

# Physiological analysis to quantify training load in badminton

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## Abstract

**Objective**—To estimate the training load of specific on court training regimens based on the magnitude of variation of heart rate-lactate response during specific training and to determine the magnitude of variation of biochemical parameters (urea, uric acid, and creatine phosphokinase (CPK)) 12 hours after the specific training programme so as to assess training stress.

**Methods**—The study was conducted on six national male badminton players. Maximum oxygen consumption ( $\dot{V}O_2$ ), ventilation ( $\dot{V}_E$ ), heart rate, and respiratory quotient were measured by a protocol of graded treadmill exercise. Twelve training sessions and 35 singles matches were analysed. Heart rate and blood lactate were monitored during technical training routines and match play. Fasting blood samples collected on two occasions—that is, during off season and 12 hours after specific training—were analysed for serum urea, uric acid, and CPK.

**Results**—Analysis of the on court training regimens showed lactate values of 8–10.5 mmol/l in different phases. The percentage of maximum heart rate ranged from 82% to 100%. Urea, uric acid, and CPK activity showed significant changes from (mean (SD)) 4.93 (0.75) mmol/l to 5.49 (0.84) mmol/l, 0.23 (0.04) to 0.33 (0.06) mmol/l, and 312 (211.8) to 363 (216.4) IU/l respectively.

**Conclusion**—Maximum lactate reported in the literature ranges from 3–6 mmol/l. Comparatively high lactate values and high percentage of maximum heart rate found in on court training show a considerable stress on muscular and cardiovascular system. The training load needs appropriate monitoring to avoid over-training. Workouts that are too intensive may interfere with coordination, a factor that is important in sports requiring highly technical skill such as badminton.

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Keywords: badminton; creatine phosphokinase; lactate; heart rate monitoring

Unlike other sports, the physical and physiological profiles of badminton players are scarce in the literature.<sup>1-8</sup> The demand of sports has been analysed and it has been reported that training games in elite badminton performers are predominantly aerobic activity, while a few

sporadic attempts have been made to assess the effect of a general training programme designed for badminton players.<sup>7,8</sup> The consensus on fitness development is that, badminton players should incorporate flexibility, strength, and endurance training in their programmes to reduce fatigue and muscular injuries, while simultaneously improving performance. Specific training routines have been developed and monitored, however, which are sufficiently intense to cause an increase in blood lactate concentration.<sup>7</sup> This type of training is probably especially beneficial for competition play where a greater reliance on anaerobic glycolysis may be expected to sustain work over rallies and games of longer duration.<sup>7</sup> This study was undertaken to consider the following aims and objectives. (1) To assess the heart rate and lactate responses during actual play to quantify the energy demand of the game. (2) To examine the physiological responses in an on court technical training regimen, to measure the comparative assessment of training load and physiological stress of match play. (3) To find out the magnitude of variation of biochemical parameters (urea, uric acid, creatine phosphokinase (CPK)) after the specific training programme compared with off season resting values, to assess training stress.

## Methods

This study was conducted on six national male badminton players attending a training camp at the Sports Authority of India. Oxygen consumption ( $\dot{V}O_2$ ), carbon dioxide production ( $\dot{V}CO_2$ ), ventilation ( $\dot{V}_E$ ), heart rate were measured during graded treadmill exercise (Jaeger, Germany). The initial speed of the treadmill was 8 km/h with an inclination of 2% and thereafter the speed was increased by 2 km/h after every two minutes until a plateau of  $\dot{V}O_2$  was attained or the respiratory quotient (RQ) value exceeded 1.15. The whole experiment was performed at room temperature varying from 23–25°C with the relative humidity varying between 50–60%.<sup>9</sup> Regression equation of  $\dot{V}O_2$ -HR was calculated to estimate indirectly the oxygen consumption from heart rate.<sup>10</sup>

## MONITORING OF A SINGLES GAME

The heart rate of each player was measured continuously at five second intervals during a singles game in competitive match play by a telemetry (sports tester PE-3000). The data stored in the memory of the watch were then downloaded to a computer and evaluated using proprietary software (Polar Electro, Finland). After each game, arterialised capillary blood

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Table 1 Training programmes adopted for speed endurance

Training	Duration of activity (s)	Intensity HR (beat/min)	Number of repetitions in set	Duration of rest between repetitions (s)	Recovery HR in between rest (beat/min)	Rest between sets (min)	Recovery HR (beat/min)
Shadow	40-50	153-190	6-8	40-50	150-165	2	105-130
Multishuttle	40-50	165-185	3-4	60-120	130-173	5	104-170

Table 2 Descriptive data for subjects (n=6)

Age (y)	24.3 (4.1)
Height (cm)	175.4 (5.4)
Weight (kg)	64.8 (6.9)
Body fat (%)	12.1 (3.4)
$\dot{V}O_2$ max (l/min)	3.57 (0.45)
$\dot{V}O_2$ max (ml/kg/min)	55.7 (4.4)
Maximum heart rate (beat/min)	183 (6)

Data shown as mean (SD).

samples were drawn from a finger tip, between two and three minutes after the cessation of the activity.<sup>11</sup> The samples were analysed in a calibrated automatic lactate analyser (Analox Instruments Ltd, UK) for estimating whole blood lactate. A total of 15 matches were analysed, of which 10 comprised two games, while the remaining five matches extended to three games. In total, 35 games were analysed, involving six players, and  $\dot{V}O_2$  was predicted from the regression equation. The heart rate and  $\dot{V}O_2$  were measured over a range of exercise intensities using the treadmill, and the HR- $\dot{V}O_2$  relation established.<sup>12</sup> Telemetered heart rate values during actual game were obtained and their corresponding  $\dot{V}O_2$  used to estimate the oxygen uptake during play. The high correlation coefficients ordinarily obtained between HR- $\dot{V}O_2$ <sup>13 14</sup> support the use of the HR- $\dot{V}O_2$  relation for estimating game  $\dot{V}O_2$ .

MONITORING THE TRAINING PROGRAMME

Specific on court programmes were given to improve speed endurance. Table 1 gives the details of the programmes. On court technical training consisted of five segments in which the different intensity of effort was imposed by manipulating work-rest ratio. These routines were three sets of "shadow play" and two sets of "multishuttle" work. Total work over 80 minutes was undertaken with a work-rest interval ratio of 1:1 in "shadow play" but in "multishuttle" the duration of activity: rest was 40-50 seconds : 60-120 seconds with repetitions varying from six to eight in each segment.

Table 3 Physiological parameters during match play (men)

Mean (work):(rest)	(4.6 (1.5)):(9.7 (2.4))
Mean $\dot{V}O_2$ (l/min)	2.29 (0.58)
Per cent of $\dot{V}O_2$ max	57.10 (24.50)
Average heart rate (beat/min)	157.00 (11.00)
Maximum heart rate (beat/min)	183.00 (9.00)
Lactate (mmol/l)	4.70 (1.90)

Data shown as mean (SD).

Table 4 Specific on court training in badminton (n=6)

	Sg 1	Sg 2	Sg 3	Sg 4	Sg 5
Time (min)	12:0	9:0	12:0	6:0	10:0
Lactate (mmol/l)	8 (3)	9.3 (2.9)	10.5 (3.1)	10.4 (2.5)	8.7 (1.4)
Average heart rate (beat/min)	157 (3)	167 (4)	175 (4)	172 (4)	153 (8)

Lactate = NS. Average heart rate: \*\* Sg 1 v Sg 2, \*\* Sg 1 v Sg 3, \*\* Sg 1 v Sg 4, \*\* Sg 2 v Sg 5, \*\* Sg 3 v Sg 5, \*\* Sg 4 v Sg 5. \*\* P < 0.01. Data shown as mean (SD).

Three training sessions of each badminton player, and a total of 15 training sessions were monitored. Lactate measurements were made after the sets in each segment. Heart rate response was monitored by Sportstester-PE-3000, and blood samples for lactate analysis were drawn immediately after each workout of shadow play and multishuttle activity.<sup>15 16</sup>

BIOCHEMICAL ANALYSIS

Blood samples were taken from the antecubital vein by venipuncture. The samples were taken on the first day of the camp and 12 hours after each specific on court training session. Haemoglobin, urea, uric acid, and CPK were analysed by HITACHI UV-2000 spectrophotometer, using Boehringer Mannheim reagents.

STATISTICAL ANALYSIS

To establish the difference in specific on court training (lactate and average heart rate), one way analysis of variance was applied followed by Schaffe's post-hoc analysis.

To establish significance in the biochemical variables in "day to day training" and "off season values" a paired t test was applied.<sup>17</sup>

Results

Table 2 gives the descriptive data for the subjects. Table 3 gives the data obtained during match play. The mean (SD) duration of rallies was 4.6 (1.5) seconds with a mean (SD) rest of 9.7 (2.4) seconds. The mean (SD)  $\dot{V}O_2$  was 2.29 l/min, that is 57% of  $\dot{V}O_2$  maximum. Peak heart rate was 183 (9) beat/min and average heart rate was 157 (11) beat/min. Mean (SD) blood lactate during match play was 4.7 (1.9) mmol/l.

Analysis of on court training revealed that mean (SD) lactate values increased from the first to the third segment (8.0 (3.0) to 10.5 (2.5) mmol/l) in "shadow play". In "multishuttle" the blood lactate decreased in the fifth segment (8.7 (1.4) mmol/l) (table 4, fig 1). Mean (SD) heart rates of the five segments were 157 (3), 167 (4), 175 (4), 172 (4), and 153 (8) beat/min respectively. Mean heart rate peaked in the third segment, after which it decreased to the fifth segment. Peak lactate was found in the third segment. The duration of the third segment was 12 minutes, with a mean heart rate of 175 (4) beat/min. Average heart rates in training were significantly lower (p<0.01) in segment 1 and segment 5 compared with other segments. Lactate, however, did not show any significant difference when compared with other segments. However, the percentage increment between segment 1 and segment 2 was 16%, and in segment 3 it further increased by 12%. In segment 5 lactate concentration was reduced by 19% from 10.4 to 8.7 mmol/l when compared with segment 4.

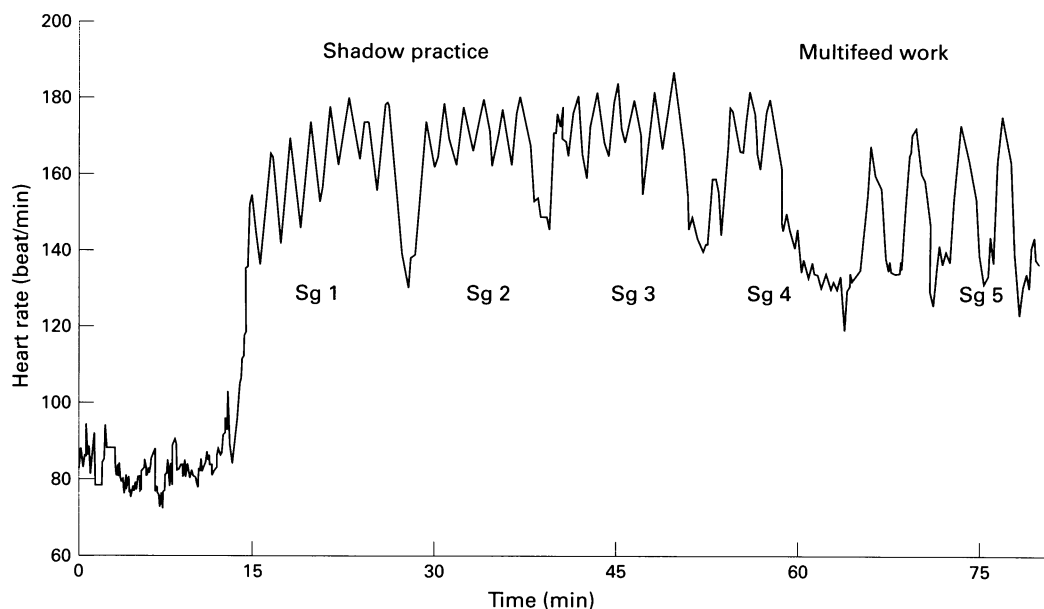


Figure 1 Example of heart rate response in on court technical training.

Table 5 Changes in biochemical variables in on court training

	Before	After	
Haemoglobin (g%)	15.47 (0.80)	15.75 (0.91)	NS
Urea (mg%)	29.50 (4.56)	32.90 (5.03)	*
Uric acid (mg%)	3.90 (0.66)	5.86 (0.96)	**
CPK (IU/l)	312.00 (211.8)	363.40 (216.2)	**

\*  $P < 0.05$ ; \*\*  $P < 0.01$ .

Table 5 shows the effect of regular monitoring of training on biochemical variables. It shows that urea has increased significantly from 4.93 (0.75) mmol/l to 5.49 (0.84) mmol/l ( $p < 0.05$ ). Uric acid concentration increased from 0.23 (0.04) to 0.33 (0.06) mmol/l ( $p < 0.01$ ). CPK also showed a significant ( $p < 0.01$ ) increment from 312 (211.8) to 363 (216.4) IU/l. The percentage increments of after training over before training values were 11%, 50%, and 16% for urea, uric acid, and CPK respectively. No significant changes were observed in haemoglobin, which in part shows there was comparatively little change in haemoglobin concentration.

### Discussion

Docherty<sup>18</sup> reported mean (SD) durations of 4.9 (1.3), 4.2 (0.5), and 4.9 (0.7) seconds per rally for badminton players of low, medium, and high

skill levels, respectively. The figures from Danish recreational badminton are also similar. This study is also in close agreement regarding the work-rest ratio (5.1 seconds : 9.3 seconds) observed by Coad *et al.*<sup>19</sup> The corresponding lactate values also indicate that the aerobic contribution to practice performed in this way is very high and aerobic system is instrumental in delaying the increase in blood lactate values. The high percentage of maximum heart rate sustained throughout the play depicts a considerable stress on the cardiovascular system. Mean oxygen uptake observed during the game was 2.29 (0.6l) minutes, which corresponds to proportionate loading of oxygen transport system (57% of  $\dot{V}O_{2\max}$ ), suggesting moderate strain on aerobic mechanisms. Bartunkova *et al.*<sup>20</sup> found a mean  $\dot{V}O_2$  value of 1.91 l/min in junior players,—that is 52% of  $\dot{V}O_{2\max}$ . Mean blood lactate during match play for Indian badminton players was 4.7 (1.9) mmol/l. The highest recorded value found by Mikkelsen<sup>3</sup> was 6.7 mmol/l. Low lactate readings may be caused by short intermittent exercise in which myoglobin can act as a short-term supplier of oxygen, particularly at the onset of activity.<sup>7</sup> The concomitant low blood lactate concentration shows that the players exhibit a high degree of aerobic fitness. The mean average heart rate of the

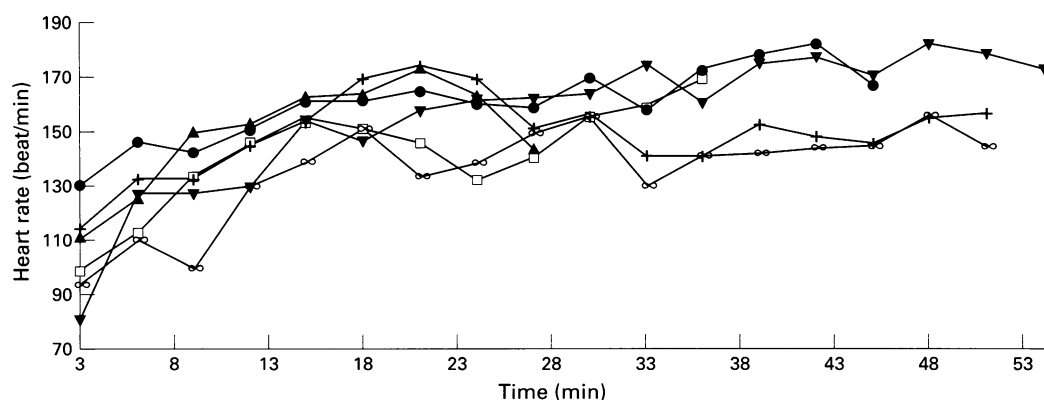


Figure 2 Heart rate response of badminton players in a game situation.

present subject players was 157 (11) beat/min (fig 2), Rittell and Waterloh<sup>21</sup> recorded higher values 175 (6) beat/min, although the play monitored may have been more intense. The present percentage of maximum heart rate was 85%, which is comparable to 80% of highly skilled players as reported by Docherty.<sup>18</sup> The average heart rate of Indian players during matchplay was 85% of maximum. Reilly<sup>10</sup> reported that the higher heart rate measured in badminton may result from the postural demands of isometric contraction in the game along with short recovery periods, which could lead to cause non-linearity of HR- $\dot{V}O_2$  relation, resulting in higher heart rate.

The high intensity work interval in on court technical training lasted for 40 to 50 seconds, a duration that is useful in overloading the glycolytic system. However, high lactate values of 8 to 10.5 mmol/l in different segments were noted in on court training. Multifeed shuttle practice with approximately one minute on: one minute off, work: rest ratio produced a blood lactate of 4.0–4.2 mmol/l in two players, while maximal shadow play sessions, (20 seconds on:40 seconds off) increased blood lactate to 7.2 mmol/l.<sup>7</sup> In this study, the higher lactate response (8–10.5 mmol/l) in shadow play is probably because of its lower technical requirement, allowing the player to operate at a greater exercise intensity than is possible for the multifeed work.

The demand of the game does not correspond to the training system as the maximum lactate seen by several authors ranges from 3–6 mmol/l.<sup>2,3,8</sup> Intense workouts can interfere with coordination, which is very important in sports requiring high technical skill such as badminton. Some authors recommended that the training intensity may be fixed below the lactate concentration of 6 mmol/l, because when coordination is disturbed, training could have negative effects on skills.<sup>22</sup> High lactate concentrations also inhibit fat oxidation when glycogen reserves are depleting.<sup>23</sup> The aerobic enzyme activity in the muscle cell is reduced by acidosis thus affecting aerobic endurance.<sup>21,24</sup> The training heart rate at various segments corresponds to actual demand, but as the duration was longer the production of lactate at various segment was high.

Urea level was increased by 11.5%, this increment may be caused by the possible involvement of protein, which is directly related to the availability of substrate. There was no significant changes in packed cell volume values (before 45.9 (2.5) and after 47.8 (2.7%)).

Uric acid significantly ( $P < 0.01$ ) increased after an exhaustive workout. Increased uric acid concentrations in the period after exercise reflects the prevailing energy state.<sup>25</sup> Excess uric acid production may lead to tissue damage because of free radicals, and may also contribute to the destruction of red cells.<sup>26</sup> An increase in uric acid of up to 50% shows the high intensity of the training programme workout.

CPK was significantly increased by 16.3%. As CPK is a large protein its presence in the blood indicates damage to the muscle cell membrane, which has been noted after intensive exercise.<sup>27,28</sup>

## Conclusion

This study concludes that the heart rate-lactate response in on court training rated relatively high compared with the game situation. Biochemical values (urea, uric acid, CPK) monitored to gauge the training intensity were also significantly higher in training. It should be noted that training that is too intense may have adverse effects on coordination and hence on skill practice.

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