SEX-RELATED DIFFERENCES IN PERCEPTUAL INDICES, SERUM CORTISOL, AND BLOOD LACTATE RESPONSES TO ENDURANCE EXERCISE IN COMPETITIVE MALE AND FEMALE ATHLETES IN A FIELD SETTING

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Abstract:
Background: Boxing requires very high aerobic fitness from male and female practitioners, therefore, endurance exercises play an important role in the preparation to competition. One of the way for rating of the state of demanded physical adaptation is monitoring of biological responses to endurance training units. The aim of the study was to examine psycho-hormonal responses to a 10km cross-country run in male and female boxers.

Material and methods: Twenty-four amateur adult boxers, 12 women and 12 men, of various weight categories, excluding heavyweight athletes, performed field a 10km run. Capillary blood was sampled in the morning at 8:00, 5 minutes prior to the run (11:00 am), and within 5 minutes after exercise. Plasma cortisol concentration (C) was determined using a commercial ELISA kit (IBL, GERMANY). Post-exercise blood lactate was determined with a Lactate Scout analyzer. Pre-run anticipatory stress (AS) was estimated on a numerical scale of 1 to 10 points, with the same tool used to measure the rating of perceived exertion (RPE).

Results: Morning plasma cortisol levels in females (540±82 nM) and males (520±73 nM) did not differ significantly but the pre-and post-run levels were higher in females. Furthermore, males rather than females showed lower pre-exercise compared to post-exercise C levels, meaning that blood lactate level was significantly higher in males (6.3±1.1 mM) compared to that in females (5.4±0.7 mM). There were no significant differences between the sexes for AS and RPE. However, both perceptual parameters were slightly higher in females.

Conclusion: Based on blood cortisol measurements and perceptual parameters it can be concluded that the psychophysiological cost of exercise is higher in female athletes, even in the case of non-competitive exercise.

Introduction

In the case of healthy subjects, assessment of blood cortisol levels (C) is often employed to evaluate the state of emotion and the level of psychophysical stress. Cortisol levels induced by arousal changes depend on several factors including personality, individual coping strategies, and physical fitness [1-4]. In competitive sports, changes in C levels are
commonly used to examine exercise stress during competition and pre-competitive anxiety [5]. However, C responses in an exerciser are modified by several factors like physical fitness, a period of a training cycle, and the time of the day, and hence all of them have to be taken into consideration to obtain a correct interpretation of the results. In the case of athletes, the post-exercise changes in C are usually examined with respect to post-training adaptations [6]. However, their directions are hard to predict. Excluding cases of chronic fatigue syndrome (overtraining), which manifests itself as a physical underperformance and deficit of C at rest and following exercise, it seems, that the type of training modulates C responses to physical and/or psychical stressors, but the results reported by several authors are contradictory. Resting and post-exercise C in male distance runners [7], female judo players [8], male karate players [9], cross-country skiers [10], and untrained subjects [11,12] were lower after training periods compared to baseline. On the contrary, other authors showed elevated resting C, reduced blood testosterone, and better physical capacity levels in road cyclists after a period of endurance training [13]. Likewise, C responses to maximum exercise were higher in cyclists than in age-matched untrained subjects, whose cortisolism, VO2 max, and post-exercise blood lactate were lowered with age [14]. C responses to laboratory exercise vary with respect to training experience and a sports skill level. Post-exercise C levels were higher in adult athletes [15]. Endurance-trained athletes at higher sports skill levels presented higher post-an aerobic test C compared to those of middle levels [16]. In two Polish elite female judo players, the higher C during laboratory tests and overtraining period presented a subject of international, Olympic level than her sparring partner of the national level [17]. The C levels during competitions were also markedly higher in other athletes of international levels than in those of national levels or having worse positions on the ranking lists [18-22]. Experience with laboratory exercise tests and so-called familiarisation play an important role in psycho-hormonal responses to those challenges. Athletes familiar with the exercise tests [23,24] or with other biomedical studies [25] show lower pre- and post-event C. 

The above results of the studies on C responses to various stimuli made us include the hormonal and perceptual observations in male and female athletes undergoing heavy exercise in a field setting. The aim of the study was to examine serum cortisol, blood lactate, self-rated pre-exercise emotional arousal (EA), and post-exercise rating of perceived exertion (RPE) in response to a 10km cross-country run.

Material and methods

Participants and procedure
Highly skilled male (n=12, aged 24.4±1.1 years) and female (n=12, aged 23.1±1.5 years), boxers participating in a central training camp performed a 10km cross-country run, and the route of the run was the same for both sexes, with the exercise starting in the morning. The ambient temperature ranged from 16-18°C and humidity was ca. 55%. Capillary blood was sampled from subjects’ earlobes in the morning at 8:00 in the fasting state, then 5 min prior to the run, and 5 min after its completion. The state of familiarisation with the whole study protocol was similar for both sexes.

Measures
Plasma cortisol concentrations were determined in duplicate in one run with analytical relative error >5 % using a commercial ELISA kit (IBL, GERMANY). Blood lactate was determined using a Lactate-Scout kit. The 10-point numerical scale was used to estimate the rating of perceived exertion (RPE) and pre-run emotional arousal as anticipatory stress (AS).

Statistical methods
After testing for the normal distribution of log-transformed data (Shapiro-Wilk test) and homogeneity of variance (the Levene test), the differences in C between sexes and time points were calculated using two-way analysis of variance (ANOVA), followed by post-hoc Tuckey test. AS and RPE were analyzed by non-parametric statistics and the Mann-Whitney test was used for two independent groups. All calculations were made using SOFTWARE STATISTICA (version 13.1). This study was approved by Ethical Research Committee at the Institute of Sport.

Results
Detailed results for cortisol levels obtained from the analysis of variance are illustrated in Table 1. The means and standard deviations for cortisol levels for both sexes and three time points are presented in Table 2. Between-sex comparisons for AS and RPE are shown in Table 3.
The analysis of variance regarding C levels showed gender and time-point differences. Morning C was almost the same for males and females. During the 3h period from morning to pre-run mean blood sampling, C levels in males significantly decreased (by almost 19%) while no such behavior was noted in females. Hence, in the male group, the mean direction of changes in C is in agreement with the diurnal rhythm. However, it should be stressed that the individual C changes vary. During the 3h time interval, two male boxers exhibited C change inverted to the diurnal rhythm. In one subject, the change amounted to 23%, in another – to 30%, while other males showed a decrease in C or no changes. In the female group, at the same time, C increased by 24, 23, and 35% in three athletes. In both sexes, the exercise led to a significantly elevated C. After the exercise, females exhibited higher C compared to their morning levels (by 40%), whereas a relative C increment in the male group was lower (21.3%). Analysis of the area under curve (AUC) based on three time points revealed that this parameter was lower in males compared to females.

The metabolic response to exercise estimated as blood lactate levels (La) was significantly more pronounced in males. In both sexes, La levels were a meaningful anaerobic component of exercise metabolism, at least at the end of the exercise. The changes between sexes were insignificant for perceptual indices (AS and RPE), although slightly higher results were found in women.

### Table 1. Between-sex and time of blood sampling differences for plasma cortisol levels based on a two-way ANOVA

<table>
<thead>
<tr>
<th></th>
<th>F-value</th>
<th>p-value</th>
<th>η-square</th>
<th>α-power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>19.9</td>
<td>&lt;0.000</td>
<td>0.232</td>
<td>0.993</td>
</tr>
<tr>
<td>Time</td>
<td>51.9</td>
<td>&lt;0.000</td>
<td>0.616</td>
<td>1.000</td>
</tr>
<tr>
<td>Sex*Time</td>
<td>3.0</td>
<td>0.054</td>
<td>0.084</td>
<td>0.560</td>
</tr>
</tbody>
</table>

### Table 2. Plasma cortisol concentrations (nM) in the morning and pre/post run in female (FB) and male (MB) boxers

<table>
<thead>
<tr>
<th></th>
<th>8:00 am</th>
<th>-5 min</th>
<th>+5 min.</th>
<th>differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
<td>(c)</td>
<td></td>
</tr>
<tr>
<td>FB</td>
<td>540±82</td>
<td>522±68</td>
<td>757±98</td>
<td>c&gt;a, b</td>
</tr>
<tr>
<td>MB</td>
<td>520±73</td>
<td>423±81</td>
<td>631±64</td>
<td>c&gt;a&gt;b</td>
</tr>
<tr>
<td>differences</td>
<td>ns</td>
<td>FB&gt;MB</td>
<td>FB&gt;MB</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table 3. Post-run blood lactate levels, pre-run anticipatory stress (AS) and post-run rating of perceived exertion (RPE) in male and female boxers

<table>
<thead>
<tr>
<th></th>
<th>Lactate (mM)</th>
<th>AS (score)</th>
<th>RPE (score)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FB</td>
<td>5.4±0.7</td>
<td>5.3±0.9</td>
<td>8.6±1.0</td>
</tr>
<tr>
<td>min-max</td>
<td>4.7-7.0</td>
<td>4-7</td>
<td>7-10</td>
</tr>
<tr>
<td>MB</td>
<td>6.3±1.1</td>
<td>5.0±0.9</td>
<td>8.10.7</td>
</tr>
<tr>
<td>Min-max</td>
<td>4.7-8.4</td>
<td>4-7</td>
<td>7-9</td>
</tr>
<tr>
<td>Z, p</td>
<td>2.02, 0.043</td>
<td>-0.89, 0.371</td>
<td>-1.44, 0.149</td>
</tr>
</tbody>
</table>

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### Discussion

Under neutral conditions, the highest C levels in humans are observed in the early morning. Next, the concentration of the hormone decreases gradually to late evening in both sexes. The more rapid drop of C according to the physiological rhythm takes place before noon. In our study, such C behavior was found only in men. However, the lack of appropriate observation performed for a similar time interval in neutral conditions does not allow for the estimation of the real effect of AS on the disruption of the C rhythm. It should be noted that the diurnal rhythm of C is not influenced by sex, but there is high inter-subject variability [26]. Due to this C behavior, the significant differences between the sexes for C immediately before the run result from the stronger reactivity of women to AS and, consequently, the blunting of the physiological rhythm of cortisol. A similar phenomenon of cortisol rhythm disruption in response to competition and higher concentrations of the hormone in women in such settings has been reported by other authors [27, 28].
Hence, one can conclude that the significant differences we observed between the sexes for C recorded immediately before the run are due to the stronger emotional reactivity of women to AS. Given the results obtained by us and by others, it is clear that the determination of cortisol in biological fluids is a useful tool for the evaluation of psychological and physical stress [29]. Furthermore, our analysis of individual C responses to anticipation of strenuous physical effort in both groups revealed that two males and seven females showed higher C levels prior to the run compared to those measured in the morning. These inverted C changes in the time course were not related to AS scores. Although pre-and post-run C was markedly higher for women, the scores for both perceptual indices (AS and RPE) did not vary in the groups. This may suggest that for highly skilled athletes, the strength of this stimulus as 10km not being a competitive effort might be insufficient to differentiate between both sexes with regard to perceptual responses but sufficient for a stronger activation of the adrenal cortex in female athletes. On the other hand, participation in such events as high-rank competitions may reveal differences between males from females regarding emotional arousal. This was confirmed in Polish male and female judo players who took part in an international competition (Judo World Cup). Females reported significantly higher perceived stress at three time points (in the morning, before, and after warm-up) as a response to the first bout before the tournament [30].

The reason for the reported gender differences remains unknown. It seems that the state of engagement with the exercise and the level of emotions contributed to this phenomenon. For this reason, the measurements of cortisol levels are often accompanied by the estimation of mood state, mainly anxiety. The relationship between psychological and physiological symptoms of stress has been widely explored and described. The relationship between C levels and psychological state has been reported in both men [31,32] and women [33, 34]. Moreover, a higher self-efficacy, which occurs in better-skilled athletes, produces lower salivary cortisol responses to intensive physical effort [35]. All of the articles quoted above that have shown higher C levels in female athletes focused on gender differences in stressful situations. In our study, morning C may be considered as a neutral state which did not differentiate between the hormonal status in both sexes. Likewise, the psychohormonal study conducted on male and female archers under non-stressful circumstances showed similar morning C in young men (564±101 nM) and women (513±88 nM ) and insignificant changes in personality traits including trait anxiety [36].

Our results lead to the conclusion that in the case of well-trained endurance athletes, the anticipation of endurance physical effort and the effort itself resulted in a significantly higher blood cortisol response in women, while perceptual indices before and after the exercise were only slightly higher in women.

Conclusions
Monitoring of blood time course of blood cortisol and perceptual indices reflexes overall psychophysical stress in both sexes.

Practical implications
1. Monitoring of biological responses to training load should include self-reported rating of perceived exertion as well as blood cortisol level of physical stress.
2. In general, female athletes response stronger to exhausting physical effort comparing to their male counterparts. That fact should be take into consideration by their coaches during long-lasting training period.
3. To avoid risk of such phenomenon as overtraining syndrome, burn out or overuse injury we postulate to use appropriate balance between workout and time for recovery.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.
References:


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