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Heart Rate and Blood Lactate Responses during Execution of Some Specific Strokes in Badminton Drills

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The present article is an attempt to investigate the physiological demand of the most popular strokes, like, over head smash, over head toss, over head drop and the shadow movements in badminton drills on the basis of heart rate and blood lactate concentration. The study will certainly help the coaches and other specialists in finding out the demands and intensities of these badminton strokes and movements on the court. In the 1st phase of the study, VO_2max of all the players was determined in the laboratory following a graded exercise protocol on a bicycle ergometer, till exhaustion. The 2nd phase of the study consisted of playing over head smash, over head toss, over head drop and shadow movement on the court on different days. The player had to play on one side of the court and he was fed the shuttle from the opposite side. The heart rate was measured on a PE 3000 (Polar Electro, Finland) polar sport tester (heart rate telemetric device) for every 5 sec interval and the blood lactate concentration; on an YSI 1500 sport model lactate analyzer. The mean VO_2max of the present players was 57.4±7.02 ml/kg/min. The mean heart rates during overhead smash, overhead drop, overhead toss and shadow movements were 183±5, 180±6, 178±8 and 182±7 beats/min, while the mean blood lactate were 11.6±1.9, 10.2±1.2, 10.7±1.1 and 12.2±2.1 mMol/L, respectively. The study indicated that the heart rate and blood lactate responses during execution of overhead smash, overhead drop, overhead toss and shadow movements were high and no differences existed among them. Theses popular and common badminton strokes exertedhigh cardiovascular and metabolic stress on the players. Repetitive execution of these strokes during training may develop both the aerobic and anaerobic capacities of the players.

key words: *Blood lactate, Heart rate, Overhead drop, Overhead toss, Overhead smash, Shadow movement*

Introduction

Badminton is a popular game not only in the whole world, but also in Asian

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countries from where most of the World Champions emerged. The game contains execution of various strokes in combination with smooth and quick movements to the different corners of the court from the middle to secure points and win over the opponent. Most scientific works in badminton have been carried out on biomechanics and on physiology than any other sports science subjects.

Physiological studies have investigated the demands of badminton on the basis of heart rate (Coad et al., 1979, Mikkelsen, 1979, Abe et al., 1989; Kim et al., 2002), heart rate and blood lactate responses (Mikkelsen, 1979, Abe et al., 1990, Ghosh et al., 1990) and metabolic responses during simulated matches (Coad et al., 1979, Mikkelsen, 1979, Faccini and Dal Monte, 1996; Cabello et al., 2004). On the other hand, the biomechanical studies have mostly been carried out in match analysis and strokes and movement analysis (Gowitzke, 1978; Gowitzke & Waddell, 1977a, 1977b, 1978, 1979; Hong, 1993; Jack et al., 1978; Jack & Adrian, 1979). The characteristics of competitive badminton on the basis of energy requirements, temporal structures and movements in the game indicate the performance level (Cabello & Gonzalez-Badillo, 2003; Cabillo et al., 2004). However, the physiological studies on analysis of badminton strokes including the shadow movements on the court are scanty in the World Literature.

The present paper is an attempt to investigate the physiological demand and intensity of popular and common badminton strokes, like, over head smash, over head toss, over head drop and the shadow movements during on court drills on the basis of heart rate and blood lactate concentration. In a game, these drills are executed from the center of the court to different corners. The study will certainly help the coaches and other specialists in finding out the demands and intensities of execution of these strokes and movements on the court during badminton drills. The main hypothesis is to investigate the amount of stress being exerted by these drills on the cardiovascular and metabolic systems.

Method

Investigation Materials

The study was conducted on 8 national level players from India, with a playing experience of 6 – 7 yrs at national level. Hence it is hypothesized that these players will be able to execute the drills skillfully and correctly for a continuous period with minimum failure.

Design

The study was conducted in two phases. In the 1st phase of the study, VO_2 max of all the players was determined in the laboratory following a graded exercise protocol on a bicycle ergometer, till exhaustion. The initial load was 1 W/kg and was increased at 0.5 W/kg after 2 min, till exhaustion. The physiological parameters, like V_E, VO_2, VCO_2 and heart rate, were measured by the computerized metabolic analyzer, Oxycon Champion (Erich Jaeger, Germany), at every 15 sec interval.

The 2nd phase of the study was conducted on the indoor badminton court. All the players were explained about the protocol of the test. This phase consisted of playing over head smash, over head toss, over head drop and shadow practice (only movement on the court with the racket) on different days. The experimental subject should drop the overhead toss on the backline of the opponent court, overhead smash on the middle to last line of the opponent court and the overhead drop near the net of the opponent court. Each day 2 players were tested. The player (experimental) had to play on one side of the court and he was fed the shuttle from the opposite side by two other players (control) who were not tested on the same day. One control player would feed the shuttle at the back line of one corner of the court and the experimental player would return the shuttle executing required stroke from the back line, moving back from the center of the court. After executing the stroke, he would take position again in the center and the 2nd control player would feed another shuttle on the backline of different corner. The frequency of shuttle feeding was controlled by a metronome. 2 control players were kept for feeding the shuttle to maintain the high intensity. The experimental subject had to hit 8 shuttles fed by 2 control subjects in 15 sec. The players were briefed about the intensity of the shuttle feeding and the stroke. Each player played 3 sets and one set consisted of 10 repetitions of 15 sec activity followed by 30 sec rest, keeping in mind the work: and rest ratio, 1:2 in game situation (Coad et al, 1979). In between each set, 1 min rest was given. During shadow movements, the players did the same movement on the court with the racket, but without any shuttle (shadow). The player would start from the middle of the court to one corner and come back quickly to the middle to start for another corner. The duration and repetitions were similar to those followed during execution of strokes. The players were exhausted after 10 repititions, i.e., after 1 set. They were given 1 min rest pause before the start of 2nd set. In this phase, all the players were tested three times on different days on different strokes and movement. All the players completed all the tests through randomized order.

The heart rate was measured on a PE 3000 (Polar Electro, Finland) polar sport tester (heart rate telemetric device) for every 5 sec interval. Blood samples were collected from the finger tip after 1 – 1.5 min of each set (10 repetitions) and were analyzed on an YSI 1500 sport model lactate analyzer. The study was approved by the ethics committee of the National Institute of Sports, Patiala, India.

Statistical Analysis

Two way repeated measure ANOVA was applied to study the level of differences between strokes and between sets in peak heart rates and blood lactate responses. The same was applied in case of recovery heart rates against time and between strokes. Level of significance was kept at 0.05. Simple effect analysis was followed, in case of a significant interaction. Statistical analysis was performed on SPSS 12.0 software package.

Results

The physical and physiological characteristics of the present players are shown in Table 1. The mean VO_2max of the present players is comparable to the previous national level players studied by Ghosh et al., (1987) and a little lower than the International level players (Ømosegård, 1996).

Table 1: Physical and physiological profile of players

	Age	Ht	Wt.	HRmax	VO_2 max
	(yrs.)	(cm.)	(Kg.)	(b/min)	(ml/kg/min)
Mean	26.4	167.9	63.4	197.0	57.4
SD	1.77	3.27	5.53	6.65	7.02

The heart rate and blood lactate responses with mean and SD values during executing different strokes and shadow practice has been shown in Table 2. No statistically significant difference was observed. The mean and SD values of recovery heart rate are shown in Fig. 1. Though the recovery of the heart rate after overhead toss was faster, but repeated measure ANOVA did not reveal any significant differences between the strokes. This might be due to high SD values. However, a significant difference did exist against time. But that was not the objective of this study. All the physiological variables responded in the similar way during execution of various strokes including the shadow practice in badminton.

Table 2. *Heart rate and blood lactate concentration of the badminton Players during executing various strokes*

Badminton strokes	HR (b/min) Mean SD	Lac(mM/L) Mean SD
Over head Smash	183 5	11.6 1.9
Over head Drop	180 6	10.2 1.2
Over head Toss	178 8	10.7 1.1
Shadow	182 7	12.2 2.1

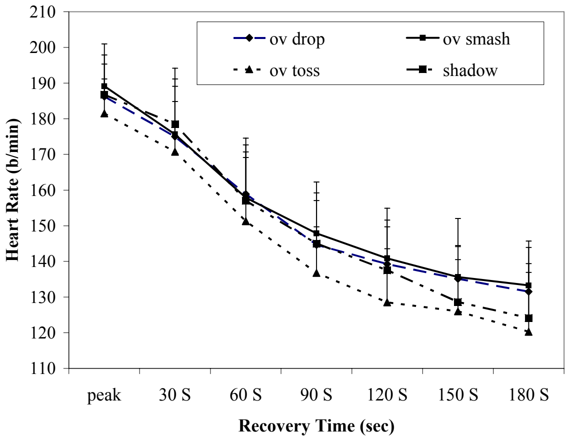

Fig 1. *Recovery heart rate (Mean ± SD) after execution of various badminton drills.*

Discussion

An optimum level of VO_2 max of the players indicated that they possessed the required aerobic capacity for the game. Since, the players have also played national level for the last 6-7 yr; it was hypothesized that they could successfully execute the proper stroke, without even minimum mistakes and the same were observed.

Various studies investigated the physiological demands of badminton using heart rate and blood lactate responses (Abe et al., 1990, Ghosh et al., 1990; Cabello & Gonzalez-Badillo, 2003; Kim et al., 2004) and also directly analysing the expired air during simulated matches (Abe et al., 1989; 1990, Faccini & Dal Monte, 1996). The scientists observed that 60 - 70% of the energy yield during play is derived from the aerobic system while 30% comes from the anaerobic systems (Faccini & Dal Monte, 1996). The statement is supported by the findings that in singles' badminton, the blood lactate in competitive games, range from 4 - 5 mMol/L (Mikkelsen, 1979, Ghosh et al., 1991; Cabello & Gonzalez-Badillo, 2003). These studies concluded that badminton players play at a high percentage of their maximal aerobic power (VO_2max), at or very close to maximum heart rate (especially in singles) but have only a moderate energy yield from the anaerobic lactic acid system. The relatively low blood lactate readings (Mikkelsen, 1979, Ghosh et al., 1991), when players are working close to maximum heart rate, have been explained by the role of myoglobin in acting as a store of oxygen to provide energy (Mikkelsen, 1979) and oxidation of muscle lactate in the rest periods between rallies (Ghosh et al., 1990; Faccini & Dal Monte, 1996).

Lo & Stark(1991) suggested that the work-rest ratio in badminton was 1:2, with average rallies varying from 7-10 sec. In the present study, a 15 sec rally was designed keeping in mind that the maximum rally time was 15 sec. (Coad et al., 1979), with a rest pause of 30 sec. to keep the ratio of rally and rest at 1:2. The 3 most popular badminton strokes like, overhead smash, overhead drops, overhead toss and shadow practice (the most common on the court training) were selected in the present study.

The mean heart rates during overhead smash, overhead drop, overhead toss and shadow practice were 183, 180, 178 and 182 beats/min, respectively and closely reflects the average maximum heart rate in game situation. The average age of the players was 26 yrs. and the maximum heart rate hypothetically should be 220-26, i.e., 194 beats/min. Previous studies showed that the heart rate of badminton players during game showed a near maximal value (Coad et al., 1979; Mikkelsen, 1979; Ghosh et al., 1990). The heart rate of the players during execution of different strokes also showed near maximal values, ranging between 90-94 % of maximum heart rate. Heart rate response concluded that all the 3 strokes and the shadow movement in badminton exerted similar stress on the heart and were equally demanding. The badminton strokes were executed during movements originating from the middle of the court to the corner where the shuttle is being placed by the opponent player. After executing the stroke the experimental player returned back to the middle of the court again. Probably due to this fact, there were no significant differences in the heart rate and blood lactate concentration during execution of different strokes.

The mean blood lactate response also showed the similar response and no statistical difference was observed among the different strokes. The mean blood lactate accumulation were 11.6, 10.2, 10.7 and 12.2 mMol/L during overhead smash, overhead drops, overhead toss and shadow movement, respectively. In this study, the blood lactate is also indicating that execution of badminton strokes repeatedly were more demanding than playing a singles game when blood lactate responses ranged from 4-5 mMol/L (Mikkelsen, 1979; Ghosh et al., 1990) in elite players. During game, the rallies and rest pauses vary and in the present study the rally and rest pauses were fixed. In the present study, each player had to execute the badminton strokes against two opponents continuously for 15 sec with 30 sec rest pause. Likewise, there were 10 such repetitions which were considered as one set and there were 3 similar sets. In between sets there was 1 min rest. Both the heart rates and blood lactate concentrations denoted the intensity as high intensity badminton drill. Spriet (1995) suggested that in 10 seconds of maximal activity the role of glycolysis may be more important than was previously thought. The implications on the bioenergetics of badminton may therefore suggest a greater reliance on the anaerobic lactic energy system if the average rally length is increased. It would be good to gain some intra-muscular evidence of what is happening in regards to the energy systems at elite level badminton but the logistics of this might make it impossible. Dias & Ghosh(1995) and Mazumdar et al.(1997) observed higher blood lactate accumulation during on court training in badminton than usual badminton match play. The present study and other studies concerning training indicated that high intensity training is required to sustain a single badminton game.

In this study, another approach was made to differentiate the load of various strokes in badminton. The recovery heart rate was measured for 3 min after execution of various strokes (Fig 1). Similar heart rate recovery pattern after execution of different strokes, also confirmed that the repetitive execution of badminton strokes imparted high stress on cardiovascular system. All the physiological variables responded in the similar way during execution of various strokes including the shadow practice in badminton.

It is concluded that the heart rate and blood lactate responses during execution of overhead smash, overhead drop, overhead toss and shadow movements were high and no differences in the physiological variables existed among them. The activities analyzed in this study imparted high load on both the cardiovascular and metabolic processes and repetitive execution of these strokes as a part of the training might improve both the aerobic and anaerobic glycolytic systems in badminton players.

References

Abe, K., Haga, S., Kato, M., Nakatani, T., Ikarugi, H., Ushiyama, Y., & Togashi, K. (1989). The Work Intensity of a Badminton Match in Japanese Top Female Athletes. *Bulletin of Health & Sports Sciences*, University of Tsukuba, **12,** 107-114.

Abe, K., Haga, S., Nakatani, T., Ikarugi, H., Ushiyama, Y., Togashi, K., & Ohta, K. (1990). The Work Intensity of Badminton Match in Japanese Top Male Players. *Bulletin of Health & Sports Sciences*, University of Tsukuba, **13**, 73-80.

Cabello, D., & Gonzalez-Badillo, J. J. (2003).Analysis of the characteristics of competitive badminton. *British Journal of Sports Medicine,* **37**, 62-66.

Cabello, D., Padial, P., Lees, A., & Rivas, F. (2004). Temporal and physiological characteristics of elite women's and men' single badminton. *International Journal of Applied Sports Sciences*, **16**, 1-12.

Coad, D., Rasmussen, B., & Mikkelsen, F. (1979). Physical Demands of Recreational Badminton. In: *Proceedings of a National Symposium on the Racket Sports*: an exploration of research implications and teaching strategies, Ed. J. L. Groppel. University of Illinois, Urbana-Champaign. Pp. 43-54.

Dias, R., & Ghosh, A. K. (1995). Physiological evaluation of specific training in badminton. In : Reilly T, Hughes, M. and Lees A. (eds.) *Science and Racket Sports.* E & FN Spon, London, p 38-43.

Docherty, D. (1978). Heart Rate Response of Badminton Players Relative to their Skill Level.

Canadian Journal of Applied Sport Sciences, **3**, 220-222.

Faccini, P., & Dal Monte, A. (1996). Physiologic Demands of Badminton Match Play. *American Journal of Sports Medicine* 24:Suppl., S64-S66.

Ghosh, A. K., Khanna, G. L., Ahuja, A., & Puri, T. P. S. (1987). Physiological variables of Indian national badminton players at anaerobic threshold level - *World Badminton,* 15, 4, 16.

Ghosh, A. K., Mazumbar, P., Goswami, A., Ahuja, A., & Puri, T. P. S. (1990). Heart Rate and Blood Lactate Response in Competitive Badminton. *Annals of Sports Medicine,* 5, 85-88.

Gowitzke, B. A., & Waddell, D. B. (1977a). Analysis of Overhead Badminton Power Strokes Using High Speed Bi-Plane Photography. In: Selected Papers Presented at the International Coaching Conference, Malmö, p11.

Gowitzke, B. A., & Waddell, D. B. (1977b). The Contributions of Biomechanics in Solving Problems in Badminton Stroke Production. In: Selected Papers Presented at the International Coaching Conference, Malmö, p10.

Gowitzke (1978). Biomechanical Principles Applied to Badminton Stroke Production. In: Science in Racket Sports. International Congress of Sports Sciences, Ed. J. Terauds, Edmonton. p. 7-15.

Gowitzke, B. A., & Waddell, D. B. (1978). Technique of Badminton Stroke Production. In: Science in Racket Sports - International Congress of Sports Sciences, Ed. J. Terauds, Edmonton. p. 17-41.

Gowitzke, B. A., & D. B. Waddell (1979). Qualitative Analysis of the Badminton Forehand Smash as Performed by International Players. In: Proceedings of a National Symposium on the Racket Sports: an exploration of research implications and teaching strategies, Ed. J.L. Groppel. University of Illinois, Urbana-Champaign. p. 1-16.

Hong, Y. (1993). The Biomechanics of Badminton Smash Technique. In: Abstracts of the International Society of Biomechanics, XIVth Congress, Paris. Vol 1. Pp. 588-589.

Hughes, M. G. (1995). Physiological Demands of Training in Elite Badminton Players. In: Science and Racket Sports. Ed. T. Reilly, M. Hughes & A .Lees. E. & F.N. Spon, London. Pp. 32-37.

Jack, M., Adrian, M., & Yoneda, Y. (1978). Selected Aspects of the Overarm Stroke in Tennis, Badminton, Racquetball, and Squash. In: Science in Racket Sports - International Congress of Sports Sciences, Ed. J. Terauds, Edmonton. Pp. 69-80.

Jack, M. & Adrian, M. (1979). Characteristics of the Badminton Smash Stroke. In: Proceedings of a National Symposium on the Racket Sports: an exploration of research implications and teaching strategies, Ed. J.L. Groppel. University of Illinois, Urbana-Champaign. Pp. 27-42.

Kim, Y. C., Sung, H. K., & Gu, H. M. (2002) Heart rate responses during badminton single matches. *International Journal of Applied Sports Sciences,* **14**, 36-45.

Liddle, S. D., Murphy, M. H., & Bleakley, W. (1996). A Comparison of the Physiological Demands of Singles and Doubles Badminton - A Heart Rate and Time Motion Analysis. *Journal of Human Movement Studies,* **30**, 159-176.

Lo, D., & Stark. K. (1991). The Badminton Overhead Shot. *National Strength and Conditioning Association Journal.* **13(4)**, 6-13, 87-89.

Majumdar, P., Khanna, G. L., Malik, V., Sachdeva, S., Arif, M., & Mandal, M. (1997). Physiological analysis to quantify training load in badminton. *British Journal of Sports Medicine* Dec, **31(4)**, 342-5

Mikkelsen, F. (1979). Physical Demands and Muscle Adaptation in Elite Badminton Players. In: Proceedings of a National Symposium on the Racket Sports: an exploration of research implications and teaching strategies, Ed. J.L. Groppel. University of Illinois, Urbana-Champaign. Pp. 55-67.

Ømosegård, B. (1996). Physical Training for Badminton. Malling Beck A/S-International Badminton Federation.

Spriet, L. L. (1995). Anaerobic Metabolism During High-Intensity Exercise. In: Exercise Metabolism, Ed. M. Hargreaves, Human Kinetics, Champaign, Il. Pp. 1-40.