SPECIAL ENDURANCE OF YOUNG GYMNASTS: THE ROLE OF AEROBIC CAPACITY IN FATIGUE DEVELOPMENT IN THE TRAINING

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Abstract In artistic gymnastic alteration of all component of coordination capacities may related to fatigue. So the resistance to fatigue is a specific endurance component, which has direct relation to the techniques of gymnastic exercises. We supposed that changes of motor actions precise in the process of fatigue development during training sessions might presumably have a negative impact on the quality of performing complex gymnastic elements and combinations and set the goal to determine the significance level of aerobic capacity for special endurance. Twelve young skilled gymnasts aged 15–18 years measured the maximum oxygen consumption (VO_2max). During the training sessions specially designed tests of specific endurance were carried out, heart rate (HR) was measured and the quality of the presentation of the combinations was evaluated (by the sum of the judges' ratings of all the elements). The interrelation between VO_2max, HR in progress of gymnastic combinations and the quality of their performance were analyzed. Results showed that a higher aerobic capacity contributes to a relatively lower HR when performing intense gymnastic combinations and a slower development. Iof "coordination fatigue" t may be of special importance for young athletes at the stage of advanced specialization when a great volume of complex combinations is learned and thus, high volume of training loads is performed. According to obtained data use of the proposed endurance tests is of great importance for control of maintenance of aerobic capacities by young athletes. Account of the factors of "coordination fatigue" development, related to aerobic capacities, may be of special importance for young gymnasts at the stage of advanced specialization when a great volume of complex combinations is learned and thus, high volume of training loads is performed.

Key words gymnastic training, specific fatigue, aerobic capacities

Introduction

Special endurance is an indispensable part of the process of forming and improving the championship of athletes of all specializations. In recent times considerable success has been achieved in understanding the essence of specific endurance, as a basis for sport-technical excellence and the individual components of stress in sport (Mac Dougall, Wenger, Green, 1991). It should be emphasized that it is particularly complex to place special endurance in the various sports. This involves primarily disciplines that consist of many competitions which need different characteristics in their movement structure and require maintaining high motor coordination regardless of fatigue (Astrand, Rodahl, 1977). These include gymnastics. It was noted that when performing full sets of gymnastic movements in competitions of a gymnastic all-round event, there was very high heart rate (HR) (Smolevsky, Gaverdovsky, 1999; Zasada, Sawczyn, Mishchenko, 2006). As it is commonly believed, after all the exercises, HR is often approximated to the heart rate of athletes practicing endurance disciplines. Therefore, many gymnastics theorists suggest that HR changes may be one of the measures of exercise load in sports gymnastics and one of the indicators of physical fitness (Arkayev, Suchilin, 1997; Sawczyn, 2000). It is well known that high physical fitness allows for a better tolerance of effort of varying intensity. Although the physical fitness may be the ability to perform a specific work in a unit of time, and thus the ability to release maximum power, the most common indicator is the maximum oxygen uptake (VO_2max). In most cases, there is a very high correlation between the ability to achieve outstanding results in endurance disciplines and the VO_2max individual value. In the case of gymnasts, aerobic capacity (as measured by VO_2max per kg of body mass) should be considered very different (Mac Dougall, Wenger, Green, 1991; Nybo, Rasmussen, 2007).

Significant and constantly increasing the difficulty of exercise in modern gymnastics causes numerous complications in proper planning of training loads and selection of the appropriate training measures. In order to shape a high technical level and the special endurance of gymnasts, there should be provided a broad and comprehensive basis for the implementation of a variety of structurally different exercises for each of the competitions. First of all, the endurance in gymnastics should include the observance of certain conditions conducive to the improvement of coordination capacities in technical preparation (Gaverdovsky, 2003; Sawczyn, Zasada, Mishchenko, 2005). High aerobic capacity allows for better tolerance of effort of different intensity (Astrand, Rodahl,1977). Although the ability to perform specific work in a unit of time, and thus the ability to improve better (Astrand, Rodahl, 1977; Loren, Chiu, 2003; Mac Dougall, Wenger, Green,1991), as well as VO_2max may be the physical fitness measure. Such a demanding programme, which the gymnast has to master at the right time, puts the athlete’s ability in the training process and training endurance to the forefront (Smolevsky, Gaverdovsky, 1999; Sawczyn, 2000). At the same time, sports activities should not be conducted at the limit of exercise capacity, in order to obtain the highest level of technique, even if the gymnast has mastered it to a very good degree. As a consequence, in the process of training, there appears the need to “create” a specific “surplus” (reserves) of energy potential for proper training and startup activities (Arkajew, Suczilin, 2004; Zasada, Sawczyn, Mishchenko, 2006). In securing specific preparation for the realization of motor skills in the technical elements of different movement patterns, there are certain limitations, which are determined by insufficient examination of these issues. At present, it is limited by the number of endurance-shaping agents used within its influence on the techniques of making various elements and gymnastic exercises.

Therefore, in sport gymnastics, the time during which fatigue occurs during training has a significant influence on the quality of performed motor tasks. In other words, the aerobic power (VO_2max) remains to have the influence on the performance of the qualities of the workload. It is assumed that the achievement of the effective training process and shaping the technique of exercising gymnastics is possible under the condition of achieving a high degree of special endurance. An important component of such endurance is the aerobic capacity of gymnasts. The purpose of the study was to clarify the effect of aerobic capacity on the exercise intensity in the case of exercising full gymnastic combinations. The study examines also how this affects the quality of performing complex gymnastic elements and combinations during a training unit.

Material and methods

Participants. Twelve gymnasts from the age of 15 to 18 years (juniors in the first level of the sport class) who attained significant sports performance in the national gymnastics and presented training at a similar level of technical training took part in the series of research. Prior to the study, all the gymnasts' height (in cm, with the accuracy of 1.5 mm) and weight (in kg, with the accuracy of 0.1 kg) were determined. The participants were measured wearing lightweight clothing and no shoes. The percentage of body fat was estimated with Tanita BC-418MA devise.

The anthropometric characteristics of the participants are presented in Table 1.

Table 1. Anthropometric characteristics of young gymnasts

Indicators	Age (years)	Body height (cm)	Body mass (kg)	BMI (kg/m2)	Fat (%)	Fat Mass (kg)	Lean Body Mass (kg)
Mean	16.1	168.0	61.0	21.6	10.9	6.7	54.3
Min	15.1	162.0	52.4	19.2	5.9	3.6	48.8
Max	18.0	176.0	73.0	23.6	15.4	9.7	63.4
SD	0.4	1.5	1.1	0.3	0.5	0.2	0.9

Training content. In order to determine the intensity of the workload of the examined gymnasts, researchers used the method of S. Sawczyn (2000). The calculation formula assumes that the intensity of the work of the athletes depends not only on the overall number of the performed elements, but also on the difficulty of the exercises specified in the regulations of the International Federation of Gymnastics. In the formula, the sum of the elements of successive difficulty groups was multiplied by a corresponding increasing coefficient:

$$I = (\Sigma EA + \Sigma 2EB + \Sigma 3EC + \Sigma 4ED + \Sigma 5EE + ...)/(T + P),$$

where: I – intensity index; T – total duration of the training (in mins); P – number of approaches; ΣEA(B, C, D) – sum of elements in particular groups of difficulty.

The characteristics of intensity of the tested group of gymnasts are presented in Table 2.

Table 2. Characteristics of daytime training loads of trained gymnasts

Indicators	Volume (number of elements)			Intensity (intensity index)			Complexity (number of elements)					
							1			2		
	M	Ś	D	M	Ś	D	M	Ś	D	M	Ś	D
Mean	318	407	482	1.69	2.20	2.95	131	163.0	194	56	108	195
Min	300	380	450	1.51	2.02	2.51	120	150.0	180	40	80	140
Max	380	450	550	2.02	2.51	3.53	150	180.0	220	80	140	250
SD	24	31	37	0.11	0.19	0.22	9	13.3	17	7	10	18

M – small, Ś – medium, D – large) with programming of training volume (number of elements), intensity (number of elements in min) and coefficient of effectiveness – complexity (1 – difficulty groups in according with FIG classification: C, D, E, F not in combinations, 2 – number of elements of higher difficulty groups in according with FIG classification: C, D, E, F in combinations.

The data presented reflect such numerical values as: values of the elements, the intensity and the complexity (the quality) of the exercises, which are characteristic for prospective gymnasts.

Procedure and endurance tests. Before the single training unit, after the gymnasts did the standard warm-up and after their completion of the unit, there was performed a test of their special endurance. Endurance tests looked as the standard practice for strictly defined motor tasks – gymnastic circuits and combinations in floor exercises and pommel horse exercises. The intensity of the test exercises was the model of the most stressful situations that happen in the training of highly qualified gymnasts. The test consisted of two parts: floor exercises and pommel horse exercises. Tests of floor exercises and pommel horse exercises were performed on different days. Each of them in one training session was carried out twice. To assess the effect of accumulation of fatigue in the training process, tests were conducted at the beginning and at the end of a typical for a high performance gymnast's microcycle. The content of the special endurance tests of the gymnasts is shown below.

Special endurance test – in floor exercise (1)

The test consisted of basic back and forward acrobatic jumps, separated by power and flexibility elements, which were to be made in a strictly defined order according to the order of their occurrence during sports competitions. This test consisted of six tasks: 1. Acrobatic backward combination: cartwheel with 1/4 turn (roundoff), backward handspring (flic-flac) and stretched salto backward to stand. (Structure III FiG); 2. Acrobatic forward combination: forward handspring and tucked salto forward to stand. (Structure II of FiG); Acrobatics backward combination: cartwheel with 1/4 turn (roundoff), backward handspring (flic-flac) and stretched salto backward to stand; 4. non-acrobatic elements: keep side split and press to handstand with straight arms and bent body (keep 2 s). With handstand 1/2 turn and return to the starting position. (Structure I FiG); 5. Acrobatic forward recombination: handspring forward and tucked salto forward; 6. Acrobatic backward recombination: cartwheel with ¼ turn (roundoff), backward handspring (flic-flac) and stretched salto backward to stand. The proposed set of six movement tasks, repeated twice in identical order of the connections with a break of 60 s (in total: 12 exercises), consist a complete test when it comes to floor exercise. The time of performance was 70 (±6) s.

Special endurance test – in pommel horse exercises (2)

Starting position – the side support frontways. The test consisted of four successive tasks: 1. Jump with double legs to the side support frontways and smoothly make the double legs four circles to the left (or right); 2. Smoothly move to the side support rearways and cut left leg back to the straddled support, then cut right leg back into the support frontways and cut left leg forward to the straddled support; 3. Without motion loss, scissors forward to the right and scissors forward to the left and cut the right leg forward to the side support rearways; 4. Without losing the rhythm, make the double legs four circles to the left. A full test consists of a two-time repetition of 4 tasks without stopping or a loss, with 60 seconds of rest. The test took over 40 ±5 s. These two types of gymnastic exercises were chosen to develop the test complex because they are the most difficult in terms of requirements for endurance and resistance to fatigue.

Before the endurance test, its reliability was confirmed on the basis of the results obtained from the same athletes in two series of tests conducted at intervals of three weeks. Correlation coefficients of HR ($r = 0.89$) and time ($r = 0.87$) were measured.

Measurement methods. Under laboratory conditions, a direct measurement of maximal oxygen uptake (VO_2max) was performed. The subjects refrained from intensive exercise during the previous 24 hours (rest day). The gymnasts were instructed to take a carbohydrate rich diet the days before the exercise tests. Before the start of the test, a warm-up of 5 min on ergometer (70–100 w) was performed. All measurements took place under the same conditions of temperatures (20–23°C) and humidity (45–55%). Before the trials, the athletes were familiarized the test procedures. The stepwise tests used a “refuse” test on a bicycle ergometer with the person in a sitting position with increasing load. The initial load was 1.5 $W \cdot kg^{-1}$ body mass at a rate of 50 rpm. After 5 minutes of effort, 0.25 in every 1 min of effort have increased the load. There has been used Jaeger’s EOS Sprint measuring tool and a bicycle ergometer connected to a computer. During these test, the following parameters were observed for respiratory and circulatory functions: oxygen consumption ($VO_{2)}$ and carbon dioxide production ($VCO_{2)}$, respiratory gas-exchange relation (RQ), lung ventilation (V_E), breath frequency and tidal volume (V_T). Heart rate (HR) was monitored by electrocardiogram (Sport-tester Polar PE 3000) in all special endurance tests using the standard procedure for applying electrodes. The heart rate was recorded continuously by the Sport-Tester in 5 s stationary average. Before the trials, the athletes were familiarized the test procedures. The average value during the execution of each test of special endurance was calculated. The maximum HR was determined as the largest HR by for 5 seconds in the final part of the stepwise load after reaching VO_2max.

In the training units, the floor exercise and pommel horse exercises tests were performed in two successive micro-cycles. In the first series the floor exercise tests and in the other of the pommel horse tests were performed. Three competent certified judges, in accordance with FiG’s refereeing rules, judged the reduction of scores (errors) of the performed exercises. The average value of the estimates from the assessments of each of the judges (experts) was used. Heart rate was also recorded during the execution of tests.

Statistical analysis. The obtained test material was subjected to mathematical and statistical analysis – with the use of program “Statistic 5.0 PL” in the “Excel 97”. One of the directions of the analysis was evaluation of using the test of the gymnasts’ special endurance for assessing the degree of gymnastics-specific fatigue, which affects the quality of performing gymnastic exercises. To do this, we compared the results of measurements obtained from the same gymnasts in the two series of tests in order to assess the significances of exercise heart rate and the performance of exercise (reduction of scores) differences between successive measurements at start and end of the training unit. Differences in the value were examined by Student’s t test. Prior to all analyses, normality of the data was assessed by the one-sample Kolmogorov–Smirnov test. Values were presented by means ± standard deviations, and statistical significance was set at $p < 0.05$.

In order to assess the relationship between the aerobic power results and the quality of the performed motor tasks, the Spearman rank correlation was used. This correlation is used when one of the qualities is measurable and the other is descriptive or when the values of the qualitative characteristics are approximates (judges' scores). Determining the intensity of the correlation based on the magnitude of the coefficient "r" was made at significance, * $p \leq 0.05$ and ** $p \leq 0.01$.

Results

The characteristics of the aerobic capacities of the examined athletes were at the levels that are typical for moderately trained healthy individuals. The levels of maximum oxygen uptake and pulmonary ventilation corresponded to those typical for gymnasts of high qualification. At the same time, there were individual differences. The characteristics of aerobic capacities shown in Table 3 indicate that there is a significant variation in the basic indicators of the peak potential of the oxygen delivery system.

Table 3. Characteristics of the gymnasts' aerobic capacities during aerobic test on the bicycle ergometer

Indicators	VO_2max ($l \cdot min^{-1}$)	VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	$V_E$max ($l \cdot min^{-1}$)	$V_T$max (l)	HRmax ($beat \cdot min^{-1}$)
Mean	2.86	46.87	110.0	2.34	193.0
Min	2.53	40.81	82.6	1.79	181.2
Max	3.08	54.02	135.5	2.95	201.5
SD	0.25	2.70	9.2	0.34	3.1

The variability of VO_2max (per kg of the body mass) and maximum lung ventilation during exercise ($V_E$max) in 3 of the best and worst performing gymnasts were 20.5 and 22.3%, respectively, with high HRmax similarity.

Evaluation of exercise intensity during training sessions based on the HR response of two standard systems at the beginning and at the end of the training unit on the sixth day of the microcycle (Table 4) shows a high level of intensity (approximately 80% HRmax). One may notice an increase of this response at the end of the training unit. This is the place both in floor exercises, and on pommel horse exercises.

Table 4. Heart rate response (beat per min, mean) of the gymnasts during two endurance tests: floor exercises and two pommel horse exercises (in bracket) in a single training unit

Indicators	Start of the training unit		End of the training unit	
	HR mean, max and min			
	Test 1	Test 2	Test 3	Test 4
Mean	148 (151)	151 (155)	151 (153)	157 (158)
Min	140 (144)	140 (146)	144 (144)	147 (147)
Max	153 (161)	160 (164)	158 (162)	163 (173)
SD	4.01 (5,28)	6.76 (5.89)	4.69 (6.11)	4.12 (7.93)

Significant differences at $p \leq 0.05$: 1–4.

According to the tables, the HR response of gymnasts on the pommel horse was individually varied to a greater extent (by maximal values) than the reaction of those doing floor exercise. This was evident when fatigue was accumulated at the end of the training unit.

The analysis of the relative intensity of exercise (by HR) during typical exercise (endurance tests) with aerobic capacity (VO_2max per kg of body mass) against fatigue accumulation at the end of the training unit showed a significant correlation (negative correlation). A similar relationship was observed in both floor and pommel horse exercises. The correlation strength increased with the second test (Table 5).

Table 5. The relationship between VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) and HR mean in two endurance exercises on floor exercise and pommel horse exercise performed at the end of workout training unit (the beginning and the end of the microcycle)

Types of exercises	Special endurance test	Correlation between VO_2max and HR mean of tests	
		the beginning of the microcycle	the end of the microcycle
Floor exercises	Test 1	–0.63*	–0.96**
	Test 2	–0.85**	–0.95**
Pommel horse	Test 1	–0.78**	–0.97**
	Test 2	–0.82**	–0.96**

Significant differences at *$p \leq 0.05$; **: $p \leq 0.01$.

The strength of the correlation was also increasing from the beginning to the end of the microcycle.

Due to the higher predicted effect of increased exercise intensity (percent HR vs HRmax) on the development of fatigue and motor coordination, there has been examined also changes in the performance of the exercise (reduction of assessment points) during the pommel horse endurance test at the beginning and at the end of the training unit (Table 6).

Table 6. Changes in the performance of exercise (reduction of scores) during endurance test on the pommel horse at the beginning and at the end of the training unit

Indicators	At the beginning of the training unit		At the end of the training unit	
	reduction of scores (errors)			
	Test 1	Test 2	Test 3	Test 4
Mean	1.44	2.72	1.86	3.25
Min	1.10	1.50	1.30	1.60
Max	1.80	3.60	2.60	4.30
SD	0.22	0.68	0.40	1.00

Significant differences at $p \leq 0.05$: 1–2, 3–4, 2–4; when $p \leq 0.01$: 1–4.

In the fourth endurance test (performed after one minute of rest after the third test), there has been observed the deepest drop in exercise precision, which confirms the magnitude of the errors. The quality of gymnastic exercises (reduction of scores) was evaluated in both special endurance tests performed on pommel horse and in floor exercise. The results of the measurements were similar. Therefore, only one of them is given. The results of the measurements of both tests were used for the subsequent analysis. The quality of exercise in the trials (reduction of scores) depended on the relative intensity of exercise (HR average) during exercise (Table 7).

Table 7. The correlation between average HR and quality of gymnastic exercises performed on pommel horse and of floor exercise (in brackets), with measured amount of errors (score reduction) during a training unit

Tests	At the beginning of the training unit		End of the training unit	
	HR mean			
	Test 1	Test 2	Test 3	Test 4
Test 1	0.30 (0.74**)	–	–	–
Test 2	–	0.74**(0.76**)	–	–
Test 3	–	–	0.76**(0.61*)	–
Test 4	–	–	–	0.79**(0.76**)

Significant differences at: * $p \leq 0.05$; ** $p \leq 0.01$.

As shown in Table 7, significant correlations (positive correlation) were found between the mean HR and the quality of exercise performed during the second, third and fourth endurance tests. These data show the increase in intensity of work from the beginning to the end of the training unit (average HR increase) and the increase in the number of exercise errors which is dependent on the HR increase.

The average heart rate of gymnasts in rehearsal tests (on fatigue) of the standard test on pommel horse and in floor exercise in training units depended on $VO_{2\ max}$ per kg of body mass (Table 8). The relationship between these oxygen performance characteristics was high (negative correlation) at the beginning and at the end (in brackets) of the microcycle.

Table 8. The relationship between VO_2max and HR mean in endurance gymnastic tests (floor and pommel horse exercises) at the end of the training unit, done at the beginning and at the end of the microcycle (in brackets)

Type of exercises	Strength test	Correlation between VO_2max and HR mean tests (r)
Floor exercises	Test 1	–0.63*(–0.90**)
	Test 2	–0.85**(–0.92**)
Pommel horse exercises	Test 1	–0.71*(–0.91**)
	Test 2	–0.82**(–0.93**)

Significant differences at *$p \leq 0.05$, **: $p \leq 0.01$.

In the fifth training unit (at the end of the microcycle), the correlations were higher than at the beginning and clearly, during two tests, they occurred at the beginning of the training unit.

The endurance tests on a pommel horse during a medium-loaded training unit indicate a high degree of variation in the quality of performed motor tasks (with the number of errors made increasing) against the increasing fatigue (Table 9).

Table 9. The characteristics of gymnastic exercise quality changes (differences of errors in points and percentages – in brackets) in four consecutive exercises (tests) performed on the pommel horse during a single training unit

Indicators	Differences of errors in points and percentages			
	2–1	4–3	3–1	4–1
Mean	0.95 (79)	1.09 (75)	0.24 (16)	1.33 (110)
Min	0.30 (150)	0.40 (130)	0.10 (67)	0.50 (222)
Max	2.40 (25)	1.60 (33)	0.60 (24)	2.00 (42)
SD	0.32	0.18	0.04	0.29

Such changes in the quality of work performed were already present in the first two tests, with a significant increase from 1 to 4 tests.

The final analysis of the aerobic power of the gymnasts for the quality of the special work performed in endurance tests indicates a high correlation of VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) with the degree of point's reduction (increasing number of errors) in training units (Table 10).

Table 10. The correlation between VO_{2max} and special performance characteristics (difference of errors in technical performance between individual tests in points and % – in brackets) during the pommel horse exercises in training units

Tests	Correlation VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) with the difference of errors in technical performance
2–1	–0.87 (–0.89)**
4–3	–0.89 (–0.72)**
3–1	–0.75 (–0.49)**
4–1	–0.91 (–0.89)**

Significant differences at **: $p \leq 0.01$.

The VO_2max correlation analysis was performed taking into account the variations in errors between the four endurance tests during the training unit. The first and the second test were conducted at the beginning and the third and fourth at the end of the training unit. Such an analysis demonstrates that high correlation during pommel horse exercises occurs in all cases, although the largest correlation was between the first and fourth test and the VO_2max of the tested gymnasts.

Discussion

Given the varied nature of individual gymnastics competitions that require the gymnasts to undergo comprehensive physical and technical training, indicators that reflect the magnitude of adaptive responses are of particular importance. Such an integral feature is the energy potential (Astrand, Rodahl, 1977). The fact is that gymnastic exercises are protected, in large part, by anaerobic energy sources. Nevertheless, the overall performance is geared towards evaluating the aerobic capacity of the energy supply system (Mac Dougall, Wenger, Green, 1991). It is known that high aerobic capacity allows for better tolerance of effort of different intensity. It can be assumed that in gymnastics, the time during which fatigue occurs (while training) has a significant influence on the quality of performed tasks. Although the measure of efficiency may be the ability to perform specific work in a unit of time, and thus the ability to release maximum power, the most common indicator of efficiency is the maximum oxygen consumption (VO_2max). When analyzing the results of the study, we can observe the differences in body mass and height of the examined gymnasts. BMI had no significant impact on the quality of exercise performed by the tested gymnasts, but was associated with VO_2max in ml·kg^{-1}·min^{-1} ($r = -0.49$; $p < 0.05$).

It is known that a gymnast taking part in an all-round event must master at least 52 elements of very high difficulty and complexity. Making exercises such difficult cause numerous complications in performing high workloads (Arkayev, Suchilin, 1997). The tremendous material that must be mastered by the gymnast at the right time puts forward also the physical efficiency, the basis of which is VO_2max. Such characteristics of efficiency can be very helpful not only in the assessment of special endurance but also in understanding the possibility of carrying out significant training loads in particular phases of long-term training (Astrand, Rodahl, 1977; Sawczyn, 2000; Sawczyn, Zasada, Mishchenko, 2005). For the examined gymnasts, the aerobic capacity (measured by VO_2max per kg of body mass) has significantly varied: from 40.8 to 54.0 ml·kg^{-1}·min^{-1}. According to most of the other studies of VO_2max per kg of body mass of gymnasts, they are at 45–50 ml·kg^{-1}·min^{-1} (Smolevsky, Gaverdovsky, 1999). Previously, the gymnastics was ranked as the sport with one of the lowest VO_2max values. On the other hand, gymnasts of all ages demonstrated significant fluctuations in individual VO_2max levels, ranging from 41 to 63 ml·kg^{-1}·min^{-1} (Barancew,, 1985; Smolevsky, Gaverdovsky,1999; Sawczyn, 2000). According to Mc Dougall et al. (1991), the scale of maximum oxygen consumption among the best gymnasts ranges from 48 up to 74 ml·kg^{-1}·min^{-1}. Sawczyn (2000) presents data on the downward trend of $VO_{2\,max}$ from 55.4 ±4.1 to 47.0 ±6.5 ml·kg^{-1}·min^{-1} in the age range of 10–11 years do 17–22 years. The author notes that the data presented may reflect the natural tendency to decrease VO_2max per kg of body mass as a result of mass gain and lack of aerobic training in gymnastics.

Performance requirements in gymnastic exercises may be characterized by the increased of heart rate. By analyzing the results of the research, it can be seen that the response of the gymnasts to the effort made is a high HR response in all gymnasts. During the fourth endurance test, the HR response was at the highest level – 158 (147–173) beat per min. The standard deviation from the mean in the fourth test was 7.93 and the coefficient of variation was 5%. This means that the fourth test scattering was at the highest level in relation to the previous day's efforts on the microcycle. This may indicate that there is the greatest variation in the level of fatigue in these conditions of the endurance of gymnasts and the associated effect of fatigue on the quality of performing complex gymnastic elements and combinations.

In gymnastics, the scale of the sports championship is the ability to perform exercises in six competitions with precision that is not as high in other sports disciplines. The gymnast has to combine all movement acts with the same precision, as they form a complete combination (system), which is evaluated according to strictly defined rules of referees (Vuillerme, 2001; Gaverdovsky, 2003; Arkajew, Suczilin, 2004). Therefore, the influence of fatigue can be seen first of all in the negative changes of the movements precision (Starosta, 1993; Sawczyn, Zasada, Mishchenko, 2005; Zasada, Sawczyn, Mishchenko, 2006). As a result of the performed gymnastics research, the obtained data show that we can characterize the effect of aerobic capacity on the quality of performed motor tasks. These results indicate that there is a high correlation and a very reliable relationship between the parameters given. The effect of greater aerobic capacity can be attributed to lower cerebral hypoxia and less central fatigue when performing gymnastic combinations (Loren, Chiu, 2003; Nybo, Rasmussen, 2007; Rasmussen et al, 2010).

It was shown that there was a negative correlation between aerobic power (VO_2max) and cardiovascular system response (HR) in performing standard endurance tests. Such dependency increases when fatigue is accumulated at the end of the training unit and training microcycle. Correlations in the last training unit of the training microcycle were even higher and were already present at the start of the training unit in the two tests. A clear increase in fatigue and an HR increase in HR max when performing standard gymnastic exercises at the end of the microcycle is typical for high-level gymnasts (Arkayev, Suchilin, 2004).

This means that even the most intense gymnastic loads of athletes with higher aerobic capacities are relatively less stressful than those with lower $VO_{2\ max}$. This presumably creates the conditions for a slower development of fatigue and for maintaining the quality of performing gymnastic combinations. In modern sports training technology, it is extremely important to seek out and use different methods to evaluate the functional capabilities of gymnasts that could increase the effectiveness of the training process. Developed endurance tests in floor and pommel horse exercises, according to HR and energy expenditure, simulate the most intense conditions of gymnastic combinations and can be a tool for the control of special endurance of gymnasts. This confirms that the method of assessing physiological load according to HR response is effective in managing training loads (Arkayev, Suchilin, 1997; Smolevsky, Gaverdovsky, 1999).

Based on the endurance tests, a number of results indicate a number of fatigue changes in the gymnasts' bodies and their impact on the quality of work done during strictly defined motor tasks, and also their association with aerobic capacity of gymnasts. During the four endurance tests carried out in high load training units, the quality of the work performed by the gymnasts was shown by the size of the errors (reduction of points). The demonstrated dependence was greater on pommel horse exercises, which may be indicative of the highest specific endurance requirements for these exercises. Manifestation of coordination stability includes the other indices of movements control as well (Enoka, Duchateau, 2008; Amann, 2011). They are integrated by fatigue impacts on the function of sensorimotor cortex, which is the highest level of voluntary motions in precise evaluation of time, motion amplitude and value of efforts in athletes. Utilization of endurance tests for evaluation of changes (stability) in coordination capacities ("coordination endurance") under the influence of fatigue is justified by the fact that mechanisms of motion control are complex and under the influence of factors of the same type as well as during various body states change unequally. There exists a positive transfer of ability to maintain stability of these or those characteristics of motor actions in similar according to main biomechanical characteristics parameters of motions (Gaverdovsky, 2003; Asseman, 2004).

The degree of fatigue, the speed of its increasing, and the speed of recovery after training depend on the specific physical fitness that is the basis of the special endurance. The quality of performing complex gymnastic elements and combinations is related to value of VO_2max per kg body mass of the gymnasts. Aerobic capacities influence on training loads and its quality in training units. This can be associated with slowing down the development of fatigue, increased metabolic acidosis that allow for long-term concentration and exercising for longer periods of time with maximum precision.

Thus presented data reflect higher stability of coordination capacities and regularities of their changes in gymnasts with greater aerobic capacity. Their interrelation may be used for evaluation of specific for gymnast special endurance. These data also indicate the one of the ways to provide "functional excess" in resistance to fatigue phenomena in order to provide high speed of recovery and efficiency of performing complex in coordination gymnastic exercises during the whole training session or preparation cycles. It can be assumed that changes in aerobic capacity at various stages of the annual cycle and many-years preparation reflect the evolution of the adaptability of gymnasts to training loads.

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