Validation of a field test for the non-invasive determination of badminton specific aerobic performance

M Wonisch, P Hofmann, G Schwaaberger, S P von Duvillard, W Klein

Aim: To develop a badminton specific test to determine on court aerobic and anaerobic performance. Method: The test was evaluated by using a lactate steady state test. Seventeen male competitive badminton players (mean [SD] age 26 [8] years, weight 74 [10] kg, height 179 [7] cm) performed an incremental field test on the badminton court to assess the heart rate turn point (HRTP) and the individual physical working capacity (PWC). All subjects performed a 20 minute steady state test at a workload just below the PWC. Results: Significant correlations (p<0.05) for Pearson’s product moment coefficient were found between the two methods for HR (r = 0.78) and velocity (r = 0.93). The HR at the PWC, 176 (5.3) beats/min was significantly lower than the HRTP (179 (5.5) beats/min), but no significant difference was found for velocity (1.44 (0.3) m/s, 1.38 (0.4) m/s). The constant exercise test showed steady state conditions for both HR (175 (9) beats/min) and blood lactate concentration (3.1 (1.2) mmol/l). Conclusion: The data indicate that a valid determination of specific aerobic and anaerobic exercise performance for the sport of badminton is possible without HRTP determination.

Although the anaerobic threshold (AT) determined from incremental exercise tests is often used, most effort is expended in attainment of the maximal lactate steady state (MLSS). The MLSS is defined as the maximal exercise intensity consistent with the steady state blood lactate concentrations during the last 20 minutes of exercise. Several steady state exercise tests are necessary for the determination of the MLSS. As this procedure is time consuming and technologically demanding, several investigators have attempted to determine the MLSS from a single incremental test.

A non-invasive approach to determining the AT has been presented by Conconi et al., using an incremental field test for runners. They found that the deflection of the heart rate (HR) near the maximal heart rate (HRmax) was significantly related to the AT. This concept has been investigated extensively, and from these studies one may conclude that the power output at the so-called “heart rate threshold” or heart rate turn point (HRTP) reflects the MLSS. The incremental test protocol used by Conconi et al. has been modified for several sports as well as for different laboratory conditions, but not for sports with a high level of technical skill such as badminton.

The difficulty associated with the determination of the HRTP and the causal relation to the AT have been addressed. However, the determination of a physical working capacity (PWC) at a workload corresponding to a fixed percentage of the HRmax is always possible. Moreover, the objectivity is high because of a simple analysis under normal testing procedures. The purposes of this study were to: (a) develop a simple, badminton specific test to determine the AT; (b) determine the individual PWC (PWCi); (c) compare PWCi with HRTP; (d) assess the PWC, by using a lactate steady state test.

Abbreviations: AT, anaerobic threshold; MLSS, maximal lactate steady state; HR, heart rate; HRmax, heart rate maximum; HRTP, heart rate turn point; PWCi, individual physical working capacity; LA, blood lactate concentration.
SUBJECTS AND METHODS
Seventeen male national and international badminton players (mean (SD) age 26 (8) years, body weight 74 (10) kg, height 179 (7) cm) gave their written informed consent to participate in this study. The institutional ethics committee of the University of Graz approved the study. All testing was performed within one week. Subjects were instructed to eat their usual meals and not to engage in strenuous activity the day before testing.

Badminton specific incremental test
All subjects performed an incremental field test using the modified Conconi test16 in one half of the badminton court (singles court) to assess the heart rate performance curve (fig 1). From a central point subjects started with a signal given by a whistle, moved 3 m forward to a marker at the right side of the court, touched the net with the racket, and moved immediately back to the central point. On the next signal, subjects moved to a second marker at the left side of the court and back again. Then they moved backwards to a third marker 3 m behind the central point performing a jump turn along the centre line carrying out a simulated smash. After they had returned to the central point, the procedure was repeated. Signals were given from a pacer (pocket computer; Sharp PC 1401, Osaka, Japan). Velocity at the beginning of the test was 0.60 m/s according to six signals per minute. The velocity was increased every minute by 0.10 m/s according to one signal per minute. The test was performed continuously until voluntary exhaustion. HR was measured continuously (Sporttester PE 4000; Polar Electro, Oy, Finland) and values stored in five second intervals. Capillary blood samples (20 µl) were taken from the hyperaemic ear lobe at the beginning and within one minute of the end of the exercise for enzymatic determination of blood lactate concentration (LA) using an Eppendorf EBIO plus lactate analyser (Eppendorf, Hamburg, Germany).

The HRTP was assessed by computer aided linear regression break point analysis.18 The PWCi at 90% of the measured HRmax was calculated by linear interpolation.

Lactate steady state test
After a rest period of at least 24 hours, the subjects performed one steady state test of 20 minutes duration at an intensity set at the PWCi minus 0.03 m/s. The reduction in velocity was necessary because of the fixed interval of the pacer system (even number of movements/minute). HR was measured continuously, and load was terminated for 30 seconds to determine LA every five minutes.

Table 1  Mean heart rate (HR) and velocity at individual physical working capacity (PWCi), heart rate turn point (HRTP), and maximal values as well as lactate values (LA) at the end of the badminton field test

<table>
<thead>
<tr>
<th></th>
<th>Maximal</th>
<th>HRTP</th>
<th>PWCi</th>
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<tbody>
<tr>
<td>HR (beats/min)</td>
<td>195 (6)</td>
<td>179 (5.5)</td>
<td>176 (5.5)</td>
</tr>
<tr>
<td>Velocity (m/s)</td>
<td>2.20 (0.2)</td>
<td>1.44 (0.3)</td>
<td>1.38 (0.4)</td>
</tr>
<tr>
<td>LA (mmol/l)</td>
<td>7.6 (2.1)</td>
<td>-</td>
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Values are mean (SD) (n = 16).

Figure 1   Badminton specific field test. CP, Central point; M1–3, markers.

Figure 2   [A] Correlation between heart rate at individual physical working capacity (HR-PWC) and heart rate turn point (HR-HRTP) [n = 16]. (B) Plot of difference against mean heart rate at individual physical working capacity (HRmean) and heart rate turn point (HRmean) [n = 16].
Statistical analysis
Values are expressed as mean (SD). Pearson’s product moment correlation coefficients were calculated. Paired t tests were used to determine significant differences between measured variables. Differences were plotted against the mean for HR and velocity at the HRTP and PWCi as suggested by Bland and Altman.25 p<0.05 was considered significant.

RESULTS
Badminton specific incremental test
The HRTP was successfully determined in 16 of the 17 subjects. Table 1 shows the data for HR, workload expressed as velocity, and LA from the incremental badminton field test.

Significant correlations (p<0.001) were found between the PWCi and the HRTP for HR (r = 0.78; fig 2A) and velocity (r = 0.93; fig 3A). The HR at the PWCi was slightly but significantly lower than that at the HRTP, but no significant differences were found between the two methods for velocity. Figure 2B shows the Bland-Altman plot for HR (mean difference 3.1 beats/min (95% confidence interval −6.2 to 12.4)). Figure 3B shows the Bland-Altman plot for velocity (mean difference 0.04 m/s (95% confidence interval −0.11 to 0.2)).25

Lactate steady state test
All subjects reached steady state conditions for both HR and LA. Figure 4 shows the mean LA and HR values obtained from the steady state test. The mean (SD) values for LA and HR of the last minute of each step were 3.1 (1.2) mmol/l and 175 (9) beats/min respectively. The mean value obtained for the HR represented 88.9% of HRmax calculated from the incremental test. All steady state HRs were significantly lower than HR at the HRTP. No differences were found between steady state HR and HR at PWCi.

DISCUSSION
The results of this study indicate that the incremental badminton specific field test was similar for the HRTP and PWCi methods. Although a slight difference between velocity at HRTP and PWCi was observed, it was not significant. Furthermore, a steady state exercise test just below velocity at the PWCi and HRTP gave steady state conditions for LA in all cases. We contend that determination of the PWCi is the preferred method because of an objective determination of the submaximal performance with respect to a lactate steady state.

The design of the incremental field test is comparable to the tests presented by Chin et al9 and Coen et al.11 Their tests required Technologically sophisticated equipment—that is, computer simulated light pulsations—that would preclude their routine application. Furthermore, these investigators used invasive procedures to determine AT, whereas we did not use such procedures in our incremental test. The workload at the PWCi from our incremental test was lower than the workload found by Chin et al9 and Coen et al11 by about 21 signals per minute. We attribute this finding to a lower skill level of the badminton players in our study. In addition, in our study there were no movement interruptions of the badminton players during the chosen incremental test procedures.

Numerous attempts have been made to determine the AT by non-invasive methods, such as by using HR.13 14 16 21 One possible method may be the use of a percentage of the age...
predicted or measured HR_{max}. In addition, it has been reported that the percentage of HR at AT determined by different methods is usually 88–93% of HR_{max}. Therefore, a percentage of HR_{max} may be used for AT determination under field and laboratory conditions.

The “Conconi test” is often used to determine the AT because of its simplicity. Some discrepancies have been found with regard to the determination and validity of the HRTP; however, it has also been shown that the AT determined using the HRTP method is 88–93% of HR_{max}. Hofmann et al. reported that the constant workload just below the predetermined HRTP leads to lactate steady state values in both kayaking and cycle ergometer exercise.

On the basis of previous findings, we used an incremental workload determined at 90% of HR_{max} defined as the PWC_{170}. We contend that this procedure provides two distinct advantages: (a) objectivity; (b) elimination of the problem of determining the HRTP despite the absence of an invasive determination of the AT. It is important to note that differences between the HRTP and the PWC_{170} were quite small when plotted against the HR_{max}.

In summary, we determined the relation between the PWC_{170} and AT, by performing a steady state test at an intensity just below PWC_{170}. Accordingly, we evaluated the HR and LA responses for the steady state conditions, as these variables are strongly related to training responses in endurance exercise.

The mean steady state HR was found at 88.9% of HR_{max} achieved during the incremental field test, which was below HR at the PWC_{170}. Although we conducted the 20 minute steady state test after a warm up session, the HR and LA values did not increase during the last 15 minutes of the test. These values indicate that all subjects had attained steady state conditions for both HR and LA. It should be noted that a velocity slightly below PWC_{170} was used in order to adapt to fixed impulses from the pacer. Therefore, one may argue that the MLSS was not obtained. However, it is important to note that the PWC_{170} is a submaximal marker of aerobic performance, which correlates closely with the HRTP.

From these data, we conclude that the incremental badminton field test gives valid information about badminton specific aerobic performance and provides important information for prescribing aerobic exercise training. From a practical point of view, this test is easy for coaches and athletes to use as it allows investigation of several subjects at the same time without the use of expensive equipment.

Direct measurement of respiratory gas exchange variables under field conditions, as previously shown for tennis players, may be useful in future research. Further studies under competition-like conditions may provide additional information about the impact of aerobic power in badminton.

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**REFERENCES**


