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ANABOLIC/CATABOLIC INDEX (T/C RATIO) IN BLOOD OF ELITE ROWERS IN SELECTED PERIODS OF AN ANNUAL TRAINING CYCLE

Key words: exercise, cortisol, testosterone, T/C ratio.

ABSTRACT

The study examined cortisol and testosterone blood levels in rowers during selected periods of an annual training cycle. Additionally, the effects of isolated physical exercise (2000 m controlled maximal time test) on blood concentrations of the hormones were assessed. The study sample consisted of 10 male members of the Polish National Rowing Team. The study was carried out in May and July at a training camp during a post-preparatory period of the rowing training macrocycle (1st trial in May, 2nd, 3rd and 4th trials in July). During the first trial, the athletes performed a controlled 2000 m test on a Concept II rowing ergometer. Blood samples were taken from the antecubital vein before the test (in the morning, after an overnight fast), one minute after completing the test, and following a 24-hour recovery period. The cortisol and testosterone concentrations were assessed in the blood serum. Additionally, creatine kinase activity was measured in plasma samples and lactate levels were determined in capillary blood samples. It was noted that fluctuations of the Anabolic/Catabolic Index (T/C) depended mainly on cortisol concentrations. The period of highest training intensity is characterized with the highest resting levels of creatinine kinase activity and the highest cortisol concentrations. Finally, the physiological, hormonal response of rowers to test and training exercises observed in this study affirms the usefulness of the T/C index in monitoring of the training process.

INTRODUCTION

Increased physical activity markedly influences testosterone and cortisol secretion. Cortisol, along with other glucostatic hormones (insulin, glucagon, adrenalin, growth hormone), participates in the control of blood glucose concentration via glycogenolysis and gluconeogenesis with a subsequent increase in myofibrillar protein degradation in skeletal muscles [Fry et al. 2010]. Moreover, along with adrenalin and growth hormone, cortisol enhances the release of free fatty acids, products of triglyceride degradation in the fatty tissue, into the blood [Obmiński 2000]. Testosterone has anabolic and anti-catabolic effects [Griggs et al. 1989]. It enhances protein restoration and protects them against degradation. Moreover, testosterone plays an important role in post-exercise resuscitation since it enhances glycogen regeneration. It was revealed that deficiencies of both hormones impairs short- and long-term exercise and decrease one's tolerance to the training

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burden [Fry et al. 1992; Raastad et al. 2000; Fry et al. 2000]. Moreover, cortisol and testosterone are the main factors that induce short- and long-term adaptation reactions, modulating the rate of homeostasis normalization through anabolic process induction [Bonfi et al. 2006].

According to literature, concentrations of both hormones and their mutual proportions illustrate the relationships between anabolic and catabolic processes that occur in the human body [Lac et al. 2000; Elloumi et al. 2003; Marinelli et al. 1994]. In 1986, Adlercreutz introduced the Anabolic/Catabolic Index (T/C) into sport diagnostics, a quotient of testosterone to cortisol concentration [Adlercreutz et al. 1986]. Implementation of this index reflects the role played by these hormones in the regulation of exercise metabolism, particularly during processes of energetic substrate mobilization (cortisol) and structural protein restoration (testosterone).

In consideration of the aforementioned roles played by cortisol and testosterone, we have studied their blood levels in rowers during selected periods of a yearly training cycle. Additionally, we have analyzed the effects of isolated physical exercise (2000 m controlled maximal time test) on blood concentrations of the studied hormones.

METHODS

The study population consisted of 10 male members of the Polish National Rowing Team (nine heavyweight rowers and one lightweight rower). The basic characteristics and sport classes of the athletes are summarized in Table 1. The study was performed in May and July at a training camp during a period between preparation and competition (1st trial – May, 2nd, 3rd and 4th trials – July). During the first trial, the athletes performed a controlled 2000 m time test. Each subject had to cover the distance on a rowing ergometer (Concept II – USA) in the shortest time possible.

Volumes and intensities of training during the weeks directly preceding consecutive trials are summarized in Figure 1. Exercise of intensity below 4 mmol/l (aerobic exercise) predominated throughout the entire period of this study. During the direct preparation period (2nd, 3rd and 4th trials), however, high intensity exercise (4 to 8 mmol/l and above 8 mmol/l) played a significant role along with tempo training.

Blood samples were taken from the antecubital vein (using dipotassium ethylene diamine tetra-acetic acid, K_2EDTA as an anticoagulant) before the 2000 m test (in the morning, after an overnight fast), one minute after completing the test, and following a 24-hour recovery period. Samples were centrifuged immediately to separate red blood cells from plasma. The serum was frozen immediately and stored at –28ºC until use (up to one week). Additionally, capillary blood samples were taken via finger prick before and after the exercise test to assess lactate levels (LA).

Serum cortisol was determined using the chemiluminescence method with an Immulite 2000 analyzer, while serum testosterone was measured by means of the immunofluorescence method using commercial immunoenzymatic tests for quantitative testosterone determinations (DPC, USA). Fluorescence was measured using the Immulite 2000 apparatus. Creatine kinase (CK) activity was determined in plasma samples with a commercially available kit (Dr Lange, Cat No. LCN 282, Germany). The results were expressed in U/L.

Statistical analyses were performed using the STATISTICA v. 9.0 software package. The distri-

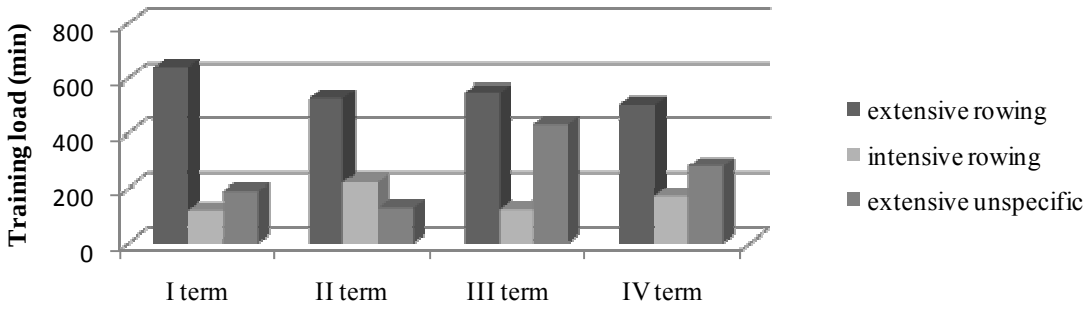

Figure 1. Training schedule in the week preceding blood-sampling (volume in min/week)

bution of data was analyzed using the Shapiro-Wilk test. The significance of differences was tested using Kruskal-Wallis and Tukey tests. All values were reported as mean ± SD. Statistical significance was set at $p < 0.05$.

All subjects were informed of the nature of the investigation and gave their written informed consent to participate in the study. The Ethics Committee at the University School of Medical Sciences in Poznan approved the study protocol.

RESULTS

The results of this study are summarized in Tables 1 and 2 and in Figures 2 and 3. Table 1 summarizes the anthropometric characteristics of study participants. The mean age of the participants was 20.7 ± 1.05 and their mean training experience was 6.9 ± 2.02 years.

Table 1. Basic characteristics of the study participants (means ± standard deviations)

Body height (cm)	Body mass (kg)	Age (years)	Training experience (years)
195 ± 4.92	87.1 ± 7.73	20.7 ± 1.05	6.9 ± 2.02

Table 2. Power output, blood lactate levels and total run time (means ± standard deviations)

Maximal power (Watt)	Exercise time (s)	LA at rest (mmol/l)	LA after exercise (mmol/l)
437.8 ± 12.02	371.3 ± 3.53	1.8 ± 0.5	19.2 ± 0.6

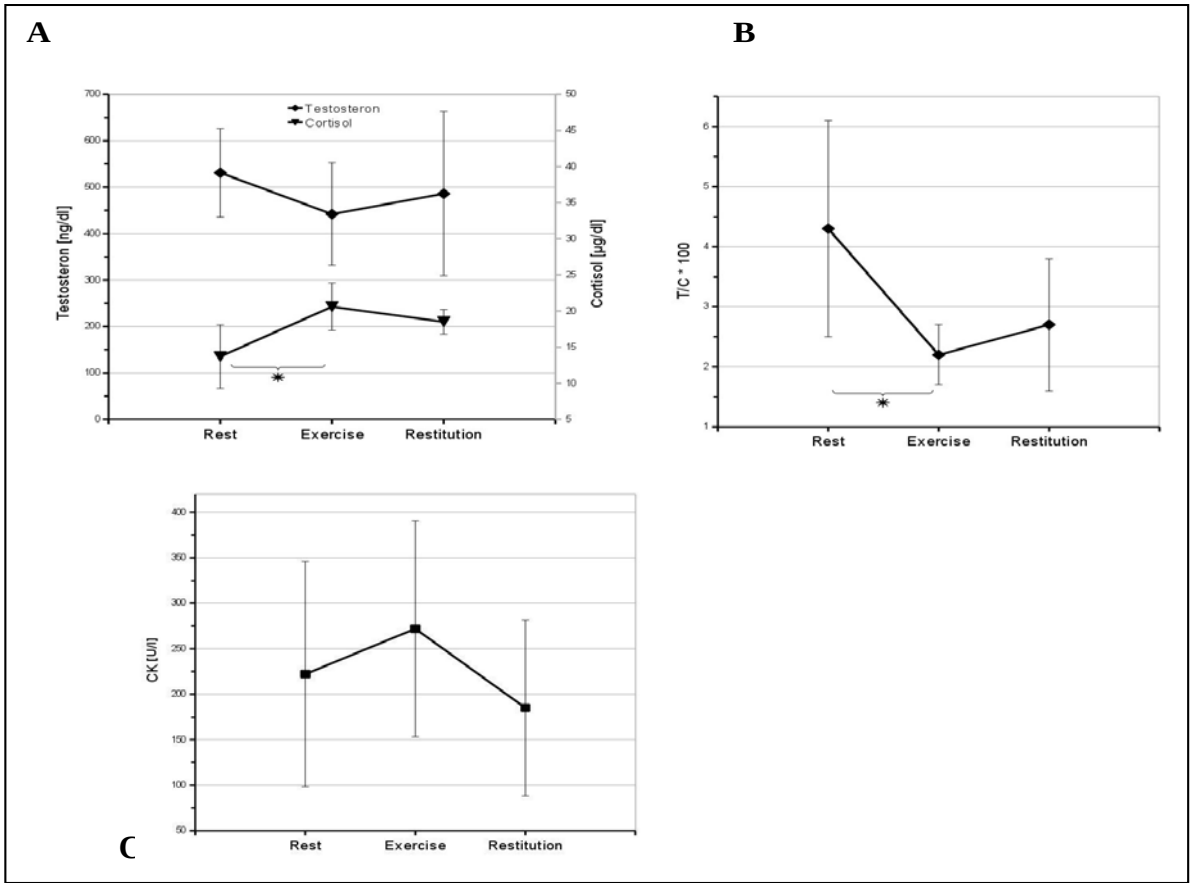

Figure 2. Changes in the studied parameters at rest, during exercise and restitution

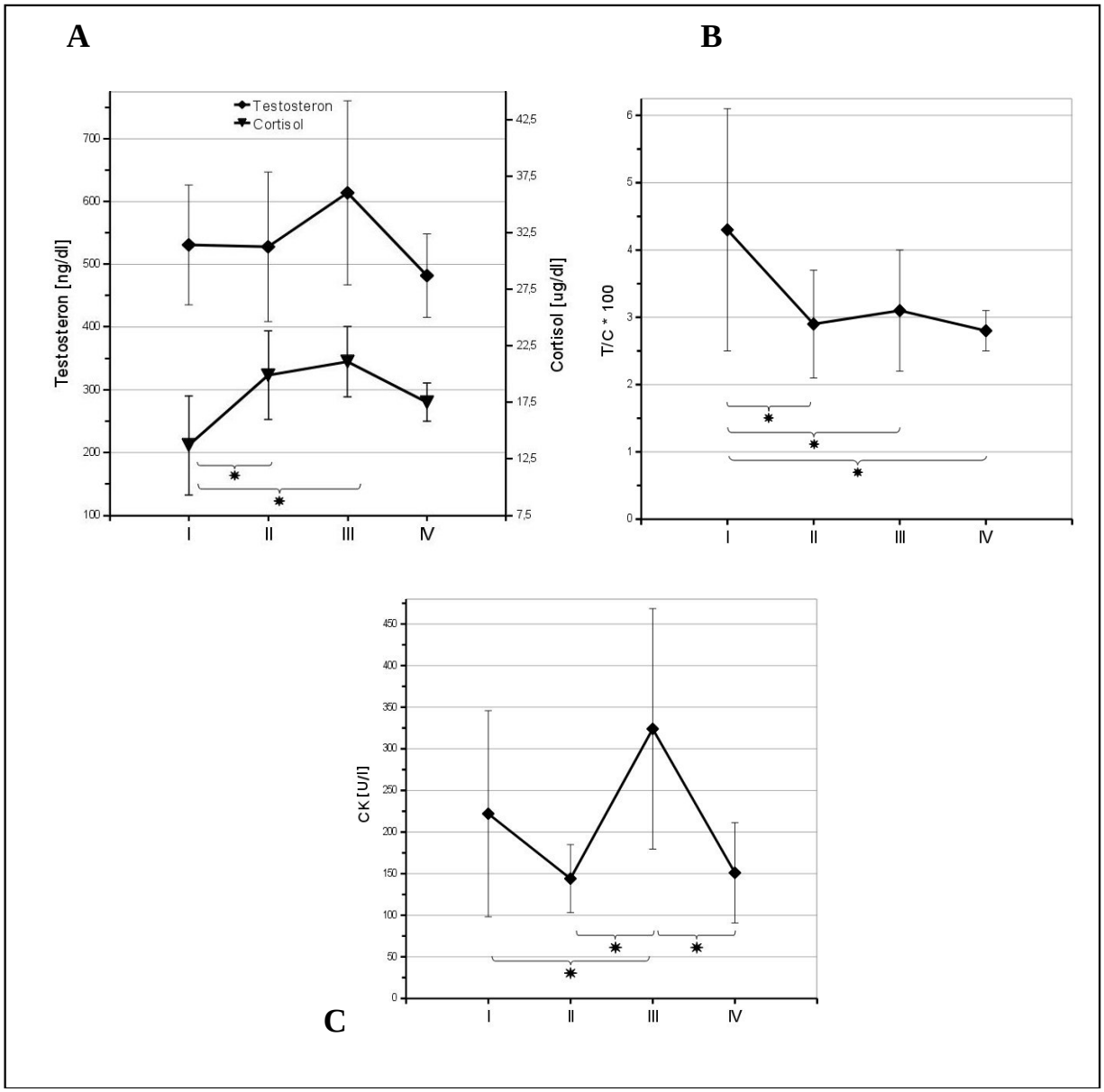

Figure 3. Changes in the studied parameters during consecutive trials

Selected parameters of the ergometric exercise test (2000 m time test) are summarized in Table 2. The test exercise was reflected by an increase in lactate concentrations by 17.4 mmol/l on the average. Mean total run time of the 2000 m time test was 371.3 ± 3.53 s and maximal power was 437.8 ± 12.02 W on the average.

The ergometric test was reflected by a post-exercise increase in serum cortisol levels with no significant changes observed in testosterone levels (Fig. 2A). These higher post-exercise cortisol concentrations resulted in a decreased value of the Anabolic/Catabolic Index [T/C] (Fig. 2B). The test exercise did not significantly influence creatinine kinase activity (CK, Fig. 2C). The resting activity of creatinine kinase, along with resting concentrations of cortisol and testosterone and the T/C index are summarized in Figure 3. When resting cortisol concentrations were compared throughout different phases of the yearly training cycle, values determined during the 2nd and 3rd trials were significantly higher when compared to the first trial. T/C index values were significantly lower during the direct preparatory phase of the

training cycle (2nd, 3rd and 4th trial) compared to the first trial (Fig. 3B). No significant differences in testosterone concentrations were observed amongst different trials (Fig. 3A), whereas creatinine kinase activity was highest during the 3rd trial and lowest during the 4th trial (Fig. 3C).

DISCUSSION

Cortisol and testosterone are compounds whose blood concentration undergo constant fluctuation with peak values noted during morning hours [Obmiński 2000]. In males, normal morning cortisol concentrations at rest range from 150 to 650 nmol/L, with testosterone levels ranging from 9 to 42 nmol/l. The results of many studies have confirmed that physical training influences testosterone levels. According to Hackney et al. [1990], testosterone levels in athletes subjected to endurance training were lower compared to untrained individuals or those who practiced power/speed sports. In a study by Bosco et al. [1998], resting testosterone concentrations in sprinters were higher and cortisol – lower when compared to cross-country skiers. In their study of male and female rowers, Obmiński et al. [1997] observed that stress related to competition was an independent factor responsible for increasing plasma cortisol concentrations. According to these authors, prolonged physical exercise results in increased cortisol levels and decreased testosterone concentrations. These findings were confirmed in a study by Lac et al. [2004]. According to these authors, values of the T/C ratio were characteristic for the catabolic phase during a 6-hour run, whereas after the run they were typical for the anabolic phase. Vervoorn et al. [1991] analyzed the training burden of rowers who prepared for the 1988 Olympic Games in Seoul and concluded that an increase in exercise intensity was reflected by a 5% to 50% drop off in T/C values. During a period of lower training intensity, however, this index increased by only up to 30% of the resting value. These findings are characteristic of increased catabolism associated with the risk of overtraining. The types and intensities of physical exercise seem to have the strongest influences on the levels of the hereby analyzed hormones. This hypothesis is supported by the results of Kokalasa et al. [2004] who analyzed Greek national team rowers. They observed that endurance training was reflected by a significant increase in cortisol levels and decreased testosterone concentrations. However, no significant changes in these hormone concentrations were observed when the same study group was subjected to power training. Other authors [Purge et al. 2006] observed that testosterone and cortisol concentrations are markedly influenced by the weekly number of training units. In their study of Estonian rowers, hormonal response decreased along with a decrease in training volume. Characteristically, the aforementioned study did not reveal any significant differences in growth hormone levels and creatinine kinase activity. According to literature [Vervoorn et al. 1991; Urhausen et al. 1995], resting values of the T/C index below 2.5 persisting for longer than a week suggest the predominance of catabolic processes over anabolic ones in the muscles. This may result in decreased muscular power, and if prolonged, may be reflected by a gradual loss of muscle mass.

We did not observed a decrease in the T/C index values below this critical threshold of 2.5 during any of the consecutive trials (Fig. 3B). During very intense preparatory phases (2nd, 3rd and 4th trial), a decrease in the T/C index was observed when compared to the first trial. This was presumably due to an increase in catabolic processes resulting from the high exercise burden and high training intensity characteristic of preparatory phases of the training cycles. A similar relationship was previously described in cyclists by Obmiński et al. [2001]. They revealed that in athletes mostly exposed to endurance training, T/C index values and testosterone concentrations are significantly higher during the preparatory phase compared to the starting period. In our study, the ergometric exercise test resulted in a significant (51%) decrease in the T/C ratio (Fig. 2), suggesting the direct influence of maximal exercise (LA concentration equal to 19.2 mmol/l) on the metabolic balance of athletes. The aforementioned changes in the Anabolic/Catabolic Index values resulted mainly from changes in cortisol concentrations since testosterone levels remained relatively stable (Fig. 3A). Post-exercise cortisol levels are modulated by many factors including one's sport class. The longer duration of exercise, the more pronounced the increase in cortisol levels [Viru et al. 1992]. Intense exercise lasting up to half an hour is reflected by transient elevation of both hormone concentrations. It should be noted, however, that testosterone concentrations decrease rapidly after exercise cessation with a

corresponding decrease in T/C values [Bird et al. 2004].

During direct preparatory phases (2nd, 3rd and 4th trial), changes in resting cortisol concentrations suggested the predominance of catabolic processes over anabolic ones. This relationship was suggested by a significant increase in cortisol levels during the 2nd and 3rd trials when compared to the first trial, with no marked changes observed in testosterone concentrations. The aforementioned changes were reflected by a decrease in T/C index values. According to a widely accepted theory, low T/C values are suggestive for increased catabolic processes and the risk of overtraining. However, the results of scant studies indicate that in sports predominated by an endurance component, optimal oxygen efficiency and endurance achieved during the training cycle are reflected by decreases in resting testosterone and increased resting cortisol concentrations [Handziski et al. 2006; Elloumi et al. 2003]. This phenomenon was confirmed in professional cyclists subjected to a 4-week training period [Hoogevan et al. 1996] as well as in rowers [Snegovskaya et al. 1993], who after one year of training were revealed to have an increase in endurance parameters and maximal power, despite marked decreases in testosterone levels and increased cortisol concentrations. In such cases, adaptation to decreased T/C values takes place at a cellular level, e.g. via changes in receptor density or compensation by other anabolic hormones [Obmiński 2000].

Post-exercise increases in the blood activity of intramuscular enzymes, particularly creatinine kinase, are a well-understood phenomenon and an indirect indicator of the increased permeability of muscle cell membranes or injury of these cells [Sorichter et al. 1995]. The enzymes may be released into the inter-cellular space due to mechanical, metabolic or inflammatory factors [Hübner-Woźniak 2006]. The degree of post-exercise changes in plasma CK activity and their temporal sequence differ depending on the type of exercise and the amount of muscular mass involved [Hübner-Woźniak 2006]. Measurements of plasma CK activity are useful in risk assessment of muscular overburdening and are widely used to monitor the training process. It should be remembered, however, that although the training itself reduces post-exercise changes in CK activity, it does not fully prevent muscle cell disorders [Hübner-Woźniak et al. 1998; Balnave et al. 1993]. In our study of rowers, ergometric exercise (2000 m time test) was not reflected by significant changes in plasma CK activity (Fig. 2C). However, significant changes in plasma CK were observed during the direct preparatory phase as a result of the higher training burden. When compared to other trials, CK activity was highest during the period of very intense preparation (3rd trial, Fig. 3C). Noticeably, an increase in CK activity during the 3rd trial was accompanied by the highest cortisol concentrations (Fig. 3A). This finding may be suggestive of increasing fatigue in the athletes during the phase of the highest training intensity, i.e. the direct preparatory phase. During another trial (4th trial), CK activity was significantly decreased compared to the 3rd trial due to the lower number of training units and resulting reduction in fatigue.

In conclusion, fluctuations of the Anabolic/Catabolic Index (T/C) depend mainly on cortisol concentrations. The period of highest training intensity is characterized with the highest resting levels of creatine kinase activity and the highest cortisol concentrations. Finally, the physiological, hormonal response of rowers to test and training exercises observed in this study suggests that the T/C index is a useful tool in monitoring of the training process.

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