Acta Scientific Orthopaedics (ISSN: 2581-8635)

Volume 3 Issue 1 January 2020

Research Article

Cardiovascular Response and Competitive Performance in Athletes with Depleted Awakening Hormonal Status

Natallia Maroz-Vadalazhskaya[1]*, Danilo Neglia[2], Anna Zakharevich[1,3], Natallia Ivanchikova[3], Elena Brutskaya-Stempkovskaya[1] and Vadim Sushynski[1]

[1]*Belarusian State Medical University, Minsk, Republic of Belarus, Europe*

[2]*Fondazione Toscana G. Monasterio, Pisa, Italy*

[3]*Republican Scientific-Practical Center of Sports, Minsk, Belarus, Europe*

***Corresponding Author:** Natallia Maroz-Vadalazhskaya, Belarusian State Medical University, Minsk, Republic of Belarus, Europe.

Received: December 12, 2019

Published: December 26, 2019

Abstract

Intensive exercise during a prolonged sport competition period is associated with adaptive changes in key physiological systems such as the sympathetic-adrenal-medullary (SAM) and the hypothalamic-pituitary-adrenal (HPA) which can be respectively evidenced by changes in heart rate variability (HRV) and awakening circulating hormonal (cortisol, testosterone) levels. The aim of the present study was to assess the reciprocal relationship between awakening hormonal status and its possible effects on both cardiac function and competitive performance in athletes. The study was performed in handball male athletes, N = 16 during a 2 weeks competition period and in the recovery period. Cortisol/testosterone, electrolytes, blood gas level, 12-lead ECG were analyzed before, daily during and after serial games competition. Transthoracic echocardiography (Echo) was performed soon before the competition period. All athletes had a normal range of Echo parameters. During the competition period, lower awakening level of cortisol and testosterone were independently associated with lower heart rate variability (HRV) and down sloping ST segment depression at resting ECG as well as with higher prevalence of game mistakes at multivariate analysis ($p < 0.05$). Among the other biomarker the relevant correlations with ECG abnormalities and competitive performance was defined for capillary plasma sodium and blood oxygen concentration in the early morning hours. In the recovery period in spite of different ECG pattern (normal ECG 33%, (sinus bradycardia 40%, early repolarization syndrome 7%, ST segment down shifting or T wave inversion 20%), no correlation was found between ECG parameters, hormonal status or other biomarkers in the recovery phase. The present study demonstrates the association of a low individual cortisol-testosterone awakening status with a low HRV and therefore maladaptation of the sympathetic drive during a prolonged competition period in handball athletes. These physiologic "maladaptive" changes may affect cardiac response to intensive exercise as assessed by ECG patterns and competition performance.

Keywords: Intensive Exercise; Handball; Athletes; Cardiovascular System; ECG; Cortisol; Testosterone; Ergometry; Echocardiography; Awakening Hormonal Status; Testosterone, Cortisol

Introduction

A regular physical activity is known to reduce the risk of cardiovascular diseases [1] by multiple mechanisms including pro inflammatory tissue response attenuation [2], improvement of glucose metabolism and cognitive function [3], myocardial compliance with diastolic and systolic function [4].

On the other hand, the possible favourable or unfavourable effects of intensive exercise during training and competition in athletes is a matter of discussion. In particular, situations such as prolonged sport competition periods, in which an individual anticipates a requirement to react or respond, are typically associated with increased biological activity including increases in neuroendocrine and cardiovascular activity. This biological up-regulation serves to prepare the individual for the forthcoming perceived demand but in some persons, such physiological responses may be abnormal potentially causing further cardiovascular overload, decreased performance and potential damage [5].

Two key physiological systems may be involved, the sympathetic-adrenal-medullary (SAM) and hypothalamic-pituitary-adrenal (HPA) axis which provide resource to deal with the expected challenge [6]. Nevertheless, the profile of cortisol concentrations does not adapt rapidly to acute stress, although its amplitude might be reduced under some conditions [7]. Acute up-regulation of cortisol, secreted by the HPA axis, increases the release of glucose and stimulates the sympathetic nervous system providing resource to deal with the anticipated physical challenge and maintain homeostasis [8]. Cortisol levels are elevated in athletes prior to competition and that levels are greatest when sampled closer to the start of competition [9]. However, while an increased hormonal secretion during competition may represent an adaptive response to challenge, a reduced or blunted response may express maladaptive response and has been a sign of unfavorable athletic performance. Similarly, an excessive activation of the SAM axis may represent a maladaptive change. As a matter of fact a reduced HRV, known to express prevalent sympathetic over parasympathetic activity, followed high monotony and overall stress with a simultaneous decrease in ST and intermittent running performance [10], but it was not investigated in handball athletes cohort.

The aim of the present study was to assess the reciprocal relationship between adaptive/maladaptive responses of the cortisol/testosterone secretion and SAM activation as expressed by HRV during a prolonged competition period in handball athletes. We also assessed the possible effects of combined individual hormonal response on competitive performance and cardiac function and homeostasis as expressed by ECG derived parameters.

Methods

All athletes were underwent two serial recordings and measurements of ECG, blood pressure, heart rate variability, blood hormone cortisol and testosteron, electrolytes and glucose analysis.

During the competition period

Superficial ECG was registered in 12-leads taking time 3 minutes. All the recordings were done in a room at ambient temperature (22 – 24°C) in the morning hours just after awakening of athletes. Standard protocol was used to analyze the spectral and time parameters.

Cortisol and testosterone levels were measured in the centrifuged blood plasma after the taking 90μl from the arm finger in the morning hours (between 7am and 8am) just after wake up. The customized immunofluorescence assay by i-CHROMA Reader analyzer (Boditech Med Inc., South Korea) was done. Reference range of cortisol was 250 - 700 nmol/l and testosterone in men 8-40 nmol/l.

Anabolic Index (IA) was calculated: IA =testosterone (nmol/L)/cortisol (nmol/ L) x100 [11].

Short performance test "Distinguishing reaction" with the analysis of wrong respect (mistakes) was estimated in all athletes.

All athletes were assessed by the described methods multiply during competition period: before the start of competition (0 day) and during the serial games (on 3rd, 4th, 7th, 9th,12th day of serial games competition period).

Additionally before competition transthoracic echocardiography (Toshiba Applio 300, 2Hz probe, Japan) was performed with standardized technique of acquisition, recommended probe positions and analyzed parameters [12].

During the rest period (after competition)

Superficial 12-lead ECG for HRV analysis was registered in the morning hours before ergometry test and assessed as described before.

Ergometry (Shiller, cycling) exhausted protocol with stepwise increasing of load from 125 Wt by 50 Wt every 2 minutes to maintain the anaerobic plateau was done under ECG monitoring.

Statistical analysis was performed using the parametric and nonparametric tests. Dynamics of serial measurements of cortisol, testosterone and ECG was estimated as significant if $p < 0.05$ by pair t-test and Mann-Whitney analysis.

Material

Sixteen man handball players (team) in age 19 - 21 years old were included in the study. Every athlete from the team was undergone similar serial investigations of ECG, HRV, blood markers, including cortisol and testosterone.

Results and Discussion

The aerobic conditioning of the regular game sports demonstrated the improvement of aerobic function of the muscle [13]. However the intensive physical exercising is followed by the increasing of the cardiovascular adverse event rate independently on the total energy equivalent of the exercise capacity (Figure1) [14].

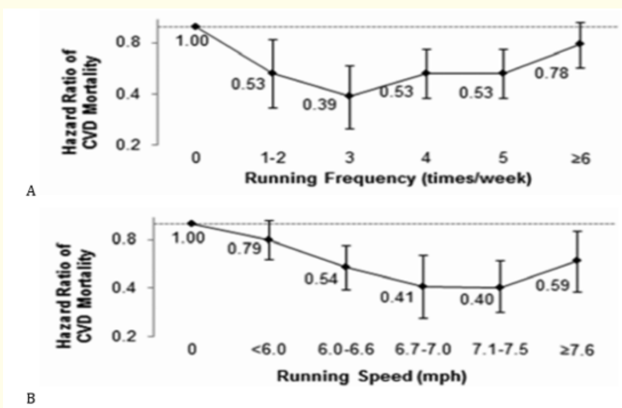

Figure 1: Cardiovascular mortality (CVM) rate in the different running protocols. A – ratio between CVM and running frequency, B - ratio between CVM and running speed [16].

Moreover, high physical exertion and psycho-emotional stress, together with an overtraining, chronic infection lead to chronic stress and impaired adaptation of the cardiovascular system [15,16]. The situation when the strength of the pathological effect exceeds the level of stress tolerance develops the dissociation of adaptability, which creates conditions for impaired metabolism, function and structure of the myocardium, which can lead to persistent focal damage, and myocardial fibrosis can form in the condition of chronic hypercortisolism [17,18].

Endogenous glucocorticoids in physiological doses provide an endogenous anti-inflammatory effect dependently to circadian release (Figure 2) and binding glucocorticoid or mineralocorticoid receptors [19].

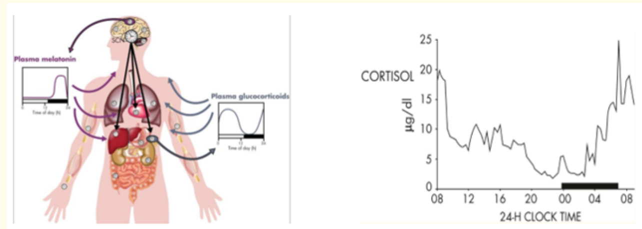

Figure 2: The 24-hour rhythms of circulating melatonin (released by the pineal gland, represented by a purple circle) and cortisol (released by the adrenals, represented by a blue circle) [Modified and redrawn from P. Pevet and E. Challet [20] with permission. © Elsevier.]: A – scheme of melatonin and cortisol release, B – 24-hour level of cortisol [18].

The circadian cortisol rhythm includes three components: (1) the cortisol awakening response (CAR), (2) a decline in cortisol levels during the rest of the day (falling in the morning and a gradual down sloping in the afternoon and early evening); and (3) a fast gradual increase in cortisol levels from the second half of the night until waking. A dysregulation of the CAR with the magnitude reduction post-awakening, independently from the rest of the diurnal HPA-axis activity, has been related to chronic stress, cardiovascular disease, sleep disorders [21].

According to H. Zhang, the dysfunction of the glucocorticoid reception system triggered by stress can produce the glucocorticoid resistance and subsequent heart disease [22,23]. An increase the level of stress hormones (cortisol, adrenaline) leads to gross structural changes also in red blood cell and attenuation of coronary blood flow [24].

The average morning cortisol level as a reflection of CAR was in normal range throughout the competition period in all handball players. The absolute maximum cortisol level in team of athletes was revealed two days before the competition (Figure 3) as it was found by other researchers with suggesting the origination of the phenomena from mental stress before the competition [25]. Other authors describe the increased cortisol level immediately before game as a reflection of an adaptive role of CAR for up-regulation to enable resources immediately prior to demand [9].

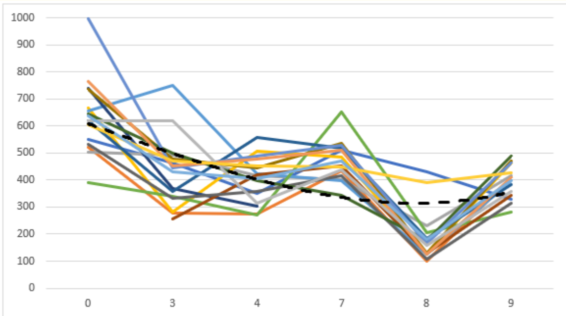

Figure 3: Athletes individual dynamics of cortisol during the competition. Stripped line shows trend.

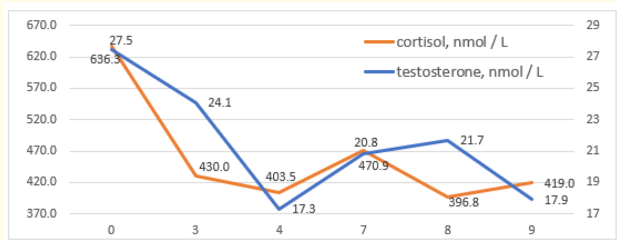

Figure 4: Awakening response of plasma hormones during the competition period.

The significant decreasing of both cortisol and testosterone with the falling of IA by 23.2% (p = 0,032) was registered on day 4 with positive fluctuation on day 7 and repeat significant cortisol decreasing at 8th day of competition (Figure 4).

Described awakening profile of cortisol and testosterone was followed by the changes of homeostasis, predominantly blood partial pressure of oxygen, sodium potassium and lactate, nonsignificant increasing of extracellular liquid and dramatic decreasing of total body liquid. Revealed severe deficit of intracellular liquid wasn't accompanied by any visible symptoms of hydration (swelling, headache, rising of arterial pressure) (Table 1 and Figure 5).

Parameter/ Day	0	2	3	4	7	8	9
pO2	67,54	64,14*	63,86**	64,0	66,68	64,19	65,70*#
Na	139,53	142,75*	144,25**##	143,3*	143,1	145,7*	143,1*#
K	4,35	4,41	4,72*#	4,56	4,98*#	4,7*	4,88
Glucose	5,18	4,93	4,67*	4,54*	4,6*	4,92	4,66
Lactate	1,45	3,05*	2,3*#	2,51*#	2,21*	2,72*#	3,48*#

Table 1: Early morning level of peripheral blood oxygen, electrolytes and metabolic products in athletes during serial games competition.

* - difference with day "0" p<0,05; ## - difference with day "0" p<0,01;

- difference between days p<0,05; ** - difference between days p<0,01.

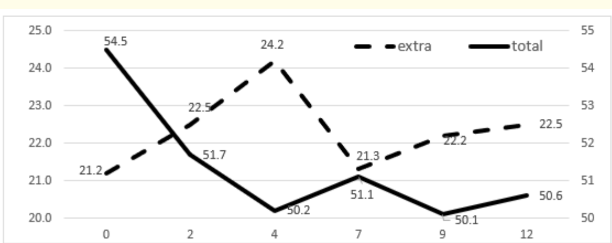

Figure 5: Total (solid line) and extracellular (striped line) water (liquid) dynamics in kilograms via bioimpedance rheography during serial games competition.

Relatively to total the extracellular liquid volume raised significantly from 38,9% before games to 48,2% on day 4 (p < 0,05) of competition period with simultaneous accumulation of sodium (p = 0,01) and falling of the blood concentration of oxygen (p = 0,02).

The falling of the cortisol and testosterone in the morning hours is followed by the significant depression of HRV on 2nd (p < 0,001) and 3rd (p < 0,003) days, sinus bradycardia (HR 50 ± 5 BPM, p < 0,002), prolongation of QTc interval (p < 0,05) on 3rd day of competition (Figure 6) which can be explained as a cardiovascular system dysregulation.

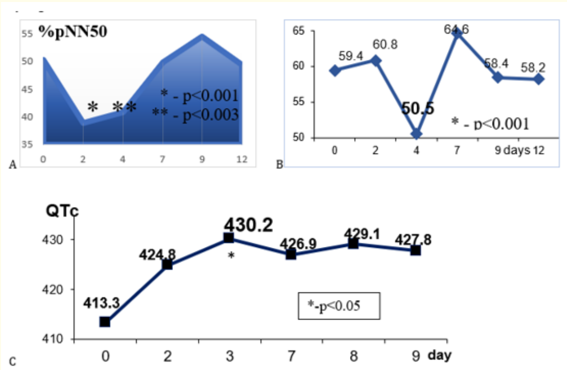

Figure 6: ECG in athletes during the competition period. A - Heart rhythm variability (HRV, %pNN50), B - Heart rate, C – QTc dynamics.

As it was shown in the recent publications the most common markers for determining muscle damage are cortisol, testosterone, and the ratio of testosterone to cortisol, which allows assessing the prevalence of anabolic or catabolic processes [26,27]. But in our study almost synchronous falling of the both level cortisol and testosterone showed the incompetence of this index for the integral evaluation of athlete status (see fig.4).

Cortisol is associated with training stress level in athletes. A decrease of cortisol level is associated with fatigue of athletes [13,28]. At the same time, in the study of Lautenbach F. 2018, the time of blood analysis was arisen, showing a negative correlation between performance and cortisol levels before the competition and a positive correlation between cortisol during the competition and performance [29]. Regarding these findings the cortisol level was analyzed in handball athletes exactly during the serial game competition reflecting the growing disturbance of homeostasis and energy support in athletes.

To assess noninvasively myocardial adaptation, testosterone determination is used [25]. According to Casto K.V. with coauthors (2017), the testosterone level at all measured time points was positively associated with athletes' assessments of their own individual performance as a general mark of cardiovascular function and tissue perfusion. Athletes showed a significant increase of testosterone and cortisol levels during the competition period - the “competition effect” [26], which may indicate a relationship between the cognitive assessment of personal performance and testosterone levels.

An anabolic index (IA) is used for an integral assessment of the metabolic state in athletes. The results of the study by Panin L. E. (2012), showed that a decrease in IA indicated an inability to adequately recover after resting with overtraining [15]. In our study this index dint work because of simultaneous dynamics of the blood level of both testosterone and cortisol, especially at the fourth day of the competition with higher rate of ECG abnormalities in the team athletes (see figure 3).

In our group of athletes the estimation of individual performance has been done via short performance test “Distinguishing reaction” with the analysis of wrong respect (mistakes). The test showed tendency to the increasing of the mistake number with the stabilization ($p < 0,05$) of psychophysiological status at the end of competition (Figure 7).

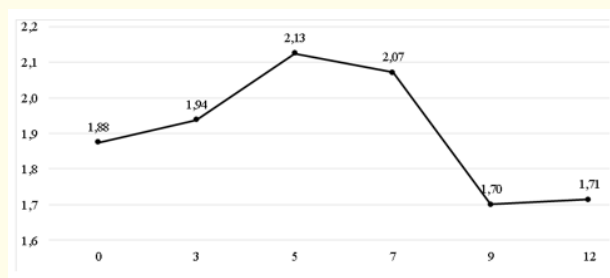

Figure 7: Mistake score by short performance test “Distinguishing reaction” in athletes in days 0-3-5-7-9-12.

Conclusion

The widely explored theory of macro and micro adaptation to intensive sport exercises with the transforming of the structural and the enzyme particles was supported by our results. Most important our findings were related to significant reciprocal link between awakening hormonal response and ECG signs of myocardial and autonomous nervous system dysfunction in young handball athletes during serial game competition.

The limitation of the study was component of transatlantic transfer and different psychophysiological condition of players regarding their field positions.

Bibliography

1. Pelliccia A., *et al*. "Recommendations for participation in competitive and leisure time sport in athletes with cardiomyopathies, myocarditis, and pericarditis: position statement of the Sport Cardiology Section of the European Association of Preventive Cardiology (EAPC)". *European Heart Journal* 40 (2019): 19-33.
2. Pedersen BK., *et al*. "Searching for the exercise factor: is IL-6 a candidate?" *Journal of Muscle Research and Cell Motility* 2-3 (2003):113-119.
3. Fealy CE., *et al*. "Exercise training decreases activation of the m mitochondrial fission protein dynamin-related protein-1 in insulin-resistant human skeletal muscle". *Journal of Applied Physiology* 117.3 (2014): 239-245.
4. Cassidy S., *et al*. "High intensity intermittent exercise improves cardiac structure and function and reduces liver fat in patients with type 2 diabetes: a randomised controlled trial". *Diabetologia* 59 (2016): 56-66.
5. McDonald D and Wetherell MA. "Competition Stress Leads to a Blunting of the Cortisol Awakening Response in Elite Rowers". *Frontiers in Psychology* (2019).
6. Hare OA., *et al*. "State anxiety and cortisol reactivity to skydiving in novice versus experienced skydivers". *Physiology and Behavior* 118 (2013): 40-44.
7. Dijk DJ., *et al*. "Amplitude reduction and phase shifts of melatonin, cortisol and other circadian rhythms after a gradual advance of sleep and light exposure in humans". *Plos One* 7.2 (2012): e30037.
8. Wetherell MA., *et al*. "The effects of an anticipated challenge on diurnal cortisol secretion". *Stress: The International Journal on the Biology of Stress* 18 (2015): 42-48.
9. Van Paridon K. N., *et al*. "The anticipatory stress response to sport competition; a systematic review with meta-analysis of cortisol reactivity". *BMC Open Sport and Exercise Medicine* 3 (2017): e000261.
10. Figueiredo DH., *et al*. "Effect of Overload and Tapering on Individual Heart Rate Variability, Stress Tolerance, and Intermittent Running Performance in Soccer Players During a Preseason". *The Journal of Strength and Conditioning Research* 5 (2019): 1222-1231.
11. Casto K.V., *et al*. "Competition-related testosterone, cortisol, and perceived personal success in recreational women athletes". *Hormones and Behavior* 92 (2017): 29-36.
12. Lang RM., *et al*. "Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging". *Journal of the American Society of Echocardiography* 28 (2015): 1-39.
13. Stone NM and Kilding AE. "Aerobic conditioning for team sport athletes". *Sports Medicine* 39.8 (2009):615-642.
14. Lee DC., *et al*. "Leisure-Time Running Reduces All-Cause and Cardiovascular Mortality Risk". *Journal of the American College of Cardiology* 64.5 (2014): 472-481.
15. Popovic B., *et al*. "Acute response to endurance exercise stress: focus on catabolic/anabolic interplay between cortisol, testosterone, and sex hormone binding globulin in professional athletes". *Journal of Medical Biochemistry* 38.1 (2019): 6-12.
16. Anderson T., *et al*. "The Cortisol Awakening Response: Association with Training Load in Endurance Runners". *International Journal of Sports Physiology and Performance* 13.9 (2018): 1158-1163.
17. Yiu KH., *et al*. "Increased myocardial fibrosis and left ventricular dysfunction in Cushing's syndrome". *European Journal of Endocrinology* 166.1 (2012): 27-34.
18. Lishmanov YB., *et al*. "The role of endogenous opioid system in the regulation of heart tolerance to stress-induced damage". *Bulletin of Experimental Biology and Medicine* 163.1 (2017): 25-27.
19. Oster H., *et al*. "The Functional and Clinical Significance of the 24-Hour Rhythm of Circulating Glucocorticoids". *Endocrine Reviews* 38.1 (2017): 3-45.
20. Pevet P and Challet E. "Melatonin: both master clock output and internal time-giver in the circadian clocks network". *Journal of Physiology-Paris* 105 (2011): 170-182.
21. Fries E., *et al*. "The cortisol awakening response (CAR): facts and future directions". *I International Journal of Psychophysiology* 72.1 (2009): 67-73.
22. Zhang HN., *et al*. "Endogenous glucocorticoids inhibit myocardial inflammation induced by lipopolysaccharide: involvement of regulation of histone deacetylation". *Journal of Cardiovascular Pharmacology* 60.1 (2012): 33-41.
23. Zhang H., *et al*. "HDAC2 is required by the physiological concentration of glucocorticoid to inhibit inflammation in cardiac fibroblasts". *Canadian Journal of Physiology and Pharmacology* 95.9 (2017):1030-1038.

24. Lishmanov YB., *et al*. “The role of endogenous opioid system in the regulation of heart tolerance to stress-induced damage”. *Bulletin of Experimental Biology and Medicine* 163.1 (2017): 25-27.

25. Souza RA., *et al*. “Heart rate variability, salivary cortisol and competitive state anxiety responses during pre-competition and pre-training moments”. *Biology of Sport* 36.1 (2019): 39-46.

26. Anderson T., *et al*. “The Cortisol Awakening Response: Association with Training Load in Endurance Runners”. *International Journal of Sports Physiology and Performance* 13.9 (2018):1158-1163.

27. Luccia TPB., *et al*. “Bouts of exercise elicit discordant testosterone: cortisol ratios in runners and non-runners”. *Archives of Endocrinology and Metabolism* 62.3 (2018): 325-331.

28. Tota Ł., *et al*. “Muscle and intestinal damage in triathletes”. *PLoS one* 14.1 (2019): e0210651.

29. Lautenbach F and Lobinger B. “Cortisol predicts performance during competition: preliminary results of a field study with elite adolescent taekwondo athletes”. *Psychophysiology and Biofeedback* 43.4 (2018): 275-280.