fundamentally, it seems that procedures independent of the test subjects' subjective feeling of exhaustion are more appropriate for use in performance diagnostics.

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