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Original Article

Functional fitness assessment of elite athletes

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Abstract
Defining functional fitness is important for effective forming of athlete training process in different periods of the annual training plan (macrocycle), as well as for reaching the high level of other types of preparedness (general, specific,technical, tactical andpsychological). Unfortunately, nowadays all existing methodological approaches to the Functional Fitness Assessment Test (FFAT) of athletes of different sports specialization are only based on the limited amount of traditional parameters usage whichdramatically decreases the efficiency of biomedical monitoring system and training process. Consequently, the pressing issue is to develop and practically implement the innovative methods of the Functional Fitness Assessment Express Test corresponding to requirements ofhigh sports performance. *The aim of our research* is to study the efficiency of the innovative Functional Fitness Assessment Test methodfor specific physical preparation increase of elite athletes in different periods of the macrocycle. *The basis and methods*: 59 elite athletes of different sports specialization (18-24 years old): 14 female and 14 male volleyball players, 13 basketball players, 12 handball players and 6 female sprinters. Testing of all athletes was conducted within the framework of preparatory periods of the two serial competitions applying the traditional and innovative approach to the functional fitness assessment. *The results of the study***.** The obtained data analysis allowed setting the high level of informativeness and objectivity of the suggested innovative Functional Fitness Assessment Test methodreflected in the quality increase of the specific physical preparedness controlin the preparatory period of the macrocycle. *Conclusions***.** Relative changes of all specific physical preparedness parameters, regardless of sex and sports specialization, registered at the final stage of the shaping experiment, credibly ($p<0,05$) surpassed the score of relative changes of these scores at the final stage of the stating experiment (among male volleyball players up to 2-12%, among male volleyball players up to 2-20%, among basketball players up to 2-3%, among handball players up to 2-4%, among female sprinters up to 2-6%). The results are recommended for practical implementation into the biomedical monitoring system control of elite athletes.
Keywords: innovative method, specific physical preparedness, volleyball, basketball, handball, track and field.

Introduction

According to the generally accepted opinion, the theory of adaptation, which has been developing rapidly in recent years, has a huge influence on the improvement of the theory and methodology of training athletes in sports. This is due to the fact that any sports activity is a sphere of human life in which various functional systems of the body often work in the mode of maximum possible reactions, which creates good conditions for the study of various adaptive reactions.According to the leading specialists in the area of physical education and sports, the insufficiency of the given system at the current period represents one of the reasons of substantial sports performance decline on the international arena [Diachenko&JabbarBanitaraf, 2015;Lisenchuk, Zhigadlo et al, 2019].Thus, functional training is a necessary condition for sports success, which makes it possible to implement all the elements of sports training of a person. The biomedical monitoring system

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improvement is one of the most significant issues nowadays. First of all, it includes the functional fitness assessment which is the basis of the general, specific, technical, tactical and psychological preparedness development[Valeria&Olexander, 2015;Tishchenko, 2016; Markovicetal, 2020].There has been a lot of research dedicated to the problem of theFFAT parameter development where the study of traditional parameters usage, such as physical work capacity, VO_2 max (Maximum Oxygen Consumption Test), heart rate, arterial pressure, residual Volume, was suggested [Astrandet al, 2003; Malikov&Bogdanovskya, 2009;Petot et al, 2012;Malikovetal, 2019]. However, so far we cannot talk about the creation of really optimal monitoring systems for the level of functional readiness. And this despite the fact that its algorithm, i.e. the main components, have long been known to coaches, athletes and specialists in sports physiology and medicine. At present, it can be argued that the extensive stage of sports development has practically ended, although at the sametime the modern periodis characterized by the intensification of the training process. Therefore, the transition to the intensive development of the training system requires a more effective management of training means of influence, which contributes to an increase in the efficiency of the training system of the athletes. And this, in turn, implies, first of all, the wide spread introduction of technical means of controlling the training process and monitoring its impact on the athlete's body.

Recently, with the introduction of automated complexes that a reused directly during the period of an athlete's physical load, before andafterit, information on the effect of physical activity on the human body has increased significantly. However, these are expensive controland corrective complexes. The intensity of the impact of physical activity is determined b ythe duration and speed of the performed motor action. By varying the selected parameters o fphysical activity, I tispossible to achieve the required degree of influence on the functional capabilities of the body and influence directly on the “key” reactions of providing and utilizing oxygen in the body. Consequently, on the basis of the oretical and design-engineering approaches, it is necessary to introduce innovative systems of automated multi-parameter control over the dynamics of the sportsman's functiona lstate. At the same time, the pressing issue is to develop and practically implement the innovative methods of the FFATinto the biomedical monitoring system corresponding to demands for sports performance. Furthermore, the insufficient FFAT effectiveness is the consequence of the complex approach absence. It is reflected in the certain functional fitness parameters registration with the test list usage [Valeriaetal, 2017;Tyshchenkoetal, 2019]. That does not only lead to the significant test duration increase, but also to the substantial body overstress, influenced by the workload which is not aimed at training and competitions. In our previous studies, there was an attempt to study the effectiveness of the FFAT software “School of Higher Sports Mastery”, that was sufficient enough dealing with handball players.Obviously, the above mentioned issue demands quick solution, including by development of highly informative apps of theFFAT, applying the latest achievements in IT-technology [Malikov et al, 2014;Kozinaet al, 2018]. Unfortunately, the literature analysis allowed us to conclude the limitation of experimental research on the issue which defines the relevance and practical importance of our study.

Materials and Methods

Participants

59 elite athletesparticipated in the study: 14 female volleyball players of “Orbita-ZNU-ODUSS” (Zaporizhzhia), 14 male volleyball players of “Novator” (Khmelnytsky), 13 basketball players of “Zaporizhzhia”, 16 handball players of “Motor” (Zaporizhzhia) and 6 female sprinters of “Metalurg” (Zaporizhzhia). All participants agreed to take part in our experiment.The studies were conducted in accordance with the ethical standards of the Declaration of Helsinki and was approved by the Ethical Committee of the University of Greenwich research (UREC). Prior of presenting a written informed consent to participate in the study, the participants were fully informed of the nature and risks of the research. Participants were required to refrain from heavy exercises for 24 hours before each test, and as well as having a meal 3 hours before tests.

Goals, methods and procedures

The aim of our research is to study the efficiency of the innovative Functional Fitness Assessment Test methodfor specific physical preparation increase of elite athletes in different periods of the macrocycle.

The object of the study –thespecific physical preparation increase of elite athletes, who specialize in various sports.

The subject of the research is the impact of the application of the innovative method of evaluating the fitness of athletes on the effectiveness of the system of medical and biological control and the training process of highly skilled athletes of different specializations.

The FFAT of all athletes was conducted at the initial and final stages of the two serial competitions (2018/2019 years and 2019/2020 years). The aim of the stating experiment (2018/2019years) was to define the effectiveness of the Functional Fitness Assessment Express Test usage in the traditional approach, to design our own innovative method, as well as to study the level of the parameters consistency defined by direct (laboratory) and indirect (innovative) methods of the research. The shaping experiment (2019/2020years) expected to approbate our method, called “Sport-express” [Malikov et al, 2014], on the basis of the athletes inspection data analysis, within the framework of the preparatory period of the macrocycle. It is necessary to underline that

evaluation of $rPWC_{170}$, rVO_2 max (Maximum Oxygen Consumption Test) was conducted by generally recognized formulas. At the same time, defining the anaerobic lactic and anaerobic alactic capacity, the anaerobic threshold (AT), heart rate at the AT level and the integral indicator was made according to our own formulas.

Statistical Analysis

Mathematical processing of the study results was carried out with assistance of the statistical software and the evaluation of the traditional parameters: the arithmetical mean ($\overline{x}$), the error in the mean (S), t – the Student's t-test and Pearson correlation coefficient (R).

Results of the research

According to the key aim of the stating experiment, we conducted the dynamics research of the FFAT of athletes (volleyball, basketball, handball, sprinting) within the framework of the preparatory period of the macrocycle.The data received in the shaping experiment completely confirmed the importance of the high quality Functional Fitness Assessment Express Test for the other preparedness type control, including specific physical preparedness. In general, the received data showed that the traditional parameters usage as the criteria of the functional fitness assessment of athletes, providing the definition of the limited amount of parameters (in our case, those are PWC_{170} and VO_2 max parameters), didn't contribute to objective evaluation of specific physical preparedness dynamics within the framework of the preparatory period of the macrocycle.

In our opinion, insufficient informativeness of $aPWC_{170}$ and VO_2 max parameters as the criteria was one of its reasons. The credible ($p<0,05$) improvement of their aerobic power and capability was shown (to 10-12% for male volleyball players; to 14-15% for female volleyball players; to 5-9% for basketball players; to 4-8% for handball players and to 6-8% for female sprinters). Furthermore, at the final stage of the stating experiment no credible criteria changes had been shown. The received data allowed making a conclusion about the traditional parameters usage insufficiency, which, according to the specialists, defines significantly further sports performance of elite athletes within the competition period of the macrocycle.

Table 1. The FFAT parameters of athletes of the different sports specialization (18-24 years old) within the preparatory period of the shaping experiment ($\overline{x} \pm S$)

Parameters	Period	Male volleyball players	Female volleyball players	Basketball players	Handball players	Female sprinters
$rPWC_{170}$, kgm/min/kg	BA	20,41±0,68	16,05±0,64	17,39±0,15	18,58±0,92	20,98±0,42
	EA	22,51±0,72*	17,79±0,58*	18,89±0,17***	20,99±0,74*	22,14±0,39*
rMOC, ml/min/kg	BA	64,01±1,44	47,29±1,35	60,02±0,38	61,12±0,62	62,09±0,71
	EA	67,11±1,32*	53,18±1,29**	61,28±0,35**	63,39±0,77*	64,12±0,72*

Note: * – $p<0,05$; ** – $p<0,01$; *** – $p<0,001$ comparing to the initial stage of preparatory period; BA – beginning of action; EA – end of action.

The abovementioned considered, we have designed our own innovative method of the FFAT which provides the traditional submaximum PWC_{170} test usage uniting with the special software "Sport-express", which was approbated within the framework of the 2019/2020competition preparatory period.

Our software "Sport-express" represents a significant modern modification of the recognized "School of Higher Sports Mastery" program [Malikov et al, 2012; Malikov et al, 2014] owing to the inclusion of additional parameters. Itshould be is stressed out that the sequence principle was applied while developing the program.

Thus, firstly, the "School of Higher Sports Mastery" program was the basis of its further modification, and, secondly, the same research group participated in developing of both programs.

The results of the shaping experiment showed that all FFAT parameters, specified by our method, reflected the integral parameter dynamics – the general level of functional fitness (Table 1). At the final stage of the preparatory period, all athletes, regardless of sports specialization and sex, revealed the credible ($p<0,05$) functional fitness improvement, which indicates the training program effectiveness within this period of the macrocycle.It should be emphasized that our method usage provides both the aerobic power and capability of the athletes and the additional amount of the parameters characterizing different ways of energy supply to muscular activity, as well as the integral parameter calculations, contributed to the more efficientspecific physical preparedness dynamics control, reflected in their credible (in contrast to the stating experiment results) improvement at the final stage of the preparatory period of the macrocycle (Table 2).

The correlation analysis results have fully confirmed the role of the high quality Functional Fitness Assessment Express Test in ensuring the other types of preparedness, including the specific physical one.

The results showed the existence of strong correlation dependence between the functional fitness and almost every parameter of their specific physical preparedness, regardless of sex and sports specialization.

Table 2. The specific physical preparedness parameters and the coefficient of their correlation with the functional fitness (R) within the preparatory period of the shaping experiment

Type	Parameters	BA	EA	Rп	Rз
«Novatok»	EnduranceJump Test, the amount of failures	5,92±0,40	4,92±0,54***	0,77	0,72
	SprintSpeedEndurance, s	24,76±0,21	21,93±0,17***	0,71	0,71
	Jumping ability, cm	60,83±0,84	67,75±0,73***	0,74	0,71
	Speed, s	8,45±0,14	8,15±0,08**	0,71	0,71
	Agility, s	3,38±0,02	3,16±0,02*	0,73	0,72
	ShoulderMobility, amount	1,61±0,04	1,64±0,04	0,75	0,70
	Legstrength, numberoftimesin 20 s	17,50±0,45	19,42±0,45**	0,71	0,74
	Hands strength, numberoftimesin10 s	17,08±0,45	20,17±0,66*	0,71	0,72
«Orbita-ZNU»	EnduranceJump Test, the amount of failures	8,92±0,54	5,92±0,40***	0,74	0,79
	SprintSpeedEndurance, s	25,93±0,17	24,76±0,21***	0,73	0,74
	Jumping ability, cm	54,75±0,73	60,83±0,84***	0,74	0,74
	Speed, s	8,95±0,08	8,45±0,14**	0,76	0,75
	Agility, s	3,46±0,02	3,38±0,02*	0,77	0,77
	ShoulderMobility, amount	1,72±0,04	1,61±0,04	0,72	0,75
	Legstrength, numberoftimesin 20 s	15,42±0,45	17,50±0,45*	0,74	0,78
	Abdomenandbackstrength, numberoftimesin 10 s	5,50±0,31	6,67±0,50	0,73	0,72
«Zapo-hia»	Verticaljump, cm	56,31±1,05	59,44±0,88*	0,77	0,78
	Sprint (3/4 courtor 20m), s	3,02±0,11	2,95±0,09*	0,75	0,76
	Running 40 s, m	170,32±3,84	177,28±2,03*	0,79	0,79
	“Snake”, s	54,72±0,94	52,19±0,88*	0,74	0,73
«Motor»	Keepingtheballat a distanceof 30 m, s	5,48±0,09	5,19±0,07*	0,76	0,74
	ThrowingAccuracy, from 9 meters, thenumberofhits	8,59±0,87	9,91±0,34*	0,74	0,72
	Performing 20 gearsperpair, s	17,94±0,55	16,72±0,33*	0,78	0,74
	Dribbling 30 m (righthand), s	7,06±0,34	6,64±0,42	0,76	0,73
	Dribbling 30 m (lefthand), s	7,45±0,29	7,03±0,21	0,78	0,73
«Metalurg»	Triplejump, cm	748,90±4,22	832,19±3,28*	0,72	0,74
	Jumpingfromfoottofootat a distanceof 3 to 60 m, s	26,02±0,11	24,02±0,10*	0,71	0,73
	Distance running 3 to 60 m, s	23,19±0,14	22,65±0,12*	0,73	0,75
	High start running with a wheel (8-10 kg) (3 to 60 m), s	25,48±0,16	24,71±0,14*	0,73	0,73
	Throwingthekernel (4kg) forwardwithtwohands, m	13,61±0,32	13,88±0,31	0,70	0,74
	Running20 m, s	2,64±0,05	2,53±0,05*	0,74	0,74
	Lowstartrunningat a distanceof 60 m, s	7,83±0,06	7,69±0,05*	0,74	0,75
	Runningat a distanceof 150 m, s	20,11±0,12	19,75±0,11*	0,72	0,72

Note: * – p<0,05; ** – p<0,01 comparing to the initial stage of the preparatory period; BA – beginning of action; EA – end of action; Rp, Rz – the coefficient of correlation according to the initial and final stages of the preparatory period. It has been registered at every stage of the shaping experiment that there is a strong correlation dependence between the functional fitness and the specific physical preparedness. Among male volleyball players the coefficient of correlation is from 0,70 to 0,77; among female volleyball players it is from 0,72 to 0,79; among basketball players it is from 0,73 to 0,79; among handball players it is from 0,72 to 0,78; and among female sprinters it is from 0,71 to 0,75 (Table 2).

Table 3. Changes of the specific physical preparedness parameters of athletes of different sport specialization (18-24 years old) at the final stage of the preparatory period of the stating and shaping experiments

Type	Parameters	Statingexperiment	Shaping experiment
«Novatok»	EnduranceJump Test, the amount of failures	-4,22±0,89	-16,90±1,69***
	SprintSpeedEndurance, s	-0,78±0,19	-4,75±1,30**
	Jumping ability, cm	5,03±0,77	11,30±1,32***
	Speed, s	-2,49±0,81	-3,55±1,17
	Agility, s	-1,73±0,58	-6,51±1,46**
	ShoulderMobility, amount	1,69±0,92	1,86±1,38
	Legstrength, numberoftimesin 20 s	6,23±0,75	10,97±1,41**
	Hands strength, numberoftimesin10 s	9,41±0,88	18,09±1,77***
	Abdomenandbackstrength, numberoftimesin 10 s	5,37±0,79	12,55±1,18***
«Orbita-ZNU»	EnduranceJump Test, the amount of failures	-29,44±1,92	-50,70±1,69***
	SprintSpeedEndurance, s	-2,09±0,81	-4,75±0,79*
	Jumping ability, cm	4,12±1,28	10,0±1,32**
	Speed, s	-2,51±1,24	-5,92±1,17*
	Agility, s	-2,08±1,33	-2,40±1,46
	ShoulderMobility, amount	-3,11±1,19	-7,16±1,38*
	Legstrength, numberoftimesin 20 s	5,32±1,39	11,90±1,41**
	Hands strength, numberoftimesin10 s	6,49±1,48	11,20±1,77*

	Abdomenandbackstrength, numberoftimesin 10 s	9,25±1,36	17,50±1,18***
«Zapo-hia»	Verticaljump, cm	2,18±0,41	5,56±0,44***
	Sprint (3/4 courtor 20m), s	-0,81±0,19	-2,32±0,31***
	Running 40 s, m	1,09±0,32	4,09±0,29***
	"Snake", s	-2,08±0,51	-4,62±0,37**
«Motor»	Keepingtheballat a distanceof 30 m, s	-2,04±0,38	-5,29±0,47***
	ThrowingAccuracy, from 9 meters, thenumberofhits	2,55±0,39	5,37±0,33***
	Performing 20 gearsperpair, s	-2,63±0,57	-6,80±0,61***
	Dribbling 30 m (righthand), s	-3,16±0,42	-5,95±0,44**
	Dribbling 30 m (lefthand), s	-3,05±0,48	-5,64±0,39**
«Metalurg»	Triplejump, cm	5,31±1,74	11,28±1,92**
	Jumpingfromfoottofootat a distanceof 3 to 60 m, s	-2,48±0,55	-7,71±1,47**
	Distance running 3 to 60 m, s	-2,09±0,37	-2,54±0,41
	High start running with a wheel (8-10 kg) (3 to 60 m), s	-1,16±0,41	-3,11±0,48**
	Throwingthekernel (4 kg) forwardwithtwohands, m	1,05±0,27	2,18±0,33**
	Running20 m, s	-2,15±0,34	-4,22±0,39**
	Lowstartrunningat a distanceof 60 m, s	-1,02±0,14	-2,05±0,18***
	Runningat a distanceof 150 m, s	-1,07±0,13	-2,03±0,15***

At the final stage of the preparatory period the comparison analysis results of the relative changes of the specific physical preparedness parameters within the framework of the stating and shaping experiments were confirmed. According to the Table 3 data, the positive changes of the specific physical preparedness parameters within the framework of the shaping experiment were distinctly better than those received throughout the stating experiment. They are the followings: among male volleyball players up to 2-12%, among female volleyball players up to 2-20%, among basketball players up to 2-3%, among handball players up to 2-4%, and among female sprinters up to 2-6%. It is also important to stress out that our FFATmethod implementation into the biomedical monitoring system control of elite athletes contributed to their sports performance improvement.

Discussion

There is a huge amount of studies where the recognized functional tests, methods using certain biochemical, physiological and psychophysiological parameters were suggested [Lisenchuket al, 2019a; Korobeynikov et al, 2019; Lima etal, 2020; Tyshchenko et al, 2020].Regardless of its sufficient effectiveness, most of them can be characterized by both the necessity of the substantial non-training workload usage in the testing process and the complex approach absence to the FFAT which is reflected in only registering the certain components of the test.The results of our study enhance the information of the authors [Falk Neto& Kennedy, 2019; Kadhim&Hamdan, 2020;Vaniuketal, 2020] about the functional fitness improvement approaches.

Nowadays, the prenatal diagnosis within the framework of functional study is necessary for both the efficient training process management and the IT-support and medical and educational aspects of making decisions about its correlation [Berendt &Wójtowicz-Marzec, 2019; Colantonio, 2020].

The received data allowed making a conclusion about insufficient effectiveness of the FFAT traditional parameters usage in the biomedical control of the specific physical preparedness, which, according to most specialists, defines the future sports performances of the athletes within the framework of the macrocycle competition period [Yuriy et al, 2016; Kostiukevychetal, 2020].The specific physical preparation importance in the sports performance was defined in the papers of recognized researchers [Kozina et al, 2016;Jebavyetal, 2020]. Moreover, during the experiment the specific physical preparedness parameters analysis showed the decline of their state at the final stage of the competitions which was reaffirmed by other specialists in the area [Pichardoetal, 2019;Lisenchuk et al, 2019b]. According to some authors, the unity of functional fitness and specific physical preparedness will obviously help in both optimizing educational and training process at the preparatory period of the macrocycle and increasing the specific physical preparation [Biçer, 2020; Ivanenkoetal, 2020; Heggondetal, 2020; Denham etal, 2020]. Our innovative method and its certain features provide simultaneous usage of the traditional submaximum PWC_{170} test united with the "Sport-express" application. It is based on the generally recognized theoretical concepts about the special features of the body functional changes in the process of different physical work [Astrandetal, 2003;Evhen& Valeria, 2017; Tyshchenko, Hnatchuketal, 2018]. Its special characteristic is that almost all body functional fitness parameters are only defined by the 10-minute submaximum PWC_{170} test. The results are automatically reflected in the test report and compared with an athlete`s norm and previous data. This allows the sports doctor to easily determine what indicators have changed or have gone beyond the norm in one direction or another. Monitoring is based on the body physiological changes analysis, specific for sports activity, the non-invasive measurement of various physiological indicators of central and peripheral hemodynamics, transport and consumption of oxygen, respiratory function.

The conducted research proved the high efficiency of the innovative method, and the implementation of "Sport-express" reaffirmed our assumption. The results, shown at the end of the competition, are a clear confirmation of this. So the female volleyball players of "Orbita-ZNU" improved their 3rd place in the Championship of Ukraine in the 2018/2019 season to the 2nd place in the 2019/2020season; male volleyball players of "Novator" – respectively, the 4th place in the major league in the 2018/2019 season to the 1st place

and the entrance to the Super League; handball players of "Motor" for the first time reached the 1/8 finals of the Champions League 2019/2020; "Zaporizhzhia" basketball players were fourth in the 2018/2019 season and became bronze medal winners of the 2019/2020Super League. At the 2020 Track and Field Championships, the girls managed to set personal records.

Conclusions

The theoretical significance of the carried out researchers lies in the establishment of general patterns and individual characteristics of the changes in the functional parameters of the body when exposed to physical activity of varying degrees of intensity and duration.The practical significance of the work lies in the fact that the developed specialized innovative Functional Fitness Assessment Test method makes it possible to select an individual training load, to regulate functional shifts of indicators in a real mode of training time (promptly) when solving various problems in training sessions.The use of FFAT makes it possible to increase the efficiency of the training process, provides an opportunity for its use at different stages of training of athletes, reveals their functional capabilities, allows to form special groups according to their level of physical fitness and to correct the adaptive reactions of the body to physical activity. The materials above have shown that our innovative Functional Fitness Assessment Test method usage in the biomedical monitoring system control of the elite athletes helps to increase the efficiency of this system and the training process in the preparatory period, which was reflected in the significant specific physical preparedness improvement of all athletes who participated in the study. This gives grounds to recommend the developed method for practical usage in the biomedical monitoring system of the general state of the elite athletes.Throughout the research procedure the high efficiency of our innovative method was experimentally substantiated, the practical implementation of which contributes to the biomedical monitoring system and the training process optimization in the preparatory period of the macrocycle.

Conflicts of interest − The authors declared no potential conflicts of interest with respect to the research, authorship and publication of this article.

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