Metabolic and Hormonal Responses, and Fluid and Electrolyte Status Following Badminton Matches in Junior Players Implications for Player Recovery

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Keywords: Badminton, Metabolic and Hormonal response, Fluid-Electrolyte status, Recovery

Introduction

Playing competitive badminton can be characterized by sporadic efforts of moderate to high intensity caused by a series of repetitive actions of short duration but of high speed (Cabello, et al., 1977) comparable to other sports with similar characteristics such as squash, tennis and volleyball (Sanchis et al., 1998; Galiano et al., 1996). The demand or intensity of a game is generally studied from the time-motion analysis or from physiological responses such as, heart rate, blood lactate, glycogen depletion, hormonal responses, etc. Previous research has analysed the characteristics and effort in training and competition in racket sports such as tennis (Galiano et al., 1996; Chrsitimass et al., 1994), and squash (Sanchis et al., 1998).

The physiological responses of badminton matches can be quantified by heart rate and levels of lactic acid concentration in the blood during and immediately after play (Kim et al., 2002; Bangsbo, 1996; Tabata, 1997; Gosh et al., 1990). The physiological demands on badminton players during training and matches have also been widely investigated (Araragi, Omori, & Iwata, 1999; Cabello et al., 2004; Cabello-Manrique& Gonzalez-Badillo, 2003; Faccini& Dal Monte, 1996; Faude et al., 2007; Hughes, 1995), with some of these research specifically focused on analysis of heart rate and blood lactate responses during training or simulated badminton competition (Smith & Chang, 1999, Ghosh et al., 1990). Studies have also attempted to evaluate the physiological and metabolic demands of competitive badminton (Abraham, 1991; Ramachandran, 1996; Cabello, et al., 2004; Manrique and Gonzalez-Badillo, 2003).

Badminton matches like any other high intensity sport competition causes acute hormonal responses (Filaire et al., 2009; Salvador et al., 2003). Exercise protocols high in volume, moderate to high in intensity, using short rest intervals and stressing a large muscle mass, tend to produce the greatest acute hormonal elevations (e.g. testosterone, GH and the catabolic hormone cortisol). Badminton being a high intensity intermittent activity, would definitely affect hormonal responses.

Fluid and electrolyte imbalances following matches have importance for players' recovery of fluid homeostasis. In badminton tournaments, especially at the junior level, players are involved in successive matches in a day. This definitely puts high physical and physiological demands on the players, who may not get enough time for proper recovery to pre-levels. How prepared the badminton player is to meet such a high demand of competition in repeated succession and how much resource and energy a player has in handling the demands of successive competition are questions that need to be critically examined in terms of a player's fluid-electrolyte imbalances post exercise and the recovery before the next successive match.

Metabolic responses including lactate concentration, glycogen depletion; and hormonal responses including serum testosterone, serum cortisol, and growth hormone during exercise are also critically important in understanding the physiological responses to match play. Metabolic acidosis, accelerated rate of glycogen depletion in the muscle and reduction in energy charge, can be revealed by the study of metabolic process and hormonal responses before, during and after match play and the kinetics of lactate removal and hormone levels will represent a powerful tool to understand the demand and intensity of the game in terms of metabolic and hormonal regulation.

Few studies have been undertaken to find the cumulative responses and pattern of metabolic and hormonal responses and fluid imbalance following badminton matches. The present research would not only add to the existing knowledge of the demands of the game, but also lay foundation for understanding the metabolic and hormonal responses, fluid and electrolyte imbalances following badminton tournament. The study results would provide clear feedback for recovery of badminton players involved in successive matches in a tournament.

The study was specifically concerned with answering the following research questions for junior players:

1. What metabolic responses are affected from pre-game to post match levels following singles matches in badminton?
2. What hormonal responses are affected from pre-game to post match levels following singles matches in badminton?
3. How much fluid and electrolyte imbalance occurs from pre-game to post match levels following singles matches in badminton?
4. What is the pattern of recovery of metabolic and hormonal responses and fluid and electrolyte levels after singles matches during a recovery period of 30 minutes?

The outcomes of the study, while providing the demands of the singles match play, would also provide valuable knowledge for developing scientific training schedule for junior badminton players. The study results would also provide valuable inputs regarding the post match recovery patterns and would make the coaches and players probe for effective mechanisms for active and quick recovery following matches.

The present study is timely considering the extreme popularity of badminton especially at the junior level. Badminton competitions are so intense at the junior level that players participate and compete in three to four events in the same tournament. Answers to the questions posed above would be of practical value to players, coaches and parents of junior level players.

Materials and Methods

Participants

Eight competitive singles players (4 male and 4 female; Mean ± SD age: 15 ± 0.85 years; height165.56 ± 7.26 cm; body mass 60.35 ± 6.79 kg) playing at the junior national level circuit in India volunteered to participate in this study. Two female players had been participating at the junior international level competitions while the others were national ranked players. The participant players were briefed about the requirement and purpose of the study. The information sheets and agreement forms were signed by the participants and prior consent obtained from the coaches and parents. Ethical clearance was obtained from the departmental ethics committee before commencement of the study.

Experimental Design

After obtaining the descriptive data on age, height and body mass, the players participated in a round robin tournament for singles matches organized for the purpose of the study. Employing a descriptive design, data on selected metabolic, hormonal and fluid and electrolyte variables were taken for pre-match, immediate post match and thirty minutes post match recovery.

Experimental Procedures and Measurements

After the participants arrived at the badminton courts and they were asked to provide a urine sample, and then their body mass (pre-match body mass) was measured using a set of precision balance scales. Blood samples were taken from antecubital vein in a sitting position.

The participants then completed a standard 5-minute match warm-up, which included players jogging, stretching, shadow practice, and strokes. Subsequently, they played best of three singles matches against competitively matched opponent on league basis. Stop watches were operated for the entire time of the match and also noted for the rest periods in between. The subjects were asked to consume only water during the matches. The amount of water consumed was measured and weighed for estimating the fluid intake during match play.

Once the match had been completed, post-match capillary blood sample were taken using the protocol outlined previously. The subjects then provided another urine sample prior to their final body mass being recorded. Subjects were instructed to towel themselves down before weighing to remove any excess sweat. The sweat rate was obtained by the difference in the body mass measured before and after the matches divided by the total time duration of the match.

The blood samples were assessed for plasma glucose, plasma lactate, serum sodium, serum potassium and serum ionized calcium. The urine sample were analyzed for urine specific gravity, urine sodium and urine potassium. Blood samples were analyzed for hormonal responses of serum testosterone, serum cortisol, and growth hormone. The blood and urine samples were analyzed in the laboratory immediately using standard laboratory techniques.Heart rate was recorded throughout the match using Polar Sport tester (V800) to obtain maximum and average heart rate of each player during the different stages of match and post match recovery period. Blood samples drawn were analysed for the selected metabolic and hormonal variables pre match, post match and 30 minutes recovery post match. Total playing time was registered by the heart rate monitor as well as by video recording of each match, from which the real playing time was estimated.

The temporal structure was obtained from subsequent analysis of videotaped matches by calculation of work interval or performance time, average rest interval or rest time, and work density (ratio of performance time to rest time).

Statistical Analysis

Data were analyzed by Statistical Package for Social Sciences SPSS (Version 20). The Shapiro-Wilk test was applied to the data in order to assess for a normal distribution. The pre match, post match and post match recovery data were analyzed by one way analysis of variance. The Tukeys (HSD) post hoc test was used for multiple comparisons. The Levene's test was used to test homogeneity of variance. The F ratios were adjusted using the Welch statistic in cases where the equal variance assumptions were not met, and the Games-Howell post hoc test was used to test the differences between paired means. An alpha level of $p < 0.05$ was considered statistically significant. All data are reported as mean and standard deviations (M ± SD).

Results

The analysis of Shapiro-Wilk test ($p < 0.05$) indicated that the assumptions of normality were met in case of all the variables (see Table 1). Additionally homogeneity of variance assessed by Levene's test indicated that assumption of homogeneity of variance was violated in case of serum cortisol, and serum urine specific gravity (in case of male); and serum potassium in case of females ($p > 0.05$). So in case of these variables the F ratios were adjusted using the Welch statistic.

Table 1. Shapiro Wilk Test for Normality (W parameter, p-value)

Variables	Male		Female	
	W	p	Wp	
Body Mass	0.874	0.074	0.877	0.079
Heart Rate	0.861	0.050	0.878	0.084
Plasma Glucose	0.931	0.393	0.929	0.368
Plasma Lactate	0.904	0.180	0.959	0.764
Serum Sodium	0.920	0.288	0.906	0.187
Serum Potassium	0.951	0.798	0.922	0.306
Serum Ionized Calcium	0.900	0.156	0.916	0.256
Urine Specific Gravity	0.884	0.393	0.875	0.077
Urine Sodium	0.934	0.425	0.904	0.180
Urine Potassium	0.951	0.655	0.977	0.966
Serum Testosterone	0.901	0.163	0.928	0.364
Serum Cortisol	0.914	0.240	0.963	0.819
Serum HGH (Growth Hormone)	0.873	0.071	0.895	0.137

Average sweat rate of 0.99 ± 0.38 l/h in case of male badminton players and 1.23 ± 0.19 l/h in case of female players were observed during the singles matches. The average rate of fluid intake in men's singles was 0.28 ± 0.10 l/h as compared to 0.20 ± 0.09 l/h in women's singles. The changes in body mass, sweat rate and fluid intake of the players showed large variability from individual to individual. The average durations of matches were 34.75 ± 6.03 minutes in men's singles and 30.0 ± 5.91minutes in women's singles. The average work time in case of men's singles was 6.8 ± 0.9 s and 6.2 ± 1.4 s in case of women's singles. The average rest time in case of men's singles was 13.2 ± 2.1 s and 12.3 ± 3.5 s in case of women's singles. The work-rest ratio was 0.54 ± 0.05 in case of men's singles and 0.47 ± 0.07 in case of women's singles. The average environment temperature during the days of matches was 28.06 ± 1.80 degree centigrade with an average humidity of 38.10 ± 7.20%.

The statistical analysis for metabolic and hormonal responses in case of male badminton players demonstrated significant differences for the pre match, post match and thirty minutes post match recovery values in case of heart rate ($F(2,9) = 130.30$, $p < 0.05$); plasma lactate ($F(2,9) = 13.95$, $p < 0.05$) and serum human growth hormone ($F(2,9) = 10.88$, $p < 0.05$) (See Table 2).

In case of female badminton players, significant differences for the pre-match, post match and thirty minutes post match recovery were observed in case of heart rate ($F(2,9) = 134.33$, $p < 0.05$); plasma lactate ($F(2,9) = 44.34$, $p < 0.05$); serum cortisol ($F(2,9) = 30.63$, $p < 0.05$); and serum human growth hormone ($F(2,9) = 24.91$, $p < 0.05$) (Table 3).

Table2. Descriptive Statistics (Mean ± SD) of Body weight and Metabolic and Hormonal Responses for the Pre, Post and 30 Minutes Recovery of Male Badminton Players

Variables	Pre match	Post match	Recovery (30 mts)
Body mass (kg.)	63.15 ± 9.46	62.65 ± 9.23	62.77 ± 9.89
Heart rate (beats/min)	89.50 ± 10.78	182.50 ± 6.45[a]	115.00 ± 7.39[b,c]
Plasma glucose (mmol/l)	4.41± 0.44	4.65 ± 0.37	4.95 ± 0.14
Plasma lactate (mmol/l)	1.38 ± 0.37	4.02 ± 0.46 [a]	2.55 ± 1.07[b,c]
Serum Na (mmol/l)	139.5 ± 1.91	138.7 ± 1.71	138.5 ± 1.29
Serum K (mEq/l)	4.70 ±0 0.32	4.33 ± 0.42	4.26 ± 0.32
Serum Ca (mg/dl)	10.22 ± 0.57	10.20 ± 0.69	1.01 ± 0.53
Urine specific gravity	1.013 ± 0.0004	1.022 ± 0.0006	1.015 ± 0.007
Urine Na (mmol/l)	159.75 ± 40.97	93.50 ± 36.70 [a]	98.75 ± 16.60
Urine K (mmol/l)	88.75 ± 25.68	57.25 ± 33.76	95.00 ± 29.06
Serum testosterone (ng/ml)	2.51 ± 0.92	2.86 ± 1.49	2.39 ± 1.53
Serum Cortisol (ug/dl)	7.57 ± 1.85	13.28 ± 3.37 [a]	9.51 ± 2.14
Serum HGH (ng/ml)	1.29 ± 1.30	14.97 ± 6.78 [a]	5.66 ± 2.48[b]

Abbreviations: NA = Sodium; K = Potassium; Ca = Calcium; HGH = Human Growth Hormone
[a] $p < 0.05$, compared with values of pre match (pre to post)
[b] $p < 0.05$, compared with values of post match (post to 30 minutes recovery)
[c] $p < 0.05$, compared with values of pre match (post to pre match)

No significant changes were found for other metabolic and hormonal variables namely plasma glucose, serum sodium, serum potassium, serum calcium, urine specific gravity, urine potassium and serum testosterone from pre to post match or post match to thirty minutes recovery period. ($p > 0.05$, Tables 2 & 3).

Heart rate values increased significantly from pre to post match in case of both male and female players ($p < 0.05$). Heart rate values decreased significantly from post match level to 30 minutes recovery period in case of both male and female badminton players, but failed to reach pre match levels ($p < 0.05$). The average heart rate of 178 beats.min^{-1} and 172 beats.min^{-1} respectively for male and female players during matches signified the high cardiovascular demand of badminton singles matches.

Table 3. Descriptive Statistics (Mean ± SD) of Body mass and Metabolic and Hormonal Responses for the Pre, Post and 30 Minutes Recovery of Female Badminton Players

Variables	Pre match	Post match	Recovery (30 mins.)
Body mass (kg.)	58.12 ± 3.23	57.17 ± 3.18	57.85 ± 3.22
Heart rate (beats/min)	87.25 ± 8.22	180.50 ± 9.81[a]	115.5 ± 6.35[b,c]
Plasma glucose (mmol/l)	3.99 ± 0.25	4.26 ± 0.64	4.47 ± 0.48
Plasma lactate (mmol/l)	1.43 ± 0.24	3.50 ± 0.37[a]	2.53 ± 0.31[b,c]
Serum Na (mmol/l)	139.8 ± 1.26	139.8 ± 0.96	139.0 ± 0.82
Serum K (mEq/l)	4.41 ± 0.18	4.13 ± 0.21	4.40 ± 0.23
Serum Ca (mg/dl)	9.63 ± 0.15	9.57 ± 0.36	9.40 ± 0.33
Urine specific gravity	1.017 ± 0.003	1.018 ± 0.005	1.018 ± 0.005
Urine Na (mmol/l)	148.70 ± 89.76	145.75 ± 83.82	94.00 ± 58.56
Urine K (mmol/l)	67.25 ± 18.99	94.50 ± 16.54	84.00 ± 8.75
Serum testosterone (ng/ml)	0.207 ± 0.12	0.300 ± 0.13	0.257 ± 0.13
Serum Cortisol (ug/dl)	7.48 ± 1.82	12.94 ± 1.29[a]	9.45 ± 1.68[b]
Serum HGH (ng/ml)	2.11 ± 2.10	5.94 ± 1.29[a]	1.26 ± 0.33[b]

Abbreviations: NA = Sodium; K = Potassium; Ca = Calcium; HGH = Human Growth Hormone

[a] $p < 0.05$, compared with values of pre match (pre to post)

[b] $p < 0.05$, compared with values of post match (post to 30 minutes recovery)

[c] $p < 0.05$, compared with values of pre match (post to pre match)

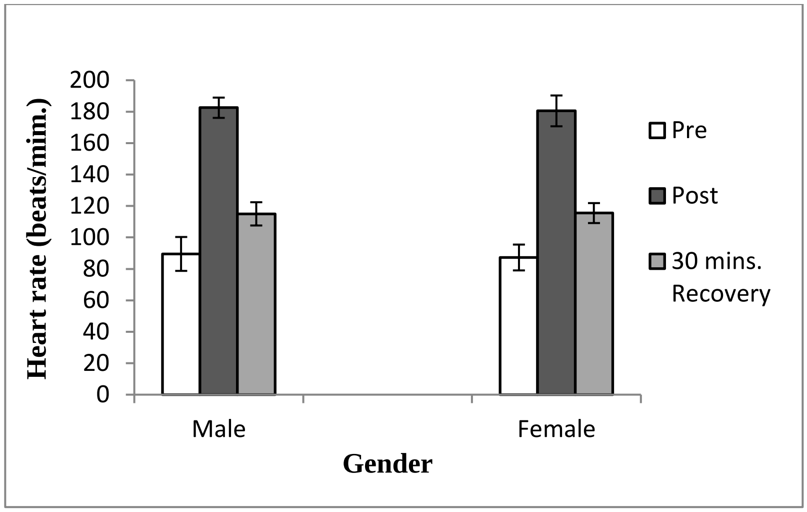

Figure 1. Heart rate responses for pre match, post match and thirty minutes post match recovery

Mean plasma lactate concentrations increased significantly from pre to post match levels ($p < 0.05$) in case of both male and female badminton players. The mean post match lactate concentrations were 4.02 ± 0.46mmol/l and 3.50 ± 0.37 mmol/l respectively in case of male and female badminton players. Plasma lactate levels showed significant decrease ($p < 0.05$) from post match to thirty minutes recovery period in both male and female badminton players. However the values were significantly higher than the pre match lactate levels ($p < 0.05$, Tables 2 & 3).

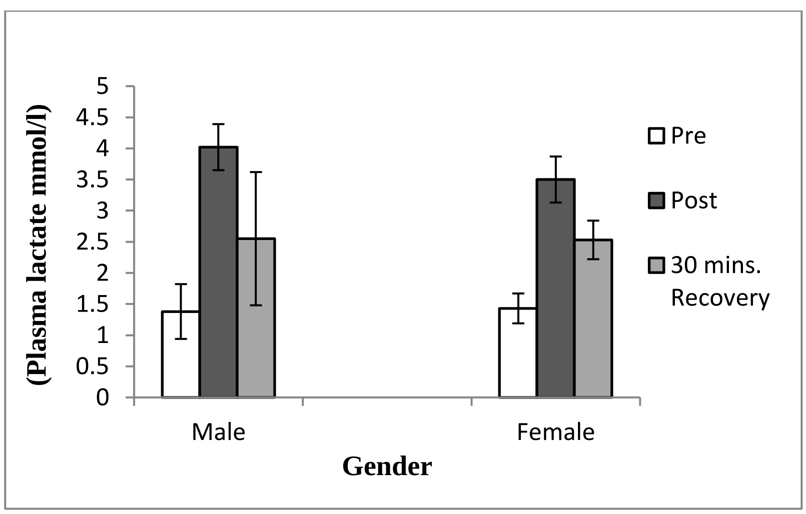

Figure 2.Plasma lactate responses for pre match, post match and thirty minutes post match recovery

Urine sodium showed significant decrease from pre to post match levels in case of male badminton players ($p < 0.05$). Serum cortisol concentration and serum human growth hormone (HGH) concentrations was significantly elevated post match in case of both male and female badminton players ($p < 0.05$). Serum HGH significantly decreased from post match to thirty minutes recovery period in case of male badminton players ($p < 0.05$); while thirty minutes post recovery cortisol levels showed significant decrease from post match levels in case of male and female badminton players ($p < 0.05$).

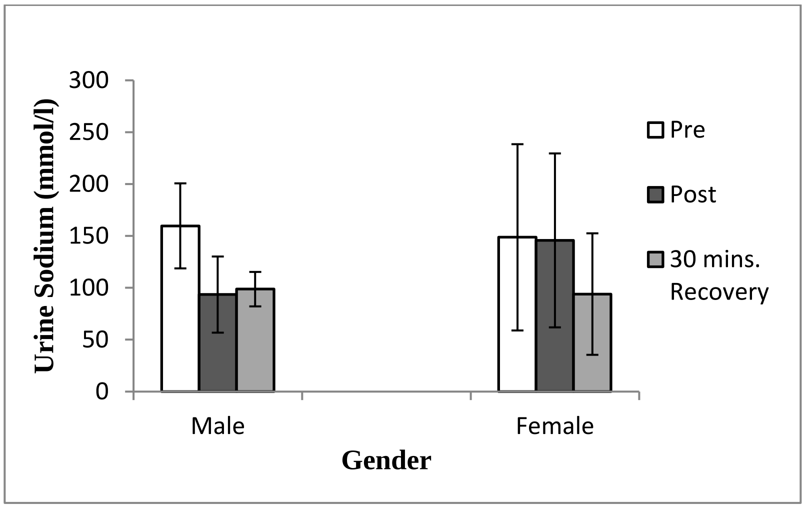

Figure 3. Urine sodium levels for pre match, post match and thirty minutes post match recovery

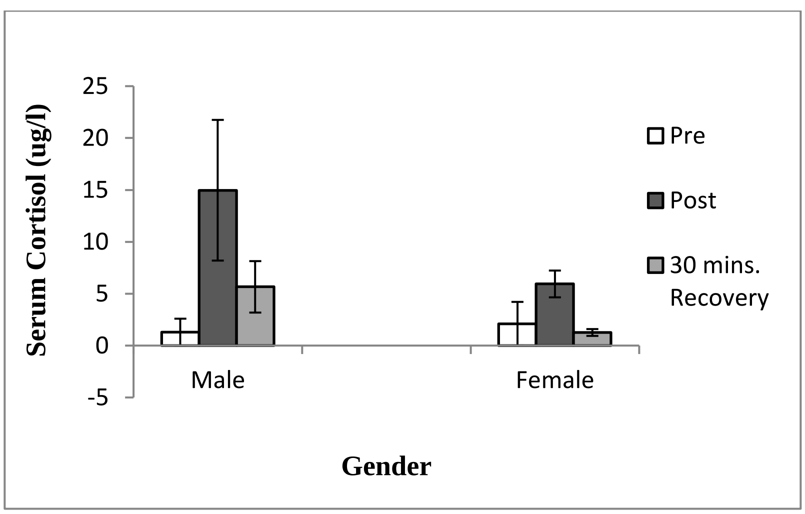

Figure 4. Serum cortisol levels for pre match, post match and thirty minutes post match recovery

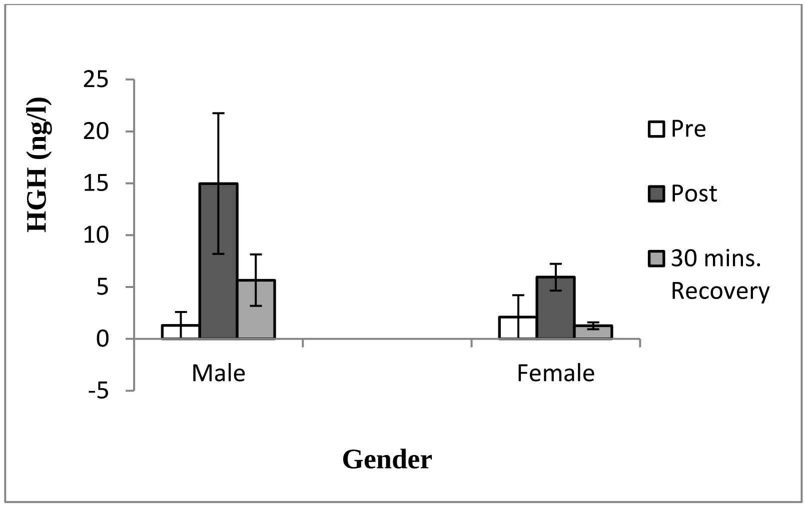

Figure 5.Serum growth hormone levels for pre match, post match and thirty minutes post match recovery

Discussion

The matches were played on wooden surface flooring with moderate mean environment temperature (28.06 ± 1.80^{0}C) with an average humidity of 38.10 ± 7.20%. The mean match playing time was 34.75 ± 6.03 mins in case of men's singles and 30.0 ± 5.91mins in case of women's singles.

Metabolic responses

The post match lactate concentrations showed a mean of 4.02 mmol/l in case of male players and 3.50 mmol/l in case of female badminton players. These values are comparable to the values found in the study by Gosh et al. (1993) in 13-14 year old female national players. The higher lactate concentrations in badminton confirm that periodic increases in exercise intensity during rallies which results in more glycolytic activity. Rallies of high intensity and long duration are likely to have caused a prompt increase in lactic acid production (Bergeron et al., 1991). The lactic acid concentrations observed in the present study were lower than as reported by Cabello et al. (2000) in top level Spanish players (7.1 mmol/l).The participants in the present study were players in the junior level with mean age of 15 ± 0.85 years. Age, fitness and training levels; and the quality and intensity of matches being played determine the lactate production to a greater extent. Lactate concentration is also depended on the work density in terms of playing time and rest time. The average heart rate of 178 beats.min^{-1} and 172 beats.min^{-1} respectively for male and female players indicates the high intensity at which the matches were played. The maximum heart rate in case of male players was 204 beats.min^{-1} and 200 beats.min^{-1} in case of female players. The heart rate values showed significant decline from post match to 30 minutes recovery ($p > 0.05$), however did not reach baseline level (pre-match). The average work time in case of men's singles was 6.8 ± 0.9 s and 6.2 ± 1.4 s in case of women's singles. The average rest time in case of men's singles was 13.2 ± 2.1 s and 12.3 ± 3.5 s in case of women's singles. The work-rest ratio of 0.54 and 0.47 for men and women matches are comparatively lesser than those reported by Carlson et al. (1985) (men: 0.75 and women 0.8) in Australian players and Cabello et al.(1995) (0.65) for top Spanish players. So a relatively lower work density and the intermittent nature of the game, with the frequently interspersed longer rest intervals might be one of the reasons for decreased lactate concentration despite higher intensity of heart rate at which the matches were played.

Lactate levels were significantly reduced form post match to 30 minutes post match recovery (4.02 ± 0.46 post match, 2.55 ± 1.07 recovery; $p > 0.05$) in case of male players; (3.50 ± 0.37 post match, 2.53 ± 0.31 recovery; $p > 0.05$) in case of female players. However the lactate levels during 30 minutes recovery did not reach baseline (pre-match levels) (1.38 ± 0.37 pre-match male, 1.43 ± 0.24 pre-match female. $p > 0.05$).The passive recovery of the subjects in the present study might be one of the reasons for lower lactate removal. Moreover, thirty minutes may not be sufficient period for lactate clearance following high intensity activity such as badminton matches. The time course of lactate removal is at least one hour to remove most of the accumulated lactate acid changes (Karlson, 1971; Fox, 1969). Moreover, lactate clearance is accelerated by post match active recovery exercises as compared to passive recovery.

No significant differences were observed in the dynamics of plasma glucose variations from pre to post match; and from post match to thirty minutes recovery period. However plasma glucose levels showed slightly increased values post match in case of both male and female players after singles matches. Elevated glucose levels have been observed following soccer matches (Bangsbo, 1992). This probably suggests that the rate of glucose release from liver is high enough to compensate the use of blood glucose during badminton matches.

Fluid and Electrolyte Concentrations

The sweat rate of the players in the present study was 0.99 ± 0.38 l/h in case of male badminton players and 1.23 ± 0.19 l/h in case of female players. The matches of the present study were played in moderate temperature of 28.06 ± 1.80^{0}C with an average humidity of 38.10 ± 7.20%. The lower sweat rate obtained in the present study as compared to other studies (Triplet et al., 2011 and Maughan et al., 2005) where the environmental temperature was relatively higher (32^{0}C and 30^{0}C) respectively. There was no significant difference in body mass pre-to post match (63.15 ± 9.46 pre, 62.65 ± 9.23 kg post; $p > 0.05$) in men players; and (58.12 ± 3.23 pre, 57.17 ± 3.18 kg post; $p > 0.05$) in women players, which represented a dehydration status of 0.50 ± 0.43% in males and 0.55 ± 0.13% in females. The mean fluid intake was 0.20 l/h in male players and 0.18 l/h in female players, which was comparatively less compared to fluid replacement observed by Horney et al. (2007) among tennis players.

The mean concentrations of electrolytes after badminton singles matches showed no significant change as compared to pre-match levels except in case of urine sodium in male players where post match values were significantly reduced from pre match levels. Significant reduction in urine sodium values post match after badminton singles matches has been reported by Ramachandran and Mohan (2018). Though decreases in potassium and calcium electrolyte levels were noted both in serum and urine, the decreases were not significant. In general, strenuous exercise decreases the excretion of urinary electrolytes (Castenfors, 1967; Grimby, 1965). Poortmans et al. (1994) reported 60% reduction in urine sodium following 20-km run. This is probably related to fluid imbalance of water loss and water intake; tubular re-absorption of sodium, and increased aldosterone concentration in plasma which is related to exercise intensity and duration.

Hormonal responses

Serum cortisol levels were significantly elevated post match in case of both male (7.57 ± 1.85 pre, 13.28 ± 3.37 ug/dl; $p > 0.05$) and female (7.48 ± 1.82 pre, 12.94 ± 1.29 ug/dl; $p > 0.05$) badminton players. Serum growth hormone were also significantly elevated post match in case of male (1.29 ± 1.30 pre, 14.97 ± 6.78 ng/ml; $p > 0.05$) and in case of female (2.11 ± 2.10 pre, 5.94 ± 1.29 ug/dl; $p > 0.05$) badminton players. Hormone response is also related to many factors closely related to hormone secretion; genetic, ethnic/racial, age, nutrition, environment, stress, mental factors (Staicu & Tache, 2011). Hormonal response to physical exercise and sports activity depends on the type of exercise (aerobic/anaerobic), duration, frequency of training sessions, and the degree of physical training (O'Conor, 2007; Lencu, 2015). Badminton matches like any other high intensity sport causes acute hormonal responses (Filaire, 2009; Salvador, 2003). The results of the present study of elevated cortisol levels for pre to post match is in agreement with the findings of Booth et al. (1989) and Filaire et al. (2009) where elevated serum cortisol levels were reported during tennis matches. Cortisol levels have shown to be elevated when the intensity of activity is above 60-70% of maximum $V0_2$ (Kraemer et al., 1989; Wittert et al., 1991). Progressive physical exercise associated with considerable anaerobic energy production is associated with increase of growth hormone, which is significant at the end of exercise (Peake et al., 2014). The high levels of serum cortisol and growth hormone after badminton matches is related to the high intensity of the activity (Ahtiainen et al., 2003; Hakkinen and Pakarinen, 1995; Booth et al., 1999 and Filaire et al., 2009).

Serum testosterone remained controlled with no significant change from pre to post match (2.51 ± 0.92 pre, 0.21 ± 0.30 ng/dl; $p < 0.05$). Testosterone concentrations elevates significantly before exercise (Booth et al., 1989; Salvador et al., 2003; Suay et al., 1999) or remains at a control level (Filaire et al, 2001; Gonzalez-Bono et al., 1999). Testosterone response during matches has shown varied results. Some studies have reported elevated testosterone concentration during matches (Bergeron et al., 1991; Booth et al., 1989; Kivilighanet al, 2005; Suay et al., 1999); while others have reported control values (Flaire et al., 2001; Gonsalez-Bono et al., 1999; Salvador et al., 2003). Serum testosterone levels depends to a greater extent on the outcome of matches; commonly increasing following victory and decreasing following loss (Booth et al., 1989; Elias, 1981; Gladue et al., 1989; Mazur et al., 1992; McCaul et al., 1992; Pound et al., 2009). Other factors like context of competition, motivation to win, cognitive appraisal, etc may also predict post-competition testosterone changes (Wood and Stanton, 2012). Though the matches played for the present study was competitively matched and played with a higher intensity, it may not have triggered the competitive seriousness and importance in terms of actual competitive context. It has been reported that serum testosterone may not be elevated if the player does not feel that the match is important, if he knows that he is going to win or lose, or if the opponent is at a different level (Booth et al., 1989; Gonsalez-Bono et al., 1999).

Conclusions

The evidence of higher heart rate during badminton singles matches; despite moderate level of lactate accumulation, indicates that badminton is a highly demanding game more in terms of cardiovascular efforts rather than on metabolic variables. The intermittent nature of the game with short lasting high intensity efforts interspersed with frequent rest intervals means the badminton game has predominance in the use of the alactic energy metabolism and to a lesser demand on the lactacid energy metabolism. The hormonal responses of elevated serum cortisol and growth hormone are reflective of the metabolic demand of badminton singles matches. Except in case of significantly lower urine sodium levels, no imbalance in fluid and electrolytes were found form pre to post match. Large variability among players was observed for metabolic and hormonal responses and fluid and electrolyte levels after singles matches and during the recovery period of thirty minutes. The metabolic and hormonal responses indicated lack of recovery to baseline after thirty minutes, which may negatively affect performances in subsequent matches.

Practical Application

Badminton singles matches present considerable cardiovascular, metabolic and hormonal responses. Players need to involve in active recovery mechanisms with adequate rest and recovery period to ensure full recovery. Schedule of tournaments need to be planned by providing adequate recovery time for players before subsequent matches. The high variability in metabolic and hormonal responses and fluid and electrolyte imbalances among players after singles matches suggests individualized consideration and advice on recovery and fluid replacement for players. High intensity interval training with work rest ratio of 0.54 for male and 0.47 for female badminton players is recommended for training junior level players. More precise and consistent knowledge is required in this area to optimize training, recovery and performance

Conflict of Interest

No conflict of interest declared.

Acknowledgements

The study was financially supported by Badminton World Federation (BWF). The author would like to thank the badminton players for their willingness and sincere participation in the study.

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