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Original Article

Peculiar properties and dynamics of physiological indicators in Handball team

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Abstract:
A longitudinal study of the dynamics of physiological indicators of highly qualified handball players was proposed to conduct. The challenges of studying the characteristics and dynamics of the indicators of the cardiovascular system, exercise capacity, heart rate, functional state, heart rate variability, autonomic regulation and energy of highly qualified handball players during the annual macro cycle have been analyzed. Data led to the conclusion that the adaptive response of the athletes' bodies at the training load in the run proceeds with different voltage regulation systems. It was revealed that some athletes achieved high level of fitness and was accompanied by considerable stress adaptive mechanisms of the cardiovascular system in violation of the regulatory function of the autonomic nervous system. There was defined no significant differences in terms of heart rate and stroke volume were observed. However, in the competitive period marked economization in the vascular unit of blood circulation and decrease in activity of the sympathetic influences was determined. The balance of the autonomic nervous system was characterized type of vegetative regulation of cardiac rhythm. There has been a slight increase in activity of the parasympathetic autonomic nervous system alone, which combines the high ability to mobilize sympathetic activity. In fact, this may indicate a functional imbalance of the cardiovascular system of athletes. It is expected that the analysis of heart rate provides a fairly informative data on the functional status of athletes and allows to make adjustments in the proper training and preparation of the recovery process.
Key words: highly qualified handball players, physiological indicators, heart rate variability, and functional efficiency.

Introduction

Modern handball − a sport with a high intensity motor actions in the interaction of explosive speed and power, with the quick change of game situations that require instant solutions, with a wide variety of methods used, the ability to sprint, acceleration, a sharp change in the direction of motion **(**Carlos Lago-Penas at al., 2013; Póvoas & Rebelo, 2011**)**. This requires a high level of development of physical qualities and skillful their implementation during competitive activity **(**Cherif, M. at al., 2012; Ziv and Lidor, 2009). Handball has specific requirements that must be the practical application of research results. Moreover, it requires control of the preparation and analysis of the training process. Thus, knowing the physiological needs of handball, you can improve specific skills that define anaerobic and aerobic systems **(**Povoas at al., 2012; Norkowski, 2002).

In handball, modern medical practice observations of players engaged in physical education and sport. That requires the introduction of minimum invasive methods of research of functional state of the body, which in the current operational inspections and provided the opportunity to get as much information about the condition of the body, ensuring adaptation to physical activity and indicate the level of fitness **(**Vanyushin and Khayrullin, 2015). These methods can be widen if we analyze the level of function of myocardial, vascular, respiratory, sensory-motor, autonomic nervous system and other important given the integral index of the cardio-vascular system, describing the central hemo-dynamics.

Typically, sports practice parameters are calculated because the use of instrumental methods during ongoing researches significantly complicates them. Therefore, the development of new approaches to the assessment of central hemo-dynamics has unquestionable importance for the further improvement of medical control. This is due to operational decision-making that need to improve sports selection, planning training loads, determine the degree of fatigue and predicting possible failure of adaptation (Guenette and Sheel, 2007). Additionally, the study of regulatory mechanisms influence spontaneous and controlled breathing on cardio-vascular activity can play a key role in determining the adaptive capacity of an athlete.

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Analysis of recent research and publications

Ultimate work and competition loads of modern sport lead to dyspraxia and significant adaptive changes. Taking into account this fact it is important to provide constant control of athlete's fitness shape. Fitness shape evaluation is a rather complicated process that requires thorough medical examination of body organs and systems.

Great attention was paid to cardiac rhythm investigation during the last decades, especially during adaptation periods to work and competition stresses. Increase of sympathetic regulation during physical and emotional overworks leads to the decrease of adaptive abilities and affects the cardiac rhythm characteristics in state of reference. Rhythm and heart force are very sensitive to any stress. They contain data about the state of regulatory and adaptive abilities of organism, and force increase depend on the increase of parasympathetic regulation link during work-out session.

Heart rate variability (HRV) is used for evaluation of vegetative regulation of physiological functions and is based on the analysis of successive RR-intervals and mathematical treatment (Petrov et al., 2015). This method allows you to register the shift of neuro-humoral balance, involvement of sympathetic and parasympathetic, nerval and humoral links of cardiac beat rhythm regulation, and the degree of centralization of its control. It is quite clear that there is a connection among all heart rate variability indicators in the beginning and at the end of pre-season and contest season.

Investigating the indicators of HRV within the dynamics of annual cycle and the effectiveness of competitions activity of highly qualified handball players, it was determined that at final stage of competitions the objects of control showed the worsening of vegetative regulation of heart rate [6]. It indicates that the players have accumulated a significant uncorrected fatigue that becomes stronger by the end of specific period and is accompanied by a decrease in efficiency during the games. It concerns both individual athletes and a team as a whole.

Demand for study of psycho physiological, vegetative, physical qualities of individual players and the team as a whole is rather strong, and different studies help to organize and optimize these qualities at different stages. At the same time, the fragmentation of such studies and researches, carried out using different methods, involving athletes of different types and using different functional parameters at random stages of sporting activities do not give an opportunity to make a proper evaluation of dynamics of changes of athletes fitness shape within a big timeframe, and respectively, prevents from making adjustments of work-out sessions at different stages. Cardiorespiratory system is a system that is responsible for energy requirements, especially during short breaks not connected with game activity. This question requires deeper research, and that is why the determination of the features of fitness shape of cardiorespiratory system of top players is of particular relevance. Given the above, we have proposed to carry out the longitudinal study of the dynamics of physiological parameters of qualified handball players during the annual macrocycle.

The purpose of the study was to examine the peculiarities and dynamics of functional state of highly qualified handball players during the annual macrocycle. In accordance with the purpose of the following tasks:

1. To study the characteristics and dynamics of physical capacity and energy of highly qualified handball players during the annual macrocycle.
2. To study the characteristics and dynamics of the indicators of the cardiovascular system and functional state of highly qualified handball players during the annual macrocycle.
3. To study the characteristics and dynamics of autonomic regulation of qualified handball players during the annual macrocycle.

Materials &methods

Overall design

The studies were carried out during an annual training and competition macrocycle at the start and at the end of pre-season, and at the start and at the end of contest season as well.20 qualified handball players of "ZTR" team – numerous champions of Ukraine in the age of 18-32 – were involved in study.

The study was approved by the local research ethics committee, performed in accordance with the ethical standards of the journal IJSM and conformed to the recommendations of the Declarations of Helsinki. Handball players gave voluntary written informed consent to participate in the experiment.

Measuring methods

At all specified stages of experiment the following indicators characterizing the level of overall physical efficiency and body energy security ($aPWC_{170}$, kgm/min; $rPWC_{170}$, kgm/min/kg), absolute (aMOC, l/min) and relative maximal oxygen consumption (rMOC, l/min/kg), lactate (N lac, vt/kg) and alactate (N alac, vt/kg) power were registered by the athletes with help of cycle ergometer test PWC_{170}.

The study of central hemodynamics was performed using tetrapolar impedance plethysmography method. The researchers determined volumetric datum of central circulation: stroke and minute blood volume (SBV, ml; MBV, l/min). The tests were conducted in laboratory conditions in a state of relative rest and seated. Heart rate (HR, bpm) was calculated on the basis of ECG record; systolic (SAP) and diastolic arterial pressure

(DAP) was determined using Korotkov auscultator method; mean arterial pressure (APmean) was determined by formula: APmean= DAP + 0,42 x APpulse.

Method of evaluation of functional status of cardiovascular system, designed to asset the degree of stress of regulatory mechanisms of blood circulatory system, allows you to evaluate the stress of regulatory mechanisms of cardiovascular system, which is fairly considered by the scientists as the main indicator of the body's response to exposure to various stresses. Heart rate variability was assessed to determine the state of vegetative homeostasis. The following indicators were calculated: mode (Mo, s), mode amplitude (AMo, %), variation range (dRR, ms), standard deviation of full massive of RR intervals standard deviation of normal-to-normal intervals (SDNN, ms), index of tension of regulatory systems (IT, c.u.). The tests were conducted in laboratory conditions at rest in prone position during 5 minutes procedure.

Statistical analysis

To reveal the factor structure of the functional state of the qualified handball players, we use factor analysis of indicators using the computer program SPSS 16. Initial data for carrying out of factor analysis were indicators of qualified handball players registered for the annual macrocycle.

Results of research

Diagnostic results at the start of pre-season show average and below average levels of indicators of overall physical efficiency, and stamina of athletes for this kind of sport.

At the end of the preparatory period, there was a significant increase in the level $PWC_{170,}$ (25%), both absolute (aPWC170) (P<0,01), and relative (rPWC170) (P<0,001) compared with the initial values.Thus, the absolute value of PWC_{170} preparation period to the beginning and the end of the competition period is increased. Changes in overall physical health be correct not only from the beginning to the end of the preparation period, but from the beginning of the preparation period to the beginning of the competition period P<0,001 (t=5,23) values for $aPWC_{170}$ and P<0,01 (t=3,88) values for $rPWC_{170}$.MOC level tended to increase (на 10%) that was not statistically reliable statistically significant indicator of character for aMOC and for rMCS celebrated its significant increase (P<0,05) to the top of the competitive period.

Anaerobic energy supply defined in tests as alactic (N alac) and lactic (N lac) power has been growing considerably during the whole pre-season and by the end of pre-season the growth of these indicators was 31% and 14% correspondingly. At the same time, a reliable character to improve these indicators was observed at the beginning of the competitive period compared to the beginning of the preparation period for creatine-phosphate power (P<0,05; t=2,45) and for N lac (P<0,01; t=3,12) .

The analysis of central hemodynamic parameters at start of pre-season indicated the matching of system arterial level with standard indicators. Normocardia and volume indices of central hemodynamics (SBV, ml; MBV, l/min) are within the upper limits of age and physiological norms.

Arterial pressure behavior throughout the study does not seem to be statistically reliable, but it shows a clear tendency to decrease of all indicators from the start of pre-season to the start of contest season as well as stabilization of these figures (SAP, DAP, APmean) until the end of the contest season, which corresponds to available reference datum. It was confirmed that there was a faster growth of anaerobic endurance combined with significant positive changes of their overall physical performance and aerobic endurance.

Chronotropic heart function was significantly reducing by the end of pre-season (on 9%, P<0,05), and by the start of contest season it shifted to the mode of functional sports bradycardia – decrease in heart rate compared to the start of pre-season by 17% (P<0,01), followed by stabilization till the end of the contest season. It was registered that 50% of handball players have high level of myocard capacity.

By the start of contest season there was steady although no significant decrease of stroke volume. Increase of stroke volume by the end of contest season to the level of pre-season had no significant nature either. Minute blood volume behavior was of the same nature as stroke volume behavior, which indicated the economization in vascular blood circulation. Increased SBV by the end of the competition period to the level of the preparation period was not significant. Dynamics of changes in indicators MBV had similar changes in SBV, the character that pointed to economization link in the vascular circulation.

Electrocardiographic parameters of cardiac output were rated as 4, based on five-grade scale at the moment of examination. This indicated the absence of maximum values. Single arrhythmias due to dysfunction of automatism were defined. These arrhythmias were often observed during the pre-season, and during the contest season they were connected with dysfunction of transition. The analysis of heart rate variability at start of pre-season indicates the balanced regulatory vegetative mechanisms and reflects a high degree of centralization of heart rate regulation.

Analysis of heart rate variability in the early preparatory period indicates balanced autonomic regulatory mechanisms and reflects a high degree of centralization of control heart rhythm. The most probable lever of functioning of cardiovascular system Mo in terms of minute volume from physiologic point of view (RR interval value which is most common and indicates the dominant level of sinus node functioning) let us to evaluate the actual condition of regulatory systems. The mode performances of handball players varied within the macrocycle and the minimum value of the index is observed at the start of the preparatory period, and the maximum – in the

end thereof. Mode amplitude (AMo), reflecting the stabilizing effect of centralization of heart rate control, which depends on activation degree of sympathetic section of vegetative nervous system, and reflecting the degree of rhythm rigidity, was changing in sinuous manner at the beginning of the preparatory period, reduced to the top of the competitive (28,42±2,28 %) and rises again at the end of the competition period (32,44±3,26 %). A single increase of mode amplitude was an indicator of predominance of sympathetic influences on sinus mode and significant rhythm rigidity.

SDNN (standard deviation normal to normal) is an integral indicator of heart rate variability and depends on the influence of sympathetic and parasympathetic sections of vegetative nervous systems on sinus node. The findings showed that there was a stress of systems responsible for compensation and adaptive abilities in relation to heavy physical activity during the sub-season. 15% of handball players had a significant growth of SDNN that indicates the increased activity of vegetative regulation loop. Combined effect of SDNN vegetative blood circulation regulation (reflects all periodic components of variability of heart rate variability consolidated figures) decreased.

The degree of variability of dRR cardio intervals values in studied statistical series showed the decrease during the contest season. There was an increase of activity of sympathetic section of vegetative nervous system and of stress index central regulation loop condition.

Stress index, provides the most comprehensive assessment of stress of central regulation mechanisms in the process of adaptation to changing effects and reflects the centralization degree of heart rage control, and was increased. Index of tension (IT), which gives the most comprehensive assessment of the voltage of the central mechanisms of regulation in the process of adaptation to changing influences and reflects the degree of centralization of heart rhythm. Stable regulation of vegetative processes is maintained throughout the whole testing period from the start of pre-season and until the end of contest season.

In the first stage of our task was to identify the most important values of the three groups functional indicators: 1) functional preparedness; 2) central hemodynamics; 3) autonomic adjusting. For this we calculated the correlation coefficients between the indicators in each group. First three by their rank functional preparedness indicators N lak, rMOC, $rPWC_{170}$, explain 56% general dispersion of the sample, were established by determination of correlation dependences between sportsmen's indicators of overall physical capacity for work and economy of work of the systems of providing energy ($aPWC_{170}$, kgm /min; rPWC170, kgm/min/kg), absolute (aMOC, l/min) and relative maximal oxygen consumption (rMOC, l/min /kg), lactate (N lac, vt/kg) and alactate (N alac, vt/kg) powers (tabl. 1).

Table 1.Correlation dependences indicators of functional preparedness of highly qualified handball players

№	INDICATORS	$aPWC_{170}$, kgm/min	$rPWC_{170}$, kgm/min/kg	aMOC, l/min	rMOC, l/min/kg	N alac, vt/kg	N lac, vt/kg	
1	$aPWC_{170}$,kgm/min		0,965	0,654	0,880	0,410	0,956	
2	$rPWC_{170}$,kgm/min/kg	0,965		0,732	0,988	0,320	0,897	
3	aMOC,l/min	0,654	0,732		0,889	0,328	0,899	
4	rMOC,l/min/kg	0,880	0,988	0,889		0,299	0,911	
5	N alac,vt/kg	0,410	0,320	0,328	0,299		0,888	
6	N lac, vt/kg	0,956	0,897	0,899	0,911	0,888		
	∑ r	3,865	3,902	3,502	3,967	2,245	4,551	22,032
	%	17,54	17,71	15,90	18,01	10,19	20,66	100
	Grade	4	3	5	2	6	1	

First three by their rank central hemodynamics indicators MBV, SBV, HR, explain 56% general dispersion of the sample, were established by determination of correlation dependences between sportsmen's indicators systolic arterial pressure (SAP, mm hg.art.), diastolic arterial pressure (DAP, mm hg.art.), mean arterial pressure (APmean, mm hg.art.), heart rate (HR, bpm), minute and stroke blood volume (MBV, l/min; SBV, ml) qualified handball players (tabl. 2).

Table 2. Correlation dependences indicators of central hemodynamics of highly qualified handball players

№	INDICATORS	SAP, mm hg.art.	DAP, mm hg.art.	APmean, mm hg.art.	HR, bpm	MBV, l/min	SBV, ml	
1	SAP, mm hg.art.		0,726	0,760	0,680	0,699	0,695	
2	DAP, mm hg.art.	0,726		0,810	0,699	0,615	0,456	
3	APmean, mm hg.art.	0,760	0,810		0,633	0,566	0,911	
4	HR, bpm	0,680	0,699	0,633		0,988	0,711	
5	MBV, l/min	0,699	0,615	0,566	0,988		0,977	
6	SBV, ml	0,695	0,456	0,911	0,711	0,977		
	∑ r	3,560	3,306	3,680	3,711	3,845	3,750	21,852
	%	16,29	15,13	16,84	16,98	17,60	17,16	100
	Grade	5	6	4	3	1	2	

First three by their rank autonomic regulation RS, AMo, dRR, explain 67% general dispersion of the sample, were established by determination of correlation dependences between sportsmen's indicators mode (Mo, ms), mode amplitude (AMo,%), standard deviation normal to normal (SDNN, ms), degree of variability of dRR cardio intervals values (dRR, ms), index of tension (IT, c.u.) qualified handball players (tabl. 3).

Table 3.Correlation dependences indicators of autonomic regulation of highly qualified handball players

INDICATORS	Mo, ms	AMo,%	SDNN, ms	dRR, ms	IT, c.u.	
Mo, ms		0,333	0,374	0,365	0,915	
AMo,%	0,333		0,451	0,656	0,943	
SDNN, ms	0,374	0,451		0,321	0,911	
dRR, ms	0,365	0,656	0,321		0,963	
IT, c.u.	0,915	0,943	0,911	0,963		
∑ r	1,987	2,383	2,057	2,305	3,732	12,464
%	15,94	19,12	16,50	18,49	29,94	100
Grade	5	2	4	3	1	

In the second stage identify the factor structure of the functional state of the qualified handball players was performed rotation matrix of factor loadings through the varimax-criterion. Results of factor analysis are given in table 8. Analysis of the matrix of factors loadings testifies that the contents of the first, the most important factor, with the highest coefficients, include indicators N lak, MBV, IN. This factor causes 40,63% of general variance and interpreted as energy production, which represents an integral characteristic of functional state (tabl. 4).

Table 4. Factor structure ofthe functional state of highly qualified handball players

№	INDICATORS	f1 energy production	f f2 central circulation of blood	f3 variational pulse rate
1	N lac, vt/kg	**0,952**	0,512	0,545
2	rMOC, l/min/kg	0,745	0,531	**0,752**
3	$rPWC_{170,}$ kgm/min/kg	0,851	**0,842**	0,595
4	MBV, l/min	**0,931**	0,513	0,510
5	SBV, ml	0,847	0,526	**0,872**
6	HR, bpm	0,855	**0,831**	0,574
7	IT, c.u.	**0,957**	0,613	0,418
8	AMo,%	0,837	**0,828**	0,533
9	dRR, ms	0,843	0,619	**0,812**
	TOTAL ∑	7,818	5,815	5,611
	%	40,63	30,22	29,16
	Grade	1	2	3

The second factor, with high values of factor loadings and the contribution to the overall general dispersion 30,22% underlined figures $rPWC_{170}$, HR, AMo. This factor was determined by as central circulation of blood. The third factor with the contribution of shares in the general dispersion 29,16% the highest values of factor loadings are indicators, such as rMOC, SBV, dRR. The factor due to these characteristics, we determined as variation pulse rate (tabl. 8). Thus, factor structure and the percentage of the effect of various parameters of the functional state of the qualified handball players. When making a comprehensive assessment of functional status of athletes' bodies, taking into account the behavior of physical performance, cardiovascular system condition and nature of vegetative reactions, it is important to pay attention to nature of interference of above mentioned regulatory loops, where the direction of changes, although expressed with varying reliability degrees, indicates these or those features of training programs. Thus, definitely achieved increase of overall physical efficiency by the start of contest season is provided mostly by means of higher capacities of anaerobic energy supply systems with less significant gains of aerobic mechanisms.

Decrease of overall physical efficiency in the end of pre-season shows a certain fatigue processes development, and is a result of statistically not significant but undirected decrease of intensity of all three tested energy systems. Along with this, at early stages of pre-season there was an optimization of cardiovascular system performance, that is reflected in hypotonic orientation of arterial blood pressure dynamics, switching to less energy-consuming functional sports bradycardia and in hypokinetic orientation of central circulation dynamics, and that is as assumed reduces the so-called "volume load" on heart.

At the later stage, during the contest season, and apparently under the influence of permanent physical and psycho-emotional stress, there are the changes in dynamics of cardiovascular system performance. Along with some weakening of the energy mechanisms and synergistically with them, they contribute to the

development of fatigue processes of an athlete's body. At the end of contest season, there is a shift to hyperkinetic type of regulation, that with some increase of activity of heart chronotropic function, apparently, due to compensatory, overcoming the fatigue processes, stimulates the sympathetic-adrenal system. It seems that in this sense the maintaining a stable balance of vegetative regulation mechanisms is a response to parasympathetic influence increasing along with fatigue. These effects confirm rather high fitness level of tested athletes.

Discussion

In preliminary studies it was found that rates of overall physical performance and availability of highly qualified handball players in submaximal regime (according to cycloergometric test PWC_{170}) and in the initial stage of the competition period was significantly increased (Mikhalev et al., 2014), whereas, there were no significant increments of the studied parameters, in the final stage. However, according to the medical and biological surveys for year cycle of preparation, dynamics of indicators of relative performance of athletes has indicated a downward. Therefore, by the end of the competition period, before the start of the final stage of the championship, the athletes appeared objective signs of fatigue. Compile information shows the change in indicators of competitive activity and the state of physical fitness of highly qualified handball players based on data about the features of the training process. Downward dynamics of the physical qualities of indicators suggests ways to improve the training process in the direction of support for their level of development throughout the long competitive period. The findings coincide with the opinions of the other authors that the prevalence of aerobic loads orientation during the training process, while during the games dominated glycolytic mode (Souza and A. Gomes, 2006).

Rannou at all (2001) assert that anaerobic capacity of handball players is dominated. However, Cardinale in his publication (2000) expressed that energy processes do not have clear structure, based on the length of events. Therefore, it can be believed that energy processes between aerobic and anaerobic threshold were estimated as of the sub-maximal character, and this was 52.6 % of anaerobic, alactic 16.2 % and one third (31.2 %) of aerobic. Further, the researches have emphasized that high baseline values of HRV are related to aerobic adaptability in team-sport players and individual athletes (Buchheit (2014), and HRV decreases during training periods with high training loads (Manzi et al., 2009). Thus, daily and weekly measurements are desirable for young handball players, otherwise there would be the lack of sensitivity of monthly resting HR and HRV and psychometric measurements to follow performance of the players (Buchheit, 2015). After using three physical performance tests during the in-season period, he found out that the difference between better players and worse was similar. The monthly measures of HR and HRV showed limited results. Therefore, the author emphasized that more often monitoring of the handball players might be required. However, our findings indicate that professional handball players were tested during the training and competitive periods of the annual year. Each handball player was participated four times within a year.For example, Kayacan Y. and Vildiz S. in their work indicated that HRV in professional handball players during the rest and following 5 min. mild jogging exercise doesn't change significantly. On the other hand, the sympathetic regulation of the autonomous nervous system increased in sedentary players (Kayacan and Yildiz, 2015).

One of the important issues of functional state of an athlete in conditions of intense muscular system is autonomic regulation of heart rate (Nowosielska-Swadźba et al., 2015). There are different approaches to identify the nature of the system response to appropriate regulation cardio load (Aubert et al., 2003). At the same time, with increasing tension regulating heart rhythm appears strengthening neuro-hormonal activation centers and parasympathetic parts of the autonomic nervous system. This result confirms data from other authors (Lucini et al., 2014).

The other important conditions for the successful performance of an athlete are to make an appropriate training program, which can help to improve functional efficiency of an athlete. Functional efficiency is an integrated characteristic in the context of effectiveness of carried out activities and involved in the implementation of systems according to criteria of reliability and inner price.

Conclusions

This study made it possible to conduct a longitudinal study of fitness shape and functional status of highly qualified athletes such as, handball players.

1. Dynamics of physical performances and energy systems condition shows positive influence on the work-out processes during and before the contest seasons as well as shows relative lack of tools for maintaining the high level of physical efficiency and as well as preventing the signs of fatigue in energy supply systems during the contest season.
2. Cardiovascular system performance and its dynamics during the whole testing period indicate the maintaining a high level of hemodynamic servicing the athletes' bodies. However, at the end of contest period there is a hyperkinetic syndrome, which is a sign of lack of tools that can't maintain the optimal regulation of cardiovascular system but it can increase its performance capabilities.
3. Maintaining a high level of vegetative homeostasis indicates the certain fitness level of athletes, sufficient to maintain the high potential of sympathetic-adrenal system and to overcome fatigue processes during activity.

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