

Reaction of heart rate regulation to extreme sport activity in elite athletes

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Abstract.

Purpose: to study elite athletes' (wrestlers) heart rate regulation reactions to extreme sport activity

Material: were studied of 21 elite wrestlers who specialized of Greco-Roman Wrestling. The heart rate regulation were studied via the cardiomonitor «Polar-RS800CX». The statistical, spectral and scattergrams parameters of heart rate variability (HRV) were investigated.

Results: the results indicate increase of stress level of autonomic heart rate regulation's mechanisms with inhibition of elite athletes' sympathetic and parasympathetic activity in competition condition. The pre-competition reaction of elite athletes is characterized by decline of determinism and increase of stochastic organization of system of heart rate regulation in competition activity. Under extreme psycho-emotional load in competition condition the predominance of higher autonomic centers over cardio-vascular centre with transition on the neuro-humoral subcortical and metabolic centers of heart rate regulation in elite athletes were observed.

Conclusions: under extreme psycho-emotional load in competition condition predominance of higher autonomic centers over cardio-vascular centre with transition on the neuro-humoral subcortical and metabolic centers of heart rate regulation were observed in elite athletes.

Key words: heart rate regulation, pre-competition reaction, competition activity, elite athletes.

Introduction

Modern sports activity is characterised by influence of different factors, which relate to psychological and emotional stress of athletes (Hanton, Fletcher, & Coughlan, 2005; Korobeynikov, Korobeinikova, & Shatskih, 2013). Thus, the study of physiological regulation of elite athletes in sport activity's extreme situations is a one of the actual ways of modern sports science.

As known, the psycho-emotional tension which connected with sport's activities may provoke the decline of performance of athletes (Woodman et al., 2009; Lane, Beedie, Devonport, & Stanley, 2011; Malakhov, Puhach, Serebrjakov, Bakanova, & Druz 2014; Ermolaeva, 2015). One of the basic physiological systems which form the functional states and adaptative reaction of organism of athletes during physical activity is an autonomic nervous system (Hartmann, & Mester, 2000; Korobeynikov, Korobeynikova, Chernozub, & Makarchuk, 2013; Kiprych, 2014; Liu, 2015; Ivashchenko et al., 2016).

From physiological point the main components of sports stress include: emotional stress (a set of negative experiences) with corresponding autonomic shifts; physiological stress (tension of organism under the influence of training and competitive loads), general fatigue, associated with intensive work, fulfilled in order to increase tolerance to physical and psycho-emotional load (Hartmann, & Mester, 2000; Goginava, & Rumba, 2014; Abdulrahman, 2015; Khmelnytska, & Filippov, 2015). These three components are correlated and can lead, finally, under irrational organization of the training process, to depletion of functional reserves.

One of important problems of modern sports is the prelaunch reactions in competition condition. For objective assessment of the prelaunch state we must use complex methods of investigation, which would reflect various components of integrated functional state of an athlete.

The structure of the sports activities of combat sport consists of the elements of psychophysiological, psychomotor and vegetative functions, as part of functional states (Korobeynikov, Rossokha, Koniaeva, Medvedchuk, & Kulinich, 2005; Bliznevsky, Kudryavtsev, Iermakov, & Jagiello, 2016; Iermakov, Arziutov, & Jagiello, 2016; Iermakov, Podrigalo, & Jagiello, 2016). The functional states of athletes reflects integral complex of functional system's, responsible for effectiveness of sports activities.

Analysis of current researches in the field of sports physiology and sports medicine shows that the majority of works are devoted to sports subjects, related to individual characteristics of athletes' functional state in various conditions of training and competition activity (Kozina et al., 2015, 2016; Kozina, & Iermakov, 2015; Radchenko, 2015; Tropin, & Pashkov, 2015). During the pre-competition and directly competition period a large number of external factors, that determine the strength of emotional stress, affects on athlete. In particular, it is a

link between the level of responsibility, caused by competition and degree of manifestation of emotional stress (Mellalieu, Neil, Hanton, & Fletcher, 2009; Kellmann, 2010; Iermakov et al., 2016; Pryimakov, Iermakov, Kolenkov, Samokish, & Juchno, 2016). Generally speaking, pre-competition state before important competitions is characterized by physiological changes that occur over time, the day before. But the pre-competition states develop directly before start. The optimality of psycho-emotional reactions is determined by changes in dynamics of athlete's physiological functions. According to the physiological mechanisms pre-competition state has been conditioned by reflex reaction. Manifestation of pre-competition reactions is associated with excitation and inhibition of the central nervous system. Pre-competition reactions reflect in activation of neuromuscular activation system, neuroendocrine system and circulatory system (Eubank, & Collins, 2000; Lagos et al., 2008; Ohromiy, Makarova, & Kasyuha, 2014; Lopatenko, Kosik, & Kosik, 2015). In fact, pre-competition reactions are a form of emotional stress, caused by competitive activity.

As per classification, there are three forms of prelaunch states: prelaunch "fever" prelaunch "apathy" and "combat readiness". Prelaunch "fever" is characterized by activation of central nervous system's excitation and sympathetic adrenal system. Prelaunch "apathy" is a result of activity's overstimulation and central nervous system's inhibition with reduction of skeletal muscles' excitability. "Combat readiness" is characterized by optimal level of central nervous system excitation, autonomic changes, mobilization of glycogen, the most favorable ratio of glucocorticoids and catecholamine (Dorofeeva, 2004; Viru et al., 2010; Lopatenko, Tumanova, & Gatsko, 2015). As it is known, in response to extreme factors of competition the responsive functional system is formed that connects nervous and humoral regulatory mechanisms of human body (Périard, Racinais, & Sawka, 2015; Yuriy, Maryan, & Valeria, 2016). In psycho-emotional stress conditions of athletes one of the important links of the functional system sympathetic-adrenal system ensures autonomic regulation of heart rate.

But the basic physiological system that optimizes pre-competition psycho-emotional state of athletes is cardiovascular system. Thus, in our opinion, features of the reactions of heart rate regulation to extreme sport activity in elite athletes, who specialize in wrestling, are understood poorly.

The purpose of the work is to study reactions of heart rate regulation to elite athletes' (wrestlers) extreme sport activity.

Materials and methods

Participants. 21 elite athletes (Greco-Roman Wrestlers) were examined. The age of the athletes was 20–25. All of the athletes were the members of Ukraine National Team of Greco-Roman Wrestling. The study was conducted during the international tournament on Greco-Roman wrestling "Azovmash Cup" (Mariupol, 15.06–16.06 2013), on the eve of the competition, and exactly on the day of the competition.

Research Design. Autonomic regulation of heart rhythm was performed with the help of cardiomonitor «Polar-RS800CX» with registration of heart rate variability (HRV) spectral characteristics. The findings were presented in the report with the help of statistical program «KubiosHRV» (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014). Heart rate variability is a non-invasive investigation method of cardiovascular system's autonomic regulation in real-life conditions. HRV reflects the level of activation of both autonomic nervous system's parts: parasympathetic and sympathetic (Cornforth, Campbell, Nesbitt, Robinson, & Jelinek, 2015). Analysis of non-stationary transient process of heart rate regulation's scattergrams as a nonparametric method of analysis was used (Kitlas, Oczeretko, Kowalewski, Borowska, & Urban, 2005). SD1 parameters (display a-periodic fluctuations of heart rate) and SD2 (slow oscillations of heart rhythm) were determined. Information-entropy characteristics of heart rate variability in dynamics of elite wrestlers' competition activity were analyzed. The parameters of information-entropy characteristics of heart rate, which were studied, are as follows: approximate entropy (ApEn), sample entropy (SampEn), Shannon Entropy (ShanEn) and Determinism (DET) (Nahshoni et al., 2004; Zapovitriana, Korobeynikov, & Korobeinikova, 2015).

Statistical Analysis. Statistical analysis was fulfilled with the help of Statgraphics 5.1 (Manugistics, Inc.) programs. Since the data obtained in the research didn't correspond to normal distribution, the methods of nonparametric statistics of Wilcoxon rank-sum test were applied. To reflect data distribution were used interquartile range, thus specifying first (lower) quarter (25%) and third (upper) quarter (75%).

Experimental study was approved by the Ethics Committees for Biomedical Research of National University of Physical Education and Sport of Ukraine with accordance the ethical standards of the Helsinki Declaration. Consents for research in writing form were given by the athletes according to the recommendations to Ethics Committees for Biomedical Research.

Results

In Table 1 the results of studies of pre- and in-condition competition reactions of elite athletes for heart rate variability statistical values are presented. The analysis of Table 1 showed statistical differences between pre and in condition competition of elite athletes for parameters of SDNN and RR triangular index. The observed facts indicate stress level increase of autonomic heart rate regulation's mechanisms of elite athletes in competition condition.

Table 1. Statistics of heart rate variability values in elite athletes of pre and in condition competition (n=21)

Indicators	Pre-condition competition			In-condition competition		
	Median	Lower quarter	Upper quarter	Median	Lower quarter	Upper quarter
Mean RR, ms	952.75	805.70	1181.20	913.60	825.95	1087.35
SDNN, ms	136.05	98.76	198.45	63.45*	37.35	81.55
HR, 1/min	62.46	56.25	66.99	66.41	55.28	73.27
RR triangular index, conv. unit	16.52	12.65	19.40	12.34*	8.930	14.01

Note: * – $p < 0.01$, comparing with the pre-competition condition

At the same time, general level of cardiovascular system’s functioning does not change. The absence of statistically confident changes between pre- and in- condition competition of elite athletes for values of Mean RR and HR confirm this fact. The results of pre- and in- condition competition for values of spectral characteristics of heart rate variability in elite athletes’ studies are presented in Table 2. Analysis of results, which are presented in Table 2, showed the significant reduction of spectral characteristics of heart rate variability in condition of competition in elite athletes.

This confirms the decreasing of the activity of low (LF) and high (HF) spectrum of heart rate in elite athletes during psycho-emotional stress.

Table 2. Statistics of values of heart rate variability’s spectral characteristic in elite athletes in pre- and in-condition competition (n=21)

Indicators	Pre condition competition			In condition competition		
	Median	Lower quarter	Upper quarter	Median	Lower quarter	Upper quarter
VLF, ms^2	5655.50	2940.37	18701.37	1179.53*	613.540	2649.53
LF, ms^2	4838.37	2628.04	13355.37	1005.28*	377.55	2115.73
HF, msc^2	4958.54	1896.56	13818.27	955.55*	244.53	1716.55
Total, ms^2	17872.5	9180.42	28391.27	3815.42*	1493.57	7107.62
LF/HF	1.27	1.02	2.26	1.15	0.74	1.99

Note: * – $p < 0.01$, comparing with the pre-competition condition

The obtained results indicate inhibition of elite athletes’ sympathetic and parasympathetic activity of autonomic nervous system in condition of competition. Exception is the parameter of vegetative balance (LF/HF), which does not show the changes in dynamics in competition activity (See table 2). But, among structure of heart rate variability’s spectral characteristics parameter of VLF is the dominant (See table 2).

According to the conception of autonomic regulation of the heart rate, R.M. Bayevsky offered the system of different level of management, which include two blocks: central and autonomous (Baevsky, 2004). The autonomous block of heart rate regulation is presented of sinus node. The central block has two parts: neural and humoral, which influence on sinus node.

The results of Table 2 indicate the predominance of central block of heart rate regulation in elite athletes’ stress condition. At the same time, the absence of changes of LF/HF values indicates the balance between sympathetic and parasympathetic tone of elite athletes’ autonomic nervous system.

The scattergrams data analysis of heart rate variability in elite athletes’ pre competition reactions are presented in Table 3. The results show significant changes in elite athletes’ competition dynamics by scattergrams data analysis (See table 3). This fact relates to average SDNN values (See table 1) and indicates increasing of regulatory mechanisms of cardio intervals rate tension level due to a-periodic and periodic fluctuations of heart rate. Apart from it, the reliable decrease of scattergrams data analysis of SD2 values reflects in activation of sympathetic and parasympathetic tone of autonomic nervous system.

Table 3. Statistics of scattergrams data analysis of heart rate variability in elite athletes in pre- and in- condition competition (n=21)

Indicators	Pre condition competition			In condition competition		
	Median	Lower quarter	Upper quarter	Median	Lower quarter	Upper quarter
SD1	92.90	55.64	185.22	36.55*	21.75	54.86
SD2	177.52	129.75	247.41	71.95*	50.95	99.48

Note: * – $p < 0.01$, comparing with the pre-competition condition

The results of information-entropy characteristics of heart rate variability in elite athletes are presented in Table 4.

Table 4. Statistics of information-entropy characteristics of heart rate variability in elite athletes of pre- and in-condition competition (n=21)

Indicators	Pre condition competition			In condition competition		
	Median	Lower	Upper	Median	Lower	Upper

		quarter	quarter		quarter	quarter
Determinism (DET), %	99.17	98.78	99.58	97.25	95.94	99.11
Shannon Entropy (ShanEn)	3.47	3.33	3.68	3.04	2.76	3.24
Approximate entropy (ApEn)	1.04	0.77	1.10	0.89*	0.82	0.99
Sample entropy (SampEn)	1.25	0.63	1.41	1.62*	1.405	1.79

Note: * – $p < 0.01$, comparing with the pre-competition condition

Analysis of information-entropy characteristics of heart rate variability shows significant changes in dynamics of pre-competition activity in elite athletes. The main changes during competition activity are shown by parameters of approximate entropy (ApEn) and sample entropy (SampEn). But we can see different vectors of change parameters: decrease of ApEn and increasing of SampEn (Table 4).

Some works, which are devoted to study of information-entropy characteristics of heart rate variability for meanings of functional states of human in different conditions, in norms and pathology, testify that SampEn are used for diagnostics of non-stationary processes of fluctuation of heart rate (Lake, Richman, Griffin, & Moorman, 2002; Richman, & Moorman, 2000). For assessment of psycho-emotional tension in extreme sports activity SampEn than ApEn are more preferably used. Basing on this, we used SampEn for heart rate of elite athletes. The pre-start reactions of elite athletes are characterized by significant rising of SampEn values (See table 4). This fact points at decline of determinism and increase of stochastic organization of heart rate regulation system in competition activity. The optimization of functionality of organism relates to the stochastic type of organization of functional system. This type of functional organization is characterized by search of required links for formation of elite athletes' optimal activity level in competition condition. The observed results are consistent with previous results: availability of balance between sympathetic and parasympathetic tone of autonomic nervous system in elite athletes. It points at systems of autonomic heart rate regulation's efficient mechanisms.

Discussion

Thus, pre-competition reactions of system of autonomic of heart rate are characterized by increase of elite athletes' autonomic heart rate mechanisms' tension level. The observed dynamic of parameters of autonomic regulation of heart rate points at inhibition of sympathetic and parasympathetic divisions of autonomic nervous system in elite athletes during competition activity. Thus, we can summarize that under extremely psycho-emotional load the predominance of higher autonomic centers over cardio-vascular centre with transition on the neuro-humoral subcortical and metabolic centers of heart rate regulation in elite athletes were observed.

At the same time, the increase of amplitude of VLF spectrum fluctuation of cardio intervals relates to correlation between psycho-emotional level of tension and activity of ergotropic suprasedgmental structures and energy deficient states (Khaspekova, 2003; Kurianova, 2008; Flashman, Martinov, Petrovsky, & Korablina, 2014). Also, the absence of parameters LF/HF changes in dynamics testifies the balance between sympathetic and parasympathetic tone of autonomic nervous system and perfection of mechanisms of heart rate regulation system in elite athletes. The dynamics of scattergrams data analysis of heart rate variability in competition condition are consistent with the changes of SDNN. This fact points at heart rate regulation's tension level caused by a-periodic and periodic fluctuations of cardio intervals.

The analysis of information-entropy characteristic of heart rate variability points at decline of determinism and increasing of stochastic of system of heart rate regulation in elite athletes. The stochastic organization of elite athletes' heart rate regulation relates to one of functional systems' form through compensation searching of optimal organization in competition condition.

Conclusions

1. The results show increase of stress level of mechanisms of autonomic heart rate regulation with inhibition of sympathetic and parasympathetic activity in elite athletes in competition condition
2. Pre-competition reactions of elite athletes are characterized by decline of determinism and increase of stochastic organization of system of regulation of heart rate in competition activity.
3. Under extreme psycho-emotional load in competition condition the predominance of higher autonomic centers over cardio-vascular centre with transition on the neuro-humoral subcortical and metabolic centers of heart rate regulation in elite athletes were observed.

Conflict of Interest.

The authors declare that there is no conflict of interest.

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