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Research article

STUDY OF PHYSIOLOGICAL PROFILE OF INDIAN BOXERS

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ABSTRACT
The present study was conducted to study the morphological, physiological and biochemical characteristics of Indian National boxers as well as to assess the cardiovascular adaptation to graded exercise and actual boxing round. Two different studies were conducted. In the first study [N = 60, (junior boxers below-19 yrs, n = 30), (senior boxers-20-25 yrs, n = 30)] different morphological, physiological and biochemical parameters were measured. In the second study (N = 21, Light Weight category- <54 kg, n = 7; Medium weight category <64 kg, n = 7 and Medium heavy weight category <75 kg, n = 7) cardiovascular responses were studied during graded exercise protocol and actual boxing bouts. Results showed a significantly higher ($p < 0.05$) stature, body mass, LBM, body fat and strength of back and grip in senior boxers compared to juniors. Moreover, the senior boxers possessed mesomorphic body conformation where as the juniors' possessed ectomorphic body conformation. Significantly lower ($p < 0.05$) aerobic capacity and anaerobic power were noted in junior boxers compared to seniors. Further, significantly higher ($p < 0.05$) maximal heart rates and recovery heart rates were observed in the seniors as compared to the juniors. Significantly higher maximum heart rates were noted during actual boxing compared to graded exercise. Blood lactate concentration was found to increase with the increase of workload during both graded exercise and actual boxing round. The senior boxers showed a significantly elevated ($p < 0.05$) levels of hemoblobin, blood urea, uric acid and peak lactate as compared to junior boxers. In the senior boxers significantly lower levels of total cholesterol, triglyceride and LDLC were observed as compared to junior boxers. No significant change has been noted in HDLC between the groups. The age and level of training in boxing has significant effect on Aerobic, anaerobic component. The study of physiological responses during graded exercise testing may be helpful to observe the cardiovascular adaptation in boxers.

KEY WORDS: Body composition, heart rate, VO_{2max}, anaerobic power, lactate, lipid profiles.

INTRODUCTION

Boxing is an intermittent sport characterized by short duration, high intensity bursts of activity. It requires significant anaerobic fitness, and operates within a well-developed aerobic system. Boxing is estimated to be 70-80% anaerobic and 20-30% aerobic (Ghosh et al., 1995). Boxing's work and rest ratio is approximately 3:1. The rule of the amateur boxing has been changed from 3 × 3 round to 2 × 5 round in 1990 world championship competition, and then 4 x 2 rounds with one minute of rest pause in between each bout. The nature of boxing requires athletes to sustain power at a high percentage of maximal oxygen uptake (VO_{2max}) (often above lactate threshold, producing high levels of blood lactate leading to premature fatigue). The primary aim of conditioning for boxing is to delay the onset of fatigue by increasing tolerance of lactic acid build-up, increasing the ATP and CP, to improve efficiency of oxygen use, and to improve recovery between intense bursts of activity (Guidettiet al., 2002)

Few studies have been reported in the literature about the cardiovascular and metabolic demands of boxing (Khanna et al., 1992, 1995

Ghosh et al., 1995). Previous studies on Indian boxers concentrated mainly on body composition, muscle strength, aerobic capacity, and anaerobic power of Indian Boxers (Ghosh et al., 1995; Khanna et al 1992, 1995; Singh et al., 2003). Few investigations into the biochemical parameters of Indian boxers (Garg et al 1985) have been conducted. Therefore, the present work focused on the morphological, physiological and biochemical characteristics of Indian National boxers as well as to assess the cardiovascular adaptation to graded exercise and actual boxing round.

METHODS

Study 1

For the present study, a total of 60 male (age range 15-25 yr) boxers of Indian National Camp participated in the study. Participants were divided into 2 groups (i) junior boxers-below 19 yrs (JB, n = 30), (ii) senior boxers-20 yrs and above (SB, n = 30). Different morphological, physiological and biochemical parameters were measured in each group.

Measurement of morphological parameters

Body mass was measured with the accurately calibrated electronic scale (Seca Alpha 770, UK) to the nearest 0.1 kg and stature with a stadiometer (Seca 220, UK) recorded to the nearest 0.1 cm. Body density was estimated from the sum of the four skin-fold sites (Durnin and Womersley, 1947), and percentage body fat was calculated by using equation of (Siri, 1956). Somatotype body configuration was done computed following Heath and Carter's method. Grip and back strength were measured by dynamometers (India Medico Instruments, India) (Jonson and Nelson, 1996).

Measurement of physiological parameters

Treadmill (Jaeger LE 500; Jaeger, Germany) tests were performed at 0% gradient to determine the cardiovascular status of the players during sub maximal and maximal exercise. Heart rate responses during rest, exercise and recovery were noted every 5 sec. using a heart rate monitor (Polar, Finland). The maximum oxygen uptake (VO_{2max}) was measured following standard methodology (Astrand and Rodahl, 1970). The participant was asked to run on the treadmill at a speed of 6 $km \cdot h^{-1}$ for 2 min. thereafter, the workload was increased by 2 $km \cdot h^{-1}$ for every 2 min until volitional exhaustion. Expired gases were sampled breath-by-breath and measured from a mixing chamber using computerized respiratory gas analyzer (Oxycon Champion, Germany).

Anaerobic power was measured using a cycle ergometer (Jaeger LE 900; Jaeger, Germany) (Inbar et al., 1996). After a 10 min warm up the participant was asked to pedal as fast as possible without resistance. Within 3 sec a fixed resistance of 0.075 kg per kg body mass was applied to the flywheel and the participant continues to peddle "all out" for 30 sec. A computerized counter continuously records flywheel revolutions in 5 sec intervals. Anaerobic power was measured using the software supplied by Jaeger, Germany.

Participants

Participants were informed about the possible hazards of the study. Each test was scheduled at a similar time of day (± 1 hr) in order to minimize the effect of diurnal fluctuation. Participants were advised not to engage in strenuous activities two days before an exercise test and not to exercise on the day of the test. Individuals were requested to maintain their normal diet. All the tests were under taken following the guidelines of American College of Cardiology (ACC, 1986).

Measurement of biochemical parameters

A 5 ml of venous blood was drawn from an antecubital vein after a 12 hour fast and 24 hour after the last bout of exercise. Hemoglobin (Hb), urea and uric acid were measured following standard methodology (Mukharjee, 1997). Total cholesterol (TC), triglyceride (TG) and high-density lipoprotein cholesterol (HDLC) were determined by enzymatic method using Boehringer Mannhein kit (Mukharjee, 1997). Low-density lipoprotein cholesterol (LDLC) was calculated from a standard equation (Friedewald et al., 1972). Arterialized samples were obtained from fingertip and under ideal conditions; this provides good approximation of arterial lactate concentration. Blood samples were analyzed immediately by a lactate analyzer (YSI Sport 1500, USA) using the YSI lactate kit. Special care was taken to prevent contamination from sweat and to enhance rapid circulation.

Study 2

In a second study, 21 male (age range 15-19 yr) boxers of Indian Junior National Camp participated. Participants were divided into 3 weight categories (i) Light weight (48-54 kg, n = 7 included Boxers of light fly, fly and bantam weight), (ii) medium weight (55-64 kg, n = 7; feather,light and light welter weight), (iii) medium heavy (65-75 kg n = 7 Welter and middle weight category) respectively. The anthropometric and physiological responses to graded exercise were estimated following abovementioned methods.

Table 1. Morphological characteristics of Indian male boxers. Data are means (±SD).

Parameters	Junior Boxers (n = 30)	Senior Boxers (n = 30)
Age (yr)	17.6 (2.9)	22.1 (3.1) ***
Stature (m)	1.74 (.06)	1.79 (.08) ***
Body mass (kg)	53.6 (4.1)	76.7 (10.9) ***
Body fat (%)	12.2 (1.1)	16.4 (3.8) ***
LBM (kg)	42.5 (3.4)	53.1 (7.6) ***
Endomorphy	1.8 (.5)	2.3 (.6) ***
Mesomorphy	3.2 (.6)	4.9 (.7) ***
Ectomorphy	4.0 (.8)	2.3 (.8) ***
BST (kg)	125.7 (6.4)	156.5 (8.6) ***
GSTR (kg)	45.6 (6.5)	62.7 (4.8) ***
GSTL (kg)	44.9 (4.6)	50.1 (3.8) ***

*** $p < 0.001$. LBM= lean body mass, BST= back strength, GSTR= grip strength right hand, GSTL= grip strength left hand.

Exercise testing

The exercise test was divided into three test protocols. First and second protocols were carried out in the laboratory, where as the third protocol was performed during the practice session.

First protocol: The participant was asked to run on the treadmill (Jaeger 500, Germany) at a speed of 6 $km·h^{-1}$ at 0% gradient for 2 min thereafter, the workload was increased by 2 $km·h^{-1}$ for every 2 min. until volitional exhaustion. Heart rate responses during rest, exercise and recovery were noted every 5 sec using a heart rate monitor (Polar, Finland). Blood sample was taken 2 min after the cessation of exercise to evaluate the peak lactate level.

Second protocol: This comprised a warm up for 2 min at 8 $km·h^{-1}$ speed followed by a graded exercise protocol was performed on the treadmill (Jaeger 500, Germany) to determine the heart rate responses to graded exercise so as to find out the sub-maximal responses of cardiovascular system. The test protocols were subdivided into 3 grades: (i) grade I- at 12 $km·h^{-1}$ speed and 2% inclination; (ii) grade II- at 14 $km·h^{-1}$ speed and 4% inclination; grade III- at 16 $km·h^{-1}$ speed and 6% inclination respectively. In every grade, 2 min of exercise was performed following 1 min rest, hence similar to actual competition. Heart rate was measured after warm up, at the end of 2 min graded exercise and during 1 min rest pause. Blood samples were taken during the rest period to determine the blood lactate concentration.

Third protocol: Heart rate and blood lactate responses of the boxers during actual bouts were measured during selection competitive trials. Each bout was performed for 2 minutes with a rest pause of 1 minute in between. Heart rate was measured at the end of 2 minutes bout and during 1 minute rest pause. Blood sample was collected immediately after each bout and blood lactate concentration was measured.

Statistical analysis

Data were presented as mean and standard deviation (±SD). Two-tail t-test was used to determine the significant differences of means in each parameter between the junior and senior boxing groups. ANOVA followed by multiple two-tail t-tests with Bonferroni modification was employed to find out the significant difference between the weights categories. Differences were considered significant when $p < 0.05$. (Das and Das, 1998). Accordingly, a statistical software package (SPSS-10) was used.

RESULTS

Study 1

Results of the present study showed a significantly higher stature, body mass, LBM and body fat in the senior boxers as compared to junior boxers. Significantly higher endomorphy and mesomorphy values were noted in senior players as compared to juniors. Moreover, a significantly higher ectomorphy body conformation was noted in junior boxers as compared to senior boxers. In addition, significantly ($p < 0.001$) higher strength of back and grips were noted in senior players compared to juniors (Table 1). The anaerobic power and aerobic capacity showed significantly higher values in senior boxers as compared to junior boxers. Further, significantly higher heart rates were noted during maximal exercise and recovery in senior boxers compared to junior boxers (Table 2).

Significantly higher values were noted in hemoglobin, serum urea and uric acid in senior boxers as compared to junior boxers. However, the junior players showed significantly higher values in total cholesterol, triglyceride and LDLC as compared to senior players. No significant

Table 2. Physiological characteristics of Indian male boxers. Data are means (±SD).

Parameters	Junior Boxers (n = 30)	Senior Boxers (n = 30)
AP ($W \cdot kg^{-1}$ BW)	4.9 (.7)	6.5 (.5) ***
VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	54.6 (4.7)	61.7 (9) ***
O_2 debt (l)	2.6 (0.9)	3.1 (1.0)*
HR_{max} (bpm)	186 (7)	191 (6) **
RHR_1 (bpm)	140 (10)	147 (10) **
RHR_2 (bpm)	115 (8)	129 (8) ***
RHR_3 (bpm)	104 (6)	117 (7) ***

* $p < 0.05$, ** $p < 0.01$, *** $p< 0.001$. AP = anaerobic power, VO_{2max} = maximal oxygen uptake, O_2 debt = oxygen debt, HRmax = maximal heart rate, RHR_1 = recovery heart rate 1st min, RHR_2 = recovery heart rate 2nd min, RHR_3 = recovery heart rate 3rd min.

difference was noted in HDLC between the groups. On the other hand, senior boxers showed a significantly higher peak lactate value than junior boxers (Table 3).

Study 2

A significant increase ($p < 0.05$) of body mass was noted among the groups. Significantly higher ($p < 0.05$) LBM, grip (right hand) and back strength were noted in medium Weight Category and medium heavy as compared to Light Weight Category (Table 4). No significant differences were noted in age, stature, body fat, flexibility and grip strength of left hand within the groups. No significant difference was found in resting heart rate, maximal heart rate and recovery heart rates amongst the groups. Further, significantly higher ($p < 0.05$) resting lactate was noted in medium weight Category when compared with light Weight Category. Peak lactate was found to be significantly higher ($p < 0.05$) in medium heavy weight category as compared to light and medium weight category boxers (Table 5).

When comparing graded exercise with actual boxing rounds, significantly higher ($p < 0.05$) heart rates were observed in first and second round and during recovery in all the rounds in Light Weight Category Boxers. Similar observations were noted in medium Weight Category boxers. However, in medium heavy Weight Category boxers no significant difference was noted in exercise heart rate and heart rate during actual boxing round. On the other hand significantly higher ($p < 0.05$) heart rates were observed during recovery, when comparing graded exercise with actual boxing round in medium heavy Weight Category Boxers. Moreover, significantly higher heart rate was noted during first graded of exercise in medium heavy Weight Category when compared with Light Weight Category and medium Weight Category (Table 6). Significantly higher ($p < 0.05$) blood lactate was noted in medium heavy Weight Category boxers during graded exercise as well as during actual boxing round when compared to Light Weight Category and medium Weight Category boxers (Table 7).

DISCUSSION

Since the ancient times, it has been believed that a suitable physique is important to achieve success in particular sports (Powers and Howley, 1997). Judging the performance of the human body by its size, shape and form has been a topic of great concern. In the present day of tough competition, when scientific principles are applied for training of athletes, the size, the shape and the form of the body coupled with its efficiency in performance have been

Table 3. Biochemical characteristics of Indian male boxers. Data are means (±SD).

Parameters	Junior Boxers (n = 30)	Senior Boxers (n = 30)
Hb ($g \cdot dl^{-1}$)	14.5 (.6)	15.1 (.5) ***
Urea ($mg \cdot dl^{-1}$)	30.1 (4.6)	34.8 (6.2) **
Uric acid ($mg \cdot dl^{-1}$)	3.8 (2.1)	4.9 (1.0) *
TC ($mg \cdot dl^{-1}$)	198.6 (11.2)	185.5 (20.5) **
Triglyceride ($mg \cdot dl^{-1}$)	80.7 (15.5)	67.2 (13.1) ***
HDLC ($mg \cdot dl^{-1}$)	52.3 (8.4)	47.8 (9.7)
LDLC ($mg \cdot dl^{-1}$)	125.4 (20.3)	96.5 (16.2) ***
RL ($mmol \cdot l^{-1}$)	2.2 (.5)	2.1 (.4)
PL ($mmol \cdot l^{-1}$)	11.4 (1.9)	16.6 (1.3) ***

* $p < 0.02$, ** $p < 0.01$, *** $p < 0.001$, Hb = hemoglobin, TC = total cholesterol, HDLC = high-density lipoprotein, LDLC = low-density lipoprotein, RL = resting lactate, PL = peak lactate.

Table 4. Morphological characteristics of Indian male boxers of different weight categories. Data are means (±SD).

Parameters	Light Weight (n = 7)	Medium Weight (n = 7)	Medium Heavy Weight (n = 7)
Age (yr)	17.4 (2.6)	17.5 (1.5)	18.1 (1.5)
Stature (m)	1.76 (.05)	1.74 (.06)	1.78 (.05)
Body mass (kg)	53.1 (3.5)	63.4 (3.2) *	74.6 (5.4) *#
Body fat (%)	12.2 (1.1)	11.6 (.9)	11.2 (1.2)
LBM (kg)	42.3 (3.2)	51.3 (2.5) *	62.4 (3.8) *
BST (kg)	124.3 (4.4)	138.0 (5.2)	142.1 (8.1) *
GSTR (kg)	44.2 (5.2)	50.7 (3.0)	52.6 (5.1) *
GSTL (kg)	43.8 (5.0)	48.7 (4.2)	50.1 (5.9)

* $p < 0.05$ compared with Light Weight Category, # $p < 0.05$ compared with medium Weight Category. LBM = lean body mass, BST = back strength, GSTR = grip strength of right hand, GSTL = grip strength of left hand. Light Weight Category <54kg, Medium Weight Category 55-64 kg, Medium Heavy Weight Category 65-75 kg.

given more importance especially from the point of view of identifying, selecting and developing the talent in sports (Khanna et al., 1992; Reilly et al., 1990). Recent researches in this field of sports sciences have clearly established that various physical activities demand different body size and proportions that is why top level sports men of different sportive events have been found to possess different physique and morphologic characteristics (Singh et al., 2003).

Stature and body mass have significant impact on elite boxers. Senior boxers possess higher stature, body mass, lean body mass and body fat compared to junior boxers. Further, the senior players showed a mesomorphic body conformation. However, the junior players showed body conformation towards ectomorphy. The estimation of body composition permits the quantification of gross size of an individual into two major structural components namely fat mass and lean body mass (Durnin and Womersley, 1947; Siri, 1956). This accurate appraisal provides an important baseline to develop an effective training program.

The body composition especially in an athlete is a better guide for determining the desirable weight rather than using the standard height-weight-age table of normal population due to the presence of high proportions of muscular content their total body composition (Beunen and Malina, 1988; Reilly et al., 1990). In addition, body fat plays an important role for the assessment of physical fitness of the players. Further, significantly higher strength of back and grip were noted in senior players compared to juniors. As boxing is a combat sports, many activities are forceful and explosive (e. g. punches, movements, changing pace etc.). The power output during such activities is related to the strength of the muscles involved in the movements. Thus, it might also diminish the risk of injury (Reilly et al., 1990). Moreover, grip and back strength also have significant impact on the performance. The higher levels of back and grip strength in the senior players may be due to their higher body mass and high level strength training compared to the junior boxers.

Table 5. Heart rate, maximal aerobic capacity and blood lactate response of Indian male boxers of different weight categories. Data are means (±SEM).

Parameters	Light Weight (n = 7)	Medium Weight (n = 7)	Medium Heavy Weight (n = 7)
VO_{2max} (ml·kg^{-1} ·min^{-1})	58.30 (2.2)	56.81 (2.1) *	51.52 (2.1) *
RHR (bpm)	71 (9)	76 (5)	70 (8)
MHR (bpm)	185 (6)	184 (4)	183 (5)
HRR_1 (bpm)	139 (10)	138 (5)	143 (11)
HRR_2 (bpm)	115 (14)	120 (5)	121 (7)
HRR_3 (bpm)	103 (5)	105 (3)	106 (10)
RL (mM·L^{-1})	2.2 (.4)	2.9 (.2) *	2.6 (.5)
PL (mM·L^{-1})	11.4 (1.9)	10.8 (1.4)	13.1 (0.9) *#

* $p < 0.05$ compared with Light Weight Category, # $p < 0.05$ compared with medium Weight RHR= resting heart rate, MHR= maximal heart rate, HRR_1 = heart rate during 1st min recovery, HRR_2 = heart rate during 2nd min recovery, HRR_3 = heart rate during 3rd min recovery, VO_{2max} = maximal oxygen uptake, RL = resting lactate concentration, PL = peak lactate concentration. Light Weight Category <54kg, Medium Weight Category 55-64 kg, Medium heavy Weight Category 65-75 kg.

Table 6. Heart rate (bpm) response to graded exercise on treadmill and actual boxing round in Indian boxers of different weight categories. Data are means (±SEM).

	Light Weight (n = 7)		Medium Weight (n = 7)		Medium Heavy Weight (n = 7)	
	Exercise	**Rest**	**Exercise**	**Rest**	**Exercise**	**Rest**
Graded exercise						
1st Grade	157 (8)	125 (6)	154 (10)	128 (7)	166 (10) #	125 (10)
2nd Grade	168 (5)	129 (8)	167 (6)	130 (7)	176 (10)	135 (9)
3rd Grade	177 (11)	138 (8)	179 (9)	141 (8)	180 (7)	146 (8)
Boxing round						
1st Round	170 (6) *	145 (8) *	170 (5) *	144 (8) *	173 (7)	145 (8) *
2nd Round	178 (5) *	154 (7) *	177 (5) *	149 (9) *	181 (5)	151 (8) *
3rd Round	184 (6) *	164 (8) *	183 (5)	168 (5) *	183 (6)	161 (7) *

* $p < 0.05$ when compared between Graded exercise and Boxing round. # $p < 0.05$ compared with Medium Weight Category.

may be due to their higher body mass and high level strength training compared to the junior boxers. Similarly in the second study, the higher level of back and grip strength in medium weight Category and medium heavy weight Category boxers as compared to light weight category boxers may be due to higher body mass.

The anaerobic power in Indian boxers showed significantly higher values in senior boxers as compared to junior boxers. In addition, senior boxers showed significantly higher peak lactate level compared to the junior players. However, no significant difference was noted in the resting lactate level among the groups. However, significant difference in blood lactate was noted in medium Weight Category and C when compared to Light Weight Category separately during graded exercise and during actual boxing rounds. High lactic acid concentration in the blood reflects the anaerobic metabolism and the degree of training intensity. When the intensity of the activity increases, production of lactic acid in the muscle becomes high, resulting in high lactic acid accumulation in blood leading to fatigue. The higher level of anaerobic power in the senior players may be due to exposure to high level of anaerobic training than the junior players. By training the lactic acid system, the athlete delays the onset of fatigue by increasing tolerance to lactic acid build-up. While the lactic acid system is most important in to boxing, training the ATP-CP system also has benefits, such as increasing the body's stores of phospho-creatine and delaying the pre-mature use of the lactic system. Training this system requires shorter interval periods (Powers and Howley, 2000).

Training programme places great emphasis on the anaerobic pathways. The Indian boxers included a form of interval running with less work/rest ratio involved, intervals matching the duration of a round (2 or 3 min), with a 1 min rest period. Intervals of this nature train the anaerobic lactic acid system, while also providing aerobic benefits. Boxing training program included situational exercises, lasting 30-60 sec for 6-8 sets, while sparring.

Not only the anerobic capacity but also the aerobic demand of present 2 × 4 rounds of boxing has also increased (Ghosh et al., 1995).The average VO_{2max} of present elite boxers was observed to be 54.6 and 61.7 $ml \cdot kg^{-1} \cdot min^{-1}$ in Indian junior and senior boxers respectively. Similar study on elite Indian boxers showed VO_{2max} value of 54.5 $ml \cdot kg^{-1} \cdot min^{-1}$ (Ghosh et al., 1995). Moreover, some other study observed VO_{2max} of 55.8 $ml \cdot kg^{-1} \cdot min^{-1}$ in Greek national boxers, 56.6 $ml \cdot kg^{-1} \cdot min^{-1}$ in

Table 7. Blood lactate ($mM \cdot L^{-1}$) response during graded exercise and during Boxing Round in Indian junior boxers of different weight categories. Data are means (±SEM).

	Light Weight (n = 7)	**Medium Weight (n = 7)**	**Medium Heavy Weight (n = 7)**
Graded exercise			
1st Grade	4.8 (2.0)	4.4 (.6)	6.6 (1.1) #
2nd Grade	5.7 (1.4)	6.0 (1.2)	7.8 (.6) *#
3rd Grade	6.5 (1.2)	7.0 (1.5)	9.7 (.4) *#
Boxing round			
1st Round	5.3 (1.5)	5.0 (1.1)	6.9 (1.9) #
2nd Round	6.2 (1.1)	6.5 (1.5)	8.1 (1.6) *
3rd Round	7.1 (1.2)	7.4 (1.3)	9.9 (1.5) *#

* $p < 0.05$ compared with Light Weight Category, # $p < 0.05$ compared with medium Weight Category.

Hungarian boxers and 64.7 ml·kg^{-1}·min^{-1} in French boxers (Ghosh et al., 1995).

Heart rate increases with an increase in work intensity and shows linear relationship with work rate (Astrand and Rodhal, 1970). It becomes the only factor to increase cardiac out put after stroke volume reaches its maximum level at about 40% of maximal work. Since heart rate can increase from 50-190 beats per min (300-400 %) in well-trained sports persons, with an increasing stroke volume of about 50-75%, heat rate plays a key role in increased cardiac out put during exercise (Astrand and Rodhal, 1970; Manna et al., 2002; Powers and Howley, 1997). Heart rates were measured during sub-maximal exercise, maximal exercise as well as during recovery to evaluate the cardiovascular fitness of the athletes (Karvitz et al., 2003; Manna et al., 2002). In the present study significantly higher heart rates were found during maximal exercise and recovery in senior boxers compared to juniors. In the second study significantly higher heart rate values were recorded during actual boxing rounds when comparing heart rates recorded during graded exercise on treadmill, this may be due to emotional attachment,stress and different muscle involvement during the game. Similar observation was noted in the study conducted by Bellinger et al. (1997).

Hemoglobin is mainly used for the transport of oxygen from blood vessels to exercising muscles, and transport of carbon dioxide from working muscles to blood vessels. Moreover, hemoglobin represents the iron status of the body (Beard and Tobin, 2000). The present study showed higher level of hemoglobin in the senior boxers compared to juniors Several studies showed that running might result in an appearance of free hemoglobin in plasma in augmented quantities. This phenomenon has been considered as a sign of typical sports anemia (Beard and Tobin, 2000; Casoni et al., 1985). It has been noted that training improved the hemoglobin concentration (Casoni et al., 1985).

The main end product of protein metabolism is urea. A prolonged exercise has been shown to cause increased urea and uric acid concentration in the blood, liver, skeletal muscle, urine and sweat (Carraro et al., 1993; Cerny, 1975). Therefore, monitoring of exercise stress through different biochemical parameters including serum urea and uric acid are common practice (Fry, et al., 1991; Urhausen and Kindermann, 2002). It may be suggested that increased levels of urea and uric acid may be due to increased intensity of training and or, excessive intake of proteins and reduced excretion of urinary urea and uric acid. Thus a high level of urea and uric acid may lead to positive nitrogen balance, which may interfere in kidney function.

Regular participation in physical activity is associated with lower plasma level of triglycerides (Berg et al., 1994; Durstine and Haskell, 1994; Khanna et al., 2005). Level of fitness influences the lipid profile as physically fit and active individuals tend to have lower levels of lipids than less active individuals (Berg et al., 1994; Durstine and Haskell, 1994; Khanna et al., 2005). Another study showed that the serum levels of HDLC and the ratio of HDLC to total cholesterol were increased in those players having more aerobic exercise in their training program (Cardoso Saldana et al., 1995). Whereas, those players exposed to more anaerobic training showed low concentration of HDLC to total cholesterol and LDLC to total cholesterol (Friedwald et al., 1972). In the present study significantly higher values of total cholesterol, triglyceride and LDLC were noted in junior boxers when compared to senior players. No significant difference was noted in HDLC between the groups. This shows that the senior players exposed to more aerobic training then the junior players. Therefore, it has been suggested that aerobic training can regulate serum lipids and lipoprotein levels and reduce the risk of coronary heart disease (Berg et al., 1994).

CONCLUSION

In conclusion, the age and level of training in Boxing has significant effect on Aerobic, anaerobic component. A very high intensive and long duration interval training to develop the needs to be incorporated in the training schedule to develop both the aerobic and anaerobic components of the boxers to meet the demand of the game. At the same time biochemical parameters including hemoglobin, urea, uric acid and lipid profiles also should be taken into consideration for training of boxers. The study of physiological responses during graded exercise testing may be helpful to observe the cardiovascular adaptation in boxers. The responses of heart rate and lactate studied during the actual bout can give a better insight about the adaptation of the boxers as compared to studying of responses in the laboratory conditions.

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KEY POINTS

- Study on Indian boxers
- Laboratory testing.
- Physical, physiological and biochemical monitoring.
- Performance analysis during actual boxing and laboratory testing.

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