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Neuromuscular and Physiological Assessment During a Vertical Jumping Test in Aerobic Gymnastics

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Abstract: *In executing aerobic gymnastics technical elements, a high level of explosive power is needed, especially at lower-body muscle groups. In addition, to maintain the specific effort during routine length (1 min 30 s - 1 min 45 s), an optimal development of specific endurance training and a high capacity of focusing is required, in order to execute the technical elements with accuracy. The purpose of this study was to elaborate a testing protocol to evaluate the physical effort capacity necessary to perform specific technical elements in aerobic gymnastics. The proposed testing protocol, is aimed at assessing neuromuscular behavior of lower-body muscle action and the physiological demands, in a maximal vertical jump test (MVJ). The neuromuscular assessment of the of lower-body was achieved by measuring the specific vertical jump parameters, respectively the power in the take-off phase (P) and the height of the jump (JH). The testing protocol consisted of three sets of maximum vertical jumps, lasting 30 s each, with a 15 s rest time between sets. For the physiological demands, as a result of test implementation, heart rate (HR) and the blood lactate concentration (La) were measured. The study was conducted on a group of 13 junior level gymnasts, 7 females and 6 males (aged 14-16 years, average height 163 SD 8.1 cm, average weight 50.69 SD 8.47 kg). The results of this study confirm the proposed methodology reflects an objective view of the physical training status necessary for specific effort accomplishment in aerobic performance gymnastics.*

Keywords: *aerobic gymnastics; neuromuscular; physiological assessment; vertical jumping test.*

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Introduction

Aerobic gymnastics is considered to be a relatively new sport, whose popularity has greatly increased since the first World Championships, held in 1995, in Paris (Aleksandraviciene et al., 2015). Therefore, in this branch of sport, there is a lack of scientific studies regarding the physiological demands produced by the specific competitive effort. The main criteria we can describe the particularities of this sport by are the requirements imposed by the competition regulations. An important approach to assessing the level of performance of an exercise is the elements degree of difficulty of the components. Depending on the difficulty, the scoring system divides the elements into four groups: Group A with Dynamic Strength Elements, Group B Static Strength Elements, Group C with Jumps and Leaps Elements and Group D with Balance and Flexibility Elements (Federation Internationale de Gymnastique, 2020, p.20).

This high variability of movements, requires aerobic gymnasts to have important qualities of power, balance and mobility. The technique and specific conditions (synchronization, posture and spatial organization) also require a high level of coordination, both at the intersegmental level, between partners, and between themselves and the musical accompaniment. The ability to perform movements with perfect technique in maximum precision, correct form, posture, body alignment is affected by the physical capacities (active and passive flexibility, strength, amplitude, power and muscular endurance), (Federation Internationale de Gymnastique, 2020, p.19). Therefore, we can state that the specific effort in aerobic gymnastics is characterized by a high degree of intensity, difficulty and complexity. Explosive power is considered one of the most significant factors in aerobic gymnastics performance (Kyselovičová & Danielová, 2012). Other important qualities are muscular strength, plyometric strength, coordination and flexibility (Mezei & Cristea 2014; Mezei et al., 2019).

As specific effort is achieved in an alert rhythm, with a relatively high length, 105 sec. on average (Aleksandraviciene et al., 2015; Raiola et al., 2013), development of power skills should be correlated with the appropriate cardiovascular and metabolic adaptation. Recent studies have shown that specific competitional effort produces maximal demands both at the cardiorespiratory level, with values of the maximum heart rate of over 190b/min (Bota & Urzeală, 2013), and at the muscular metabolism, with maximum concentrations of the lactic acid of 17.3Mmol/l (Kyselovičová & Danielová, 2012). These general characteristics of the specific effort explain the difficulty in setting up training plans in order to cause appropriate physiological adaptation and neuromuscular development, both to the requirements of the specific effort and to the individual particularities. Considering these aspects in the study, we intended to design a basic skill assessment protocol in aerobic gymnastics, mainly for power during maximal effort at the level of the triple extension movement, power endurance and cardiovascular and metabolic adaptation to effort. In order to evaluate the effort capacity in high performance sports, different tests are used, field or lab tests, aimed at measuring explosive force in maximum vertical jumps (Kyselovičová & Zemková, 2010). In order to evaluate neuromuscular abilities, we have used a modified maximal jumping test, made on OptoJump device. This device is used in many recent studies, in order to evaluate the energetic potential at the level of the lower body muscles groups (Healy et al., 2016, Ilie & Graur, 2017; Sattle et al., 2014). One of the standard protocols, offered by the OptoJump program, includes 15 jumps series on both feet and on one foot alternatively. To be as close as possible to the length of the competitional exercises in the aerobic gymnastics, we have proposed a protocol of 3 x 30”as follows: on both feet, on the left foot and on the right foot. To determine the physiological demands produced by this effort, heart rate and lactic acid concentration in the capillary blood were measured. Heart rate measurement during effort is a frequently used method in sports training. Heart rate monitoring provides a valuable means of distinguishing physical activity patterns and provides an indication of the intensity, duration and frequency of physical activity (Armstrong, 1998; Marina & Rodríguez, 2014). The heart rate response is directly proportional and linear to the intensity of exercise, and as intensity of exercise increases, the heart rate until exercise reaches maximal intensity (Hoffman, 2014, p.66). Therefore, the aim of this study was to develop a methodology for evaluating the motor skills specific to the effort in the aerobic gymnastics.

Objectives of the research:

1. Evaluation of power endurance capacity;
2. Evaluation of the energetic potential at the level of the lower body muscles groups;
3. Optimizing general and specific physical training according to the body's response to objectively measured demands;
4. Improving the evaluation methodology of the performance capacity of athletes;
5. Improving individual training plans and recovery programs.

Methods

Research participants

The study was conducted on a group of 13 junior level gymnasts, 7 females and 6 males (aged 14-16 years, average height 163 SD 8.1 cm, average weight 50.69 SD 8.47 kg). The research was carried out at the request of the coach and with the individual consent of each athlete. The tests were held in the training room, during a specific training program.

Testing instruments used and measured parameters:

1. **OPTOJUMP** – This device has been used in order to evaluate the energetic potential at the level of the lower body muscles groups (triple extension movement). The following parameters have been measured: the maximum number of jumps on two feet (F), the maximum number of jumps on the left foot (Fl), the maximum number of jumps on the right foot (Fr), height of the jump on both feet (H), hight of the jump on the left foot (Hl), hight of the jump on the right foot (Hr), contact time on both feet (T), contact time on the left foot (Tl), contact time on the right foot (Tr), power on both feet (P), power on the left foot (Pl), power on the right foot (Pr).

2. POLAR Team 2 – to determine heart rate (HR). This device is specially made to measure heart rate in physical activities and offers the possibility to record, store and processing data. Heart rate was measured individually during exercise with an acquisition frequency of 5cmsec. For this study, the maximum value of the heart rate recorded by each athlete during the effort was determined. (Table no. 3)

3. Lactate Pro 2. The Lactate Pro 2 device was used to measure the concentration of lactic acid in the capillary blood. This device provides quite rapidly, in approximately 15 sec. the lactate concentration values, in a small quantity of blood (0.3µl), harvested at the capillary level (http://www.lactatepro.com.au/lactatepro/PRODUCT.html/17.05.2018). The concentration values of the lactic acid for each athlete have been determined at a 2 min and 30 sec interval after stopping the effort. (Table no. 3).

Testing procedure description

Athletes performed three sets of maximum vertical jumps: on both legs, on the right leg and on the left leg.

- The duration of each set was 30 sec;
- The break between sets was 15 sec;
- Heart rate was measured throughout the exercise;

- The concentration of lactic acid in the capillary blood was measured, at an interval of 2 min and 30 sec after the end of the effort, for each athlete.

Data acquisition and processing

The OptoJump device returns the values of the measured parameters, both for each jump made and the average values for each item of the test. The average values of the measured parameters, for each subject, are presented in table no.1.

In order to analyze the results obtained at the level of the group of subjects, the average values of the measured parameters were statically processed, using the EXCEL 2016 program. The following descriptive statistical parameters were calculated: Average (M), Minimum values (MIN), Maximum values (MAX), Standard Deviation (SDEV) and Coefficient of Variability (CV), (Table No.2). From the date presented in tables 1 and 2, one can notice a high homogeneity at the level of the subject group in what concerns the maximum number of jumps with average values for the jumps on both feet F=44.31, on the left foot Fl=46.15 and on the right foot Fr=45.54 and low values of the variability coefficient, mainly CV=4.82 for both feet, CV=5.37 for the left foot and CV= 6.49 for the right foot.

Table No.1 Average individual values of the measured parameters

	F(cm)	Fl(cm)	Fr(cm)	T(s)	Tl(s)	Tr(s)	H(cm)	Hl(cm)	Hr(cm)	P(W)	Pl(W)	Pr(W)
S1	46	47	44	0.17	0.33	0.4	30.2	11.50	12.00	46.55	13.07	14.50
S2	45	43	49	0.2	0.29	0.46	27.2	12.70	7.90	37.92	16.10	9.91
S3	45	45	45	0.23	0.38	0.36	25.4	10.30	10.30	32.64	12.31	12.12
S4	46	47	46	0.18	0.35	0.34	29.8	12.80	12.70	45.28	15.09	15.10
S5	44	47	49	0.18	0.3	0.34	33.1	12.80	11.90	49.69	16.46	14.59
S6	48	51	50	0.17	0.28	0.28	26.6	13.10	12.30	42.73	16.79	16.31
S7	46	49	50	0.19	0.29	0.31	29.3	12.30	12.00	43.29	15.93	15.21
S8	43	41	40	0.18	0.39	0.33	79.1	17.10	20.60	102.17	17.96	21.99
S9	40	46	43	0.19	0.34	0.34	38.7	15.80	12.50	53.98	17.77	14.81
S10	44	48	47	0.18	0.33	0.31	32.2	12.50	13.70	47.96	15.16	16.62
S11	41	44	42	0.21	0.4	0.37	36.2	12.90	13.60	46.95	14.05	15.27
S12	44	43	42	0.27	0.43	0.41	22.0	10.80	10.40	26.25	12.04	11.93
S13	44	49	45	0.21	0.38	0.35	28.4	10.60	9.80	37.89	12.45	12.41

Source: original data resulting from research

Related to the contact time, we can notice that at the level of the group, similar average values were registered for the contact time on the left foot (Tl = 0.345) and the contact time on the right foot (Tr=0.354), and an average level of variability of the values obtained, both for the contact time on both feet (CV= 14.27) and the left foot (CV=13.87) and the right foot (CV= 13.48).

Table No.2 Statistic parameters values

	F(cm)	Fl(cm)	Fr(cm)	T(s)	Tl(s)	Tr(s)	H(cm)	Hl(cm)	Hr(cm)	P(W)	Pl(W)	Pr(W)
MEDIE	44.31	46.15	45.54	0.20	0.345	0.354	33.71	12.71	12.28	47.18	15.01	14.67
MIN	40	41	40	0.17	0.28	0.28	22	10.3	7.9	26.25	12.04	9.91
MAX	48	51	50	0.27	0.43	0.46	79.1	17.1	20.6	102.17	17.96	21.99
SDEV	2.14	2.85	3.31	0.03	0.05	0.05	14.34	1.93	2.98	18.11	2.06	2.93
CV	4.82	6.18	7.26	14.27	13.87	13.48	42.55	15.17	24.23	38.40	13.73	19.94

Source: original data resulting from research

From the data in table 1 and 2, one can notice a high variability for the following parameters: the height of the jump on both feet (H=42.55) and power on both feet (P= 38.4). This high variability is determined by the extreme values recorded by subject S8, as compared to the average value at the level of the group, mainly H=79.10 compared to H= 33.71 and P=102.17, compared to P=47.18. We can notice a similar behavior between the left and the right foot at the level of the subject group, both for the height of the jump, and the power, with average values for the height of the jump on the right foot Hr=12.28 and Hl=12.71 for the left foot, and an average value Pr=14.67 for the power on the right foot, compared to the power on the left foot Pl=15.01.

The values of the measured parameters in evaluating the power endurance capacity, maximum heart rate (HR) and the lactic acid concentration (La), recorded for every athlete are shown in table no. 3.

Table No.3 Maximum heart rate values and lactic acid concentration

No.	Subjects	HR max (b/min)	La (mmol/l)
1	S1	197	12.4
2	S2	186	14.5
3	S3	196	11.4
4	S4	188	131
5	S5	194	12.6
6	S6	185	13.7
7	S7	173	11.6
8	S8	194	13.6
9	S9	194	8.8
10	S10	179	15.6
11	S11	181	11.1
12	S12	166	12.7
13	S13	171	11.4

Source: original data resulting from research

In table no. 4 a high homogeneity of the maximum heart rate values, with a variability coefficient of 5.57 and an average value of 184.92., at the level of the group, can be noticed. On the other hand, we notice a medium level homogeneity for the lactic acid concentration, with a variability coefficient CV=13.77 and an average value (M) of 12.50.

Table No.4 Statistic parameters values

Statistc parameters	HR(b/min)	La (mmol/l)
MEAN	184.92	12.50
MIN	166.00	8.80
MAX	197.00	15.60
SDEV	10.29	1.72
CV	5.57	13.77

Source: original data resulting from research

Data interpretation:

In order to improve the training plans, it is also necessary to analyse both the results obtained at the level of the group and individual data. A general characterization of a group of athletes offers important information about the homogeneity of training for certain components of training. Depending on the homogeneity ratio obtained in the group of subjects we can group the results into three categories. We distinguish a high homogeneity (CV<10) for the parameters: the maximum number of jumps on both feet, on the right foot and on the left foot, and maximum heart rate. A medium degree of homogeneity (CV<20), for the contact time on both feet, on the right foot and on the left foot, height of the jump on the left foot, the power on the left foot and the right foot, and the lactic acid concentration. A low degree of homogeneity (CV>20) is seen for the height of the jumps on both feet, on the right foot and on the right foot, as well as for the power on both feet.

Low variability in parameters such as frequency of the jumps, contact time and maximum heart rate can show a similar training program had been applied in what concern the abilities related to speed and cardiovascular adaptation to effort. However, important differences between athletes, recorded for the height of the jump, power and concentration of the lactic acid highlight the different individual abilities for the qualities of strength and muscular metabolism, at the level of the lower body. These differences can be determined on the one hand by the lack of tailoring in the training plans to individual particularities and, on the other hand, by the dynamic in the specific physiologic development to teenagers.

Analyzing individual parameters, one can notice that subject S8 recorded very high values for power and height of the jump on both feet P=79.cm, H= 102.17W, which explains a high variability at the level of the group for these particular parameters. A lower evolution can also be noticed, compared to the best scores and the average values at the group level for subject S12, for all the measured parameters (F=44, Fl=43, Fr=42, H=22.00, Hl=10.80, Hr=10.40, P=26.25, Pl=12.04 and Pr=11.93). In addition, subject S12 had high values in the contact time T=0.27, Tl= 0.43 and Tr=0.41.

In what concern the physiological demands (cardiovascular activity and muscular metabolism) we notice that the effort applied by the gymnasts can be identified in two effort zones. (Tocitu, 2000):

1. Oxygen – Lactate 1 Zone, also called «lactate tolerance». The efforts included in this zone are characterized by values of the

heart rate (HR) of 180+/-5 b/min. and values of the lactic acid (La) between 12 and 18 mmol/l;

2. Oxygen – Lactate 2 Zone, also called the maximum oxygen uptake (VO2max) effort zone. Efforts included in this zone are characterized by values of the heart rate (HR) of 170+/-5 b/min. and values of the lactic acid concentration (La) between 5 and 12 mmol/l.

From Table no. 4 we can depict that the effort applied by most of the athletes (S1, S2, S4, S5, S6, S8, S10 si S12) is within the Oxygen -Lactate 1 Zone, whereas athletes S3, S7, S11 and S13 are within the Oxygen -Lactate 2 Zone. Athletes S7 and S13 present an optimum equilibrium between the cardiovascular system and the muscular metabolism. We would like to emphasize a very good cardiovascular activity for S12, with a good balance between heart rate value (HR=166b/min) and the lactic acid value (La= 11.4mmol/l). An imbalance can be seen between the muscular activity and the cardiovascular system at subjects S1, S2, S3, S5, S4, S6, S8 and S9. This imbalance is represented by too high values of the heart rate, compared to the lactic acid concentration values. Moreover, athlete S9 shows an important imbalance between the muscular activity and the cardiovascular system, with a very high value of the heart rate (HR=194), compared to the lactic acid concentration value (La = 8.8). The highest value in lactic acid concentration was registered by subject S10 (La=15.6mmol/l). This intense muscular metabolic activity should be supported by an adequate aerobic capacity, in which the oxygen supply can facilitate an optimum process of recovery, both during the pause between exercises and between different training sessions.

Conclusions

In high level sports performance, training plans improvement involves the individualization based on an objective assessments of the level of the effort adaptation for each athlete, corelated to the competition specific effort characteristics. As high performance aerobic gymnastics involves a high degree of physiological adaptation, together with a complete development of motor skills conducting specific training sessions implies both knowing the specific skills determining high performance levels, and the methods and means of assessment and development of the specific abilities.

Measurement of the physiological, metabolic and neuromuscular parameters, using the methodology presented in this study offers relevant data related to the level of individual development on each analyzed component, together with a general overview over the appropriate approach of the specific training programs. A unitary training of the group members on components such as power and cardiovascular adaptation can be seen. We notice that in what concerns the physiological adaptation, most of the athletes present an imbalance between the muscular metabolism and the cardiovascular development, with very high values of the heart rate, compared to the lactic acid concentration values. The positive outranged values are a high performance potential indicator, which suggests paying special attention to individualizing the training process.

We consider that the results presented in this study offer objective information in setting up tailored training programs both for individual needs, and based on requirements of the sports specific effort. The proposed methodology can be used as a long term assessment method of the aerobic gymnastics specific skills.

In addition, an optimal timeframe between the assessment stages should be set, so that, the information resulted from the individual performance analysis, as well as at a group level could allow the on-going improvement of training plans.

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