Physiological and perceptual responses to three consecutive official matches in female boxer. A case study

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Summary

Study aim: The purpose of this study was to assess the physiological cost of three consecutive official boxing fights played during a 3-day tournament and two non-contact specific drills against handheld pads of the same time-profile as the contest, 4 × 2 minutes with 1-minute intervals between them. This assessment was based on the determination of selected hormones and metabolites in the blood sampled directly prior to the contests and throughout short-term post-contest recovery.

Material and methods: A female amateur boxer was enrolled on the study during a 3-day Polish Boxing Championship, where one match was played on each day. The timing of capillary blood sampling during each match and the drill was as follows: 10 minutes prior to the effort, and 3 and 30 minutes after its completion. Cortisol (C), testosterone (T), and glucose (G) were determined in the serum, while lactate (LA) was determined in the blood. In addition, prior to each effort, serum creatine kinase (CK) and urea (U) was determined. Directly after each effort, the perception of fatigue (PF) was rated.

Results: G, C, and T during official matches were significantly higher than those during non-contact drills. Post-event G, C, T, and LA were higher compared to pre-event values.

Conclusions: An official boxing match produced higher stress than a drill of the same time-profile and similar modality. Changes in blood indices corresponded well with the perception of fatigue.

Key words: Box – Female – Competition – Blood – Hormones – Fatigue perception

Introduction

Despite the mandatory use of a special helmet for protecting boxers’ heads from direct punches, official competitions of this sport are considered a great psycho-physical challenge. A typical boxing tournament lasts 3–4 days, where one fight is played on one particular day. Failure during a fight excludes a contestant from the successive round of the tournament, and a knockout is considered to be a putative brain injury, and therefore a contestant that experiences this injury has to stop fighting until neurological examination confirms the appropriate health recovery. Impact force during execution of power punches among female and male boxers was rated on the base of shot put performance [17]. During a boxing match (3 rounds × 2 min) fought by male junior boxers, the total number of punches thrown by the winners towards their opponents’ heads is higher than by the losers [3]. There is a high frequency of boxing actions executed during about (1.4/sec), which consists of thrown punches and other whole body movements, acceleration/deceleration/skipping that are performed interspersed with short-term rest intervals. Such intensive exercise requires high aerobic and anaerobic capacity [3, 4], as well as rapid and corrected information processing. An official boxing match is a concurrent physical and mental effort, as a contestant is coerced into decision-making about the type of punch he/she should throw and at what moment [8]. In psychometric, laboratory studies, this dilemma is known as a go/no-go task, and is performed without huge and acute fatigue, contrary to the conditions occurring during a real fight. No wonder that physiologists offer boxing contestants various pharmacological aids to improve their punching performance [5, 24]. The other, non-directed way leading to enhanced psycho-physical abilities among boxers is based on comprehensive understanding of the physiological processes that occur during a boxing competition. Based on observations of selected blood indices, such attempts have been earlier undertaken in male [19] and female [18] boxers during official competitions of higher rank (International Boxing Tournament of Feliks Stamm Memory).
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Unfortunately, the results of these studies were of limited diagnostic value, as blood specimens were sampled only once, just after a match, and perceptual responses to the effort were lacking, despite the fact that numerical assessment of the parameters provided importance information [20]. The aim of the study was to check which physiological blood parameters best correspond with the perceived post-match fatigue.

Material and methods

A highly skilled female amateur boxer was enrolled on the study that took place during a 3-day Polish Boxing Championships, which for an athlete of national level may be considered a competition of mild rank. Previously, on two occasions separated by one day, the female underwent a non-contact specific drill against handheld pads of the same time-profile as an official fight (4 rounds × 2 minutes with 1-minute rest intervals between bouts). The tempo of various types of executed punches against the pads was imposed by the operator of the pads, who evoked a punch against a target by extension of his left or right arm with handheld pads towards the boxer. These right and left stimuli were in a randomized order and the timing of the interval between them was unexpected for the subject, who had to move around a ring like the pad operator. The types of punches thrown towards the pads were as usual, jabs, cross hooks, and a series of punches. Regarding the official competition, according to the rules, one fight was fought per day, and a defeat excluded a contestant from the next fight(s). The timing of the capillary blood sampling from the earlobe was as follows: 10 minutes prior to the effort, and 3 and 30 minutes after its completion. All efforts were performed in the afternoon. Cortisol (C), testosterone (T), glucose (G), and urea (U) were determined in the serum, while lactate (LA) was determined in the blood. In addition, prior to the efforts, serum creatine kinase (CK) and urea (U) were determined. All serum samples were analysed in duplicates, and the control samples, as reference material provided by BIORAD, five for each parameter, were attached to the assays. Serum samples from the official competition were assayed in one run (2nd run) and the same procedure was used with specimens obtained from two separate training sessions (1st run). All analytical methods were previously validated, and the precision and reproducibility were estimated, based on a large number of analyses. Within-assay errors with the assay specimen have normal distribution, it was assumed that when Z is 1.96 or 2.56, the appropriate p values are less than 0.05 or 0.01 respectively. In this study, biological within-subject variability was omitted because of the inadequate number of observations; hence, comparison was conducted on the mean results of serum parameters (P) and general analytical uncertainty (AU), the parameter commonly used for estimation of quality control of a validated analytical method. The parameter is calculated from within-assay (WAE) and between-assay (BAE) according to the formula: AU = [(WAE)] + (BAE)². AU for the determined parameters is displayed in the table below:

| Parameter | Mean ± SD |
|-----------|-----------|
| C | 4.9 ± 0.5 |
| T | 4.6 ± 0.5 |
| G | 4.5 ± 0.5 |
| U | 4.9 ± 0.5 |
| CK | 4.3 ± 0.5 |
| LA | 5.6 ± 0.5 |

Comparison of each parameter determined in various circumstances regarding two time points (pre – and post-effort) and two types of effort was conducted with confidence levels of 95%.

(I) pre-mitt drills (MD) with post-mitt drills, (II) pre-struggles (ST) with post-struggles, (III) pre-mitt drills vs. pre-struggles, (IV) post-mitt drills with post-struggles. The following criteria for the existed differences were assumed:

Pre – and post-effort:

\[ P_{MD} + P_{MD} (2.5 \times 1.96 \times \text{AU}_p / 100) < P_{ST} - P_{ST} (2.5 \times 1.96 \times \text{AU}_p / 100) \]
and
\[(P_{\text{pre}} + P_{\text{pre}} (20.5 \times 1.96 \times \text{AU}_p/100)) \leq P_{\text{post}} - P_{\text{post}} (20.5 \times 1.96 \times \text{AU}_p/100)\]
for mitts and struggles. The study design was approved by the Ethical Commission at the Institute of Sport, in accordance with the Helsinki Declaration.

**Results**

Individual parameters C (nmol/L), T (nmol/L), G (mmol/L), and La (mmol/L) were recorded during all the efforts and are presented in Table 1. Resting (pre-exercise) CK (U/L) and U (mmol/L) is presented in Table 2.

Table 1. Individual parameters recorded during two non-contact efforts 1 and 2 (4 × 2 min punching against handheld pads) and during official consecutive boxing struggles

| Effort          | 10 min (a) | +3min (b) | +30min (c) |
|-----------------|------------|-----------|------------|
|                 | C          | T         | G          | LA | C   | T   | G   | LA |
| mitts drills 1  | 345        | 1.2       | 5.1        | 1.9 | 588 | 1.4 | 6.7 | 7.7 | 565 | 1.3 | 5.3 | 2.6 |
| mitts drills 2  | 466        | 1.1       | 4.9        | 1.2 | 512 | 1.2 | 7.0 | 8.4 | 492 | 1.3 | 5.0 | 3.5 |
| struggle 1      | 423        | 1.9       | 5.6        | 1.9 | 924 | 2.1 | 9.6 | 9.1 | 1025| 2.2 | 7.4 | 2.9 |
| struggle 2      | 760        | 1.9       | 6.1        | 2.8 | 1144| 2.5 | 11.8| 8.3 | 1180| 2.4 | 9.9 | 5.3 |
| struggle 3      | 590        | 1.8       | 5.3        | 2.2 | 1095| 3.2 | 12.0| 9.3 | 1173| 2.3 | 8.9 | 4.2 |

**Table 2.** Pre-event (resting) serum CK and U, and post-event perception of fatigue (PF)

| circumstance    | pre exercise | +3 min |
|-----------------|--------------|--------|
| event           | CK  | Ur  | PF |
| training 1      | 233 | 4.3 | 73 |
| training 2      | 302 | 4.6 | 69 |
| struggle 1      | 242 | 3.4 | 88 |
| struggle 2      | 328 | 5.3 | 94 |
| struggle 3      | 648 | 4.3 | 97 |

According to the assumed criteria, levels of the determined parameters were compared.

*Cortisol.* Drills did not trigger a rise in serum cortisol, while struggles did. Pre-mitt cortisol did not differ from the pre-struggle mean of the hormone, although a difference appeared when the pre-mitt level was compared with the second pre-struggle level. Post-struggle cortisol was higher than the post-mitt level.

*Testosterone.* The pre-mitt testosterone level was lower than the pre-struggle level. Mitts and struggles did not affect the testosterone level.

**Glucose.** Post-drill, the parameter was unchanged, while directly post-struggle (+3 min), the parameter was higher than the post-mitt and pre-struggle level.

*Lactate.* Both drills and struggles elevated lactate levels to the same extent.

The other interesting finding is that during competition, testosterone responses to successive struggles, 1st, 2nd, and 3rd became stronger and stronger. Taking into account the entire time points (5 events*3 time points n = 15), there were significant correlations between C and T (0.858), C and G (0.893), and LA and G (0.646). After two successive struggles, CK activity was two-fold higher than on the other occasions.

**Discussion**

As has been shown, an official fight produces higher C, T, and G responses compared to those induced by a non-contact simulated contest. Interestingly, relatively low, non-significant differences between official and simulated struggles were found for LA. This fact indicated that the intensity of physical activity of both types of exercises that consisted of punches and actions of the lower limbs, and acceleration and deceleration of the whole body mass, was not very different. In fact, punches against handheld pads, also called mitt exercises, may even have a higher frequency and intensity than those during an official fight, as an exercise is not at risk of counterattack, concussion, or any other injury. However, in this study, the somewhat higher post-struggle lactate level may be explained by the effect of the putative higher adrenaline level, which enhances lactic glycolysis. This hypothesis is supported by a higher lactate level following running, compared to playing tennis, with a similar oxygen uptake during both efforts [6]. Regarding the appraisal of reactivity to stress, it is usually based on hormonal system responses. Thus, it was found that regarding the activity of the pituitary-adrenal axis, there are “low” and “high” responders, although
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no such diversity was found for the sympathetic-adrenal system [23]. As a consequence, any type of stress, not only induced by physical exertion, elevates both blood hormones and lactate [13]. For this reason, the levels of so-called stress hormones and lactate in the blood are always higher following competitive effort than those of similar work output but of lesser emotional excitation [14–16].

In female athletes, the androgenic and glucocorticoid status of the blood is closely related to their sport achievements and athletic rank. Athletes of the international skill level [1] and of better athletic fitness [22] demonstrate higher C and T levels than those of national skill level. In our study the female boxer exhibited almost two-fold higher levels of C and T during official struggles than mmi exercises, which might be associated with additional psychological arousal related to the participation in the entire tournament. This association has also been found during more important boxing competitions [18]. On the other hand, females’ testosterone and its androgenic precursor, androstenedione, fluctuate throughout the menstrual cycle, reaching maximal values on the days of the late follicular phase [11], and one may deliberate whether the phase of the menstrual cycle, which, however, has not been established in this study, had any effect on athletic predisposition. Serum CK, a marker of muscle damage, increased from day to day during the entire competition. Apart from one 4-round match per day, no other physical effort was performed during the competition. Vigorous but relatively very short-lasting daily activity is hard to consider as the only reason for the more than two-fold elevation of CK above the initial value after the two matches. It is more likely that, apart from the work output, skeletal muscle contusion also contributed to the rise in CK. This mechanism of muscle damage has been observed, for instance, among rugby players due to repetitive collisions [12]. The final CK level was, however, approximately three-fold lower than the average values recorded among male wrestlers during their preparatory and competition season [21], which resulted in the well-documented gender differences.

Study limitations

Short lasting, very intensive effort triggers a temporary and transient plasma volume (PV) decrease of 10–15% [10, 21]. Thus, this effect contributes to the rise of each plasma parameter by a similar value regardless of the contribution to the other factors influencing the concentration, such as the rates of the secretion and elimination from circulation. When post-effort changes in value of blood indices greatly exceed the value of plasma volume shift, there is no doubt that the total post-effort circulatory amount of examined variable is higher than the initial amount, and omitting the effect of hemoconcentration has no marked impact on statistical data analysis and interpretation. On the contrary, when recorded changes of serum/plasma parameter are comparable with those of plasma volume, it may be assumed that the elevations would be explained in whole or in part, as a result of hemoconcentrations induced by an effort.

In the present study, post-effort PV values were not tested; therefore, small changes in the levels of some variables are comparable to putative ΔPV. On the other hand, biological activity in the blood of some indices such as hormones and glucose depends on their concentration not on total amounts; therefore, observation of the levels also provide diagnostic information, although it does not strictly allow elucidation of the reasons for the changes. Hence, the ignored effect of ΔPV in this study may be considered as a minor methodological shortcoming.

Conclusions

1. An official boxing struggle induces higher hormonal and metabolic responses in the blood, as compared to those after non-contact effort of a similar time-profile and modality.
2. Perceived fatigue after cessation of an exercise is in accordance with physiological responses.
3. Both the simulated and official struggles have minor effects on post-exertion changes in testosterone levels.

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Received 21.10.2014
Accepted 28.11.2014
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