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Original Article

Effect of boxing exercises on physiological and biochemical responses of Egyptian elite boxers.

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Abstract:
Boxing is a combat sport characterized by High intensity movements during limited rounds, with short breaks are insufficient for full recovery. Physiologists should be conscious of the physiological and biochemical changes that might cause by boxing exercises. The aim of the study is to assess the effects of boxing exercises on physiological and biochemical responses of Egyptian elite boxers. Seventeen Egyptian elite male boxers (age range 18-23 years) registered in the Egyptian boxing federation, volunteered to participate in the study. Physiological and biochemical measures were obtained at baseline and at the end of boxing training programme. Student's (T) test was followed out to examine pre- and post-test values. Data noted that boxing exercises were associated with significant decreases ($p < 0.05$) in resting heart rate (HR_{rest}), recovery heart rate after 1 minute (RHR_{1st}), recovery heart rate after 2 minutes (RHR_{2nd}), recovery heart rate after 3 minutes (RHR_{3rd}), respiratory exchange ratio (RER) values, and blood lactate (BL) concentration, while they connected with significant increases ($p < 0.05$) in peak heart rate (HR_{Peak}), relative and absolute VO_{2Max}, Creatine Kinase (CK) and Lactate Dehydrogenase (LDH) values. The authors' statistics demonstrate considerable physiological and biochemical changes significantly affected by boxing exercises in elite boxers. Examining relationships connected with the effects of training on physiological and biochemical aspects add new dimensions that can help in assessing, directing and developing athletic training programmes.
Key Words: Boxing, VO2max, Heart rate, Blood lactate, Creatine kinase

Introduction

Boxing is a combat sport where two participants of the same weight battle each other with their fists in a series of three-minute rounds (AIBA, 2010). Modification in boxing technical & competition rules especially in the duration and number of rounds might have incorporated ascending physiological changes in boxers. Despite the shortness of boxing match length (3 rounds x 3 min), it is distinguished that boxers should be equipped for huge efforts on the ring (El-Ashker, 2011). Most specialists in the combat sports fields emphasized on the importance of studying physiological changes associated with combating effort (Beneke et al., 2004; Toskovic et al., 2002; Kravitz et al., 2003; Ghosh, 2010; Chatterjee et al., 2006). The level of performance advances whenever such positive physiological changes occurred to achieve training adaptations lead to execute boxing bouts efficiency, without decreasing energy production (El-Ashker, 2004).

Energy from aerobic and anaerobic metabolism relies on the intensity and length of the activity (Kraemer et al., 2011). Boxing is characterized by High intensity movements during rounds with short breaks are not enough for full recovery. Consequently, this results in the production of lactic acid, and elevated blood lactate (Khanna and Manna, 2006). Boxing rounds put a heavy load on boxers who have ascending heart rate and blood lactate concentration through bouts (Ghosh et al., 1995). Simultaneously, physiologists and athletes should be more conscious of the biochemical changes that might caused by prolonged exercise (Warburton et al., 2002). As a result, the best method to assess training adaptations and to prevent overtraining is examining the selected biochemical markers (Urhausen and Kindermann, 2002; Gleeson, 2002; Umeda et al., 2008). Therefore, the trainer should be familiar with the physiological aspects related to training.

A small number of studies have been informed in the literature concerning the physiological demands of boxing (Khanna and Manna, 2006). The physiological requirements of boxing have been investigated on account of heart rate, maximal oxygen uptake (VO_{2Max}), blood lactate (BL) (Kravitz et al., 2003; Ghosh, 2010; Ghosh et al., 1991). Earlier studies on Egyptian boxers focus on motor ability, aerobic and anaerobic capacities of Egyptian Boxers (El-Ashker, 2004; Hafez, 1997; El-Hawy, 1983). Rare studies investigated the biochemical responses of Egyptian boxers (Shehata, 2010) have been conducted. To the authors' information, this is the first study to analyse both physiological and biochemical responses in Egyptian boxers. Consequently, the purpose of this study was to investigate physiological and biochemical responses of Egyptian elite boxers subsequent to boxing exercises.

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Materials and methods

Participants

The study was approved by the Ethics and Research Committee of the Faculty of Sports and Physical Education, Mansoura University, Egypt, and the guidelines of the American College of Sports Medicine (ACSM) for the use of human subjects were accepted in the study. A total of 17 Egyptian elite male boxers (age range 18 ~ 23 yr) volunteered to participate. Subject characteristics (Mean ± SD) are located in Table 1. All of them were registered in the Egyptian boxing federation, with a minimum of 4 years of national boxing participation. The objective of the study was explained to the participants. Selected boxers are volunteered, and could withdraw if they wished.

Table 1. Baseline characteristics of the study subjects (n= 17).

Variable	(Mean ± SD)	Range
Age (years)	19.47 ± 1.26	18.0 – 22.6
Height (m)	175.3 ± 0.02	1.71 – 1.79
Body mass (kg)	73.8 ± 5.1	68.0 – 83.2
% Body Fat	14.4 ± 1.9	11.8 – 17.54
Training age (years)	5.1 ± 1.27	3.6 – 7.5

Before acceptation as a subject, all participants were supplied with a consent form and a physical activity willingness questionnaire. The willingness questionnaire asked about any medical troubles or situations that may exclude participants from the study. Participants were given the type of food they are accustomed to, as well as the training programme has been conducted in the same conditions they are familiar with.

Procedures

To evaluate the physiological and biochemical variables, Participants attended the laboratory in a comfortable situation with at least one full rest day since their last training session. For all Participants, physiological [resting heart rate (HR_{rest}), peak heart rate (HR_{Peak}), recovery heart rate after 1 minute (RHR_{1st}), recovery heart rate after 2 minutes (RHR_{2nd}), recovery heart rate after 3 minutes (RHR_{3rd}), relative maximal oxygen uptake (VO_{2Max1}), absolute maximal oxygen uptake (VO_{2Max1}), and respiratory exchange ratio (RER)] and biochemical [Blood Lactate (BL), Creatine Kinase (CK), and Lactate Dehydrogenase (LDH)] measures were acquired two times; at baseline and at the end of the training programme. Data collected using a well defined data capture sheet. Research assistants registered physiological and biochemical measures at baseline and after eight weeks. Participants were told not to take any drugs or tobacco in the day their physiological and biochemical measures were to be estimated. They were also informed not to execute any exercises in the 48 hours before assessing measures.

Physiological parameters Measurement

Heart rate responses were calculated automatically by a pulse monitor (Polar Sport-tester™ PE 3000; Polar Electro, Finland) and calculated at 15-second intervals. Relative and absolute $VO2_{max}$ and RER were calculated according to standard methodology (Astrand and Rodahl, 1986). After warming-up for 15 min comprised (a standardized 10 min routine followed by 5 min of full-body stretching routine) all participants were asked to run on the motor-driven treadmill at a velocity of 6 km/h for 2 min. After that, the workload was augmented by 2 km/h for each 2 min unto causing volitional exhaustion. Expired gases were sampled and calculated from an integration chamber by programmed respiratory gas analyzer device (ZAN 600™, nSpire Health GmbH, Germany).

Biochemical parameters Measurement

Blood lactate (BL) was calculated with a portable lactate analyzer (Accusport, Boehringer Mannheim, Germany) using adequate blood sample amount of finger pricking taken immediately after cessation of complete boxing match. Ten millilitres of a blood sample were taken from an antecubital vein under the influence of fasting conditions early in the morning, in complete comfort for a period of not less than 6-8 hours prior to tests under research. Five millilitres of the blood sample were utilized to examine CK, and 5 ml were utilized to examine LDH. Samples were cooled and stocked at -20°C until analyses for CK, and LDH. Specialists from the medical laboratories at Mansoura University Hospital helped the researchers take blood samples, and carry out the biochemical Measurements.

In order to protect the participants and guarantee the accuracy of the values, nine participants were excluded from the experiment because of medical conditions (high blood pressure - high blood sugar), and those whose biochemical examinations have shown up normal values in the CK, LDH enzymes, due to their association with certain pathogens affecting the activity of enzymes.

Training programme

The training programme was planned by the coach of Mansoura sports club. It comprised 8 weeks of total 32 sessions (≈53 hours). Researchers divided the training programme into three phases (see Table 2). 1st phase was aimed to overall development of physical fitness components (e.g. strength, mobility, endurance) as well as developing fundamental motor skills; 2nd phase intended to develop specific physical fitness components and enhance advanced technical skills alongside competition experience; 3rd phase was proposed to adjust technical performance, train for the main competition in addition to emphasizing tactical and competition experience.

Intensity of the training programme was calculated by means of Karvonen's formulae [Target Heart Rate = $((HR_{Peak} - HR_{rest}) \times \%Intensity) + HR_{rest}$] (Brown et al., 2006); HR_{Peak} was estimated as 220 minus participant's age. HR_{rest} was acquired for all participants at pre-test by asking them to recline on their own for 5 min and wearing a pulse monitor (Polar Sport-tester™ PE 3000; Polar Electro, Finland), in calm area with no distractions. HR_{rest} was subsequently recorded and used to estimate target heart rate intensities. Workouts consist of [core conditioning – running - speed work - strength training - shadow boxing - skipping rope - boxing cardio exercises - working on heavy, double end and speed bags -boxing combinations - defensive, offensive and counter attack skills - free sparring].

Table 2. Boxing training programme phases and variables during the training period.

phases / Variables	1st phase (Basic)	2nd phase (Specific)	3rd phase (Taper)
Weeks	2	3	3
Workouts per week	4	4	4
Resting days per week	3	3	3
Workout duration per min	110	100	90
Intensity	70 %	80 %	90 %

Data Analysis

Data were collected from participants and then were collated and inserted in the statistical software package, SPSS-16 (SPSS Inc, Chicago, Il). Descriptive statistics were determined for all variables. Values are presented as Mean ± Standard deviation. Student's (T) test was followed out to examine pre- and post-test results. For all statistics, the level of significance was set at $P < 0.05$.

Results

Were the intervention boxers alike in physiological parameters at baseline and after 8 weeks boxing exercises?

Table 3 illustrates statistical significant differences in all of the physiological parameters at $p < 0.05$ between pre and post values. Boxers' mean HR_{rest} decreased (from 73.1 to 67.3 beats/min), but, in contrast, boxers' mean HR_{Peak} increased (from 197 to 204 beats/min). During the same period, Boxers' mean RHR_{1st}, RHR_{2nd} and RHR_{3rd} dropped ($p < 0.05$) (from 171, 146.5 and 139 beats/min to 166.6, 141 and 128 beats/min respectively). Simultaneously, relative and absolute VO_{2Max} increased significantly ($p < 0.05$) (from 58.2 to 64.6 ml/kg/min; from 4.65 to 5.23 l/min respectively). During the same period intervention boxers' mean RER decreased significantly ($p < 0.05$) (from 0.83 to 0.79).

Table 3. Pre and post-training programme physiological parameters (n=17).

Parameter	Pre-Test Mean (SD)	Post-Test Mean (SD)	Difference[a]	95% Confidence Limits Min	95% Confidence Limits Max	P-value
HR_{rest}	73.1 ± 2.7	67.3 ± 1.9	- 5.8	+ 3.4	+ 7.1	< 0.05
HR_{Peak}	197 ± 5.8	204 ± 7.2	+ 7.0	- 8.1	- 4.4	< 0.05
RHR_{1st}	171 ± 7.2	166.6 ± 5.1	- 4.4	+ 3.9	+ 5.1	< 0.05
RHR_{2nd}	146.5 ± 6.9	141 ± 6.9	- 5.5	+ 4.6	+ 6.1	< 0.05
RHR_{3rd}	139 ± 7.1	128 ± 5.1	- 11.0	+ 6.6	+ 8.6	< 0.05
$VO_{2\ Max1}$	58.2 ± 6.9	64.6 ± 7.2	+ 6.4	- 10.3	- 3.2	< 0.05
$VO_{2\ Max2}$	4.65 ± 0.30	5.23 ± 0.60	+ 0.6	- 0.68	- 0.36	< 0.05
RER	0.83 ± 0.02	0.79 ± 0.2	- 0.04	+ 0.02	+ 0.06	< 0.05

Note: [a] = post-test mean minus pre-test mean, HRrest = resting heart rate (beats/min), HR_{Peak} = peak heart rate (beats/min), RHR_{1st} = recovery heart rate after 1 minute (beats/min), RHR_{2nd} = recovery heart rate after 2 minutes (beats/min), RHR_{3rd} = recovery heart rate after 3 minutes (beats/min), VO_{2Max1} = relative maximal oxygen uptake (ml/kg/min), VO_{2Max2} = absolute maximal oxygen uptake (l/min), RER = respiratory exchange ratio.

Were the intervention boxers alike in biochemical parameters at baseline and after 8 weeks boxing exercises?

Table 3 illustrates statistical significant differences in all of the biochemical parameters at $p < 0.05$ between pre and post values. A significant reduction in the BL concentration was reported among the intervention boxers (from 8.7 to 7.3 mMol/L). Furthermore, intervention boxers' mean CK increased significantly ($p < 0.05$) (from 205.4 to 239.4 IU/l). Additionally, intervention boxers' mean LDH increased significantly (from 279.7 to 349.9 IU/l).

Table 4. Pre and post-training programme biochemical parameters (n=17).

Parameter	Pre-Test Mean (SD)	Post-Test Mean (SD)	Difference[a]	95% Confidence Limits		P-value
				Min	Max	
BL	8.7 ± 1.1	7.3 ± 1.0	- 1.4	+ 1.2	+ 1.5	< 0.05
CK	205.4 ± 16.6	239.4 ± 9.2	+ 34.1	- 42.9	- 25.3	< 0.05
LDH	279.7 ± 14.1	349.9 ± 79.5	+ 70.25	- 81.1	- 58.8	< 0.05

Note: [a] = post-test mean minus pre-test mean, BL = Blood Lactate (mMol/L), CK = Creatine Kinase (IU/l), LDH = Lactate Dehydrogenase (IU/l).

Discussion

The studied boxers executed the training programme period without any symptoms of clinical signs that would exclude them from the study. The authors' statistics express significant physiological and biochemical responses to boxing exercises in elite boxers. Regarding physiological parameters, by comparing the post-training programme values with pre-training programme values (Table 3), our results noted that boxing exercises training programme was associated with significant decreases in $HR_{rest,}$ $RHR_{1st,}$ $RHR_{2nd,}$ $RHR_{3rd,}$ and RER values, while it associated with significant increases in HR_{Peak} , relative and absolute VO_{2Max}. In connection with HR values, a lowered resting HR has long been known as an indicator of improving aerobic capacity (Reilly et al., 1990). It has become a fact that physical activity has a high impact on well-being enhancement in athletic activities (Aubert et al., 2003). Our findings proposed that boxing exercises may be helpful in promoting physiological parameters among elite boxers. This could be consequently interpreted as improved aerobic capacity in boxers (Chatterjee et al., 2006). Thus, we can say that boxing exercises help to develop cardiovascular fitness over time, in other words, boxing exercises are cardioprotective (serving to protect the heart). The maximal oxygen uptake (VO_{2max}) is one of the essential indicators that provides an appropriate prediction of performance in amateur boxing (Guidetti et al., 2002), and it is considered as one of the best tests of aerobic performance (Hale, 2003; Morris, 2010), which plays a vital role in boxing and has a main effect on technical and tactical performance effectiveness (El-Ashker, 2004). The findings of the recent research pointed out that boxing exercises affect significantly VO_{2max}, which affirms possibility of boxing exercises's for enhancing aerobic performance. Pre-training relative and absolute VO_{2max} values began at 58.2 ml/kg/min and 4.65 l/min respectively. Subsequent to the 8-weeks boxing training programme, relative and absolute VO_{2max} values were elevated to 64.6 ml/kg/min and 5.23 l/min respectively. The average values for VO_{2max} of post-training programme were higher than the Indian elite boxers (59.5 ml/kg/min) (Ghosh, 2010); and also much higher than levels of previous Indian boxers (54.5 ml/kg/min) (Ghosh et al., 1995); and slightly higher than England senior national boxers (63.8 ml/kg/min) (Smith, 2006). This statistics proposes that boxing exercises improve VO_{2max} efficiently within an eight-week period.

The respiratory exchange ratio (RER) refers to the ratio of carbon dioxide produced to oxygen used during metabolism (v_{co2} / V_{O2}), and it is associated with the intensity of training exercises and the major kind of energy used (Kraemer et al., 2011; Guidetti et al., 2002). As regards RER, by comparing the pre and post-training programme values, our findings suggested that boxing training programme was connected with decreases in RER levels from 0.83 at baseline to 0.79 after eight-week period. This supported proposals that RER is lower compared with before training in participants doing exercise at an sub-maximal power output (Friedlander et al., 1997; Martin et al., 1993).

Furthermore, numerous biochemical parameters are changed by exercise. By comparing the post and pre-training programme values (Table 4), our results showed that boxing exercises were associated with significant decreases in BL values, and with significant increases in both CK and LDH values.

One of the main significant biochemical parameters in sport medicine is lactate (Karnincic et al., 2009), a metabolite formed from glycolytic pathways, which is a sign for the onset of fatigue (Garrett and Kirkendall, 2000). With reference to BL, Table 4 illustrates statistical significant differences between pre and post-training programme values in the concentration of BL, which decreased from 8.7 at baseline to 7.3 mMol/L after the intervention training programme. Lactate constructed by muscles or other tissues can circuit in the blood and then be used by inactive skeletal muscles, cardiac muscle, and the kidneys to produce glycogen or be altered to pyruvate (Brooks, 2000). For instance, when blood lactate concentration increase higher than resting values, such in anaerobic performance, inactive muscle can use lactate to create glycogen or pyruvate, consequently reducing blood lactate concentration (Kraemer, et al., 2011). Accordingly, our result proves that the reduction of BL concentration attributes to the development of the athletes' functional training.

Analyzing both CK and LDH at baseline illustrates that, although the participants had not started boxing training programme yet, the average values of CK and LDH levels were 205.4 IU/l and 279.7 IU/l respectively, which were greater than the normative values for healthy men. Normative values in healthy men ranged between 55 to 170 IU/l for CK (Pagana and Pagana, 1995; Tilkian et al., 1995), and between 100-190 IU/l for LDH (Rosmarakis et al., 2005). We can explain that by their previous conditioned training programme they participated in. The comparisons of baseline with post-test values suggested a positive relationship between boxing exercises and elevating CK, LDH levels. Changes in glycolytic enzymes may enhance performance in aerobic and anaerobic actions together with rising ATP availability from glycolysis (Kraemer et al., 2011). Increases in LDH levels have been revealed after weight training (Tesch and Alkner, 2003), speed training (MacDougall et al., 1998; Ross and Leveritt, 2001) and endurance training (Abernethy et al., 1990). A number of similar researches supported our findings that significant increases in the activity of CK enzyme have been demonstrated after physical exercises (Parra et al., 2000; Ehlers et al., 2002).

There are several potential limitations of this study. One of these limitations is the complexity in quantifying each exercise load in the boxing training programme. The outcome results would need to be confirmed by extra studies including a larger sample size, so as to be sufficiently powered statistically. Prospective studies need to confirm the recent findings, examine further possible physiological and biochemical variables and, investigate more issues (e.g., psychological – immunological – neuromuscular).

Conclusions

Within the research sample and the available possibilities, we can conclude that boxing exercises have positive impact on the physiological and biochemical variables under research. This impact may be the result of participating in a boxing training programme regularly, which declares that boxing exercises induce changes in various physiological and biochemical parameters. In view of the fact that physiological and biochemical statistics on Egyptian boxers are insufficient, the recent study might supply useful data help to promote boxing training. The study of the physiological demands through sport activity helps in designing training programmes on a biological foundation. Physiological and biochemical variables are considerable indicators of changes in body systems as a result of training. In conclusion, detecting relationships associated with the effects of training on physiological and biochemical aspects adding new dimensions that can assist in evaluating, directing and developing athletic training programmes.

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