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SPECIFIC DEMANDS OF THE EFFORT ON THE POMMEL
HORSE IN ARTISTIC GYMNASTICS

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Abstract

An important element in the preparation plan of high performance gymnasts is the training of the specific effort endurance. The planning of such activities is done considering the effort stress involved in the difficulty and complexity of each full exercise and the individual adaptive particularities, corresponding to each preparation stage. Developing an optimal preparation scheme means measuring all physiological parameters which can offer an objective description of the intensity and energetic costs involved by the specific competition exercise. In this context, we performed a study with the participation of six high performance gymnasts aged between 24 and 27. The aim of this study was to measure the level of individual metabolic and cardiorespiratory stress induced by the specific effort during a full exercise on pommel horse. The measured parameters were heart rate and the lactic acid concentration in the capillary blood network, afterwards correlated to the volume and difficulty level of the full exercise of each gymnast. In this study, subjects have a different level of value in exercises that they present on the pommel horse apparatus. This procedure was the first stage in developing the methodology of the individual training programme, with the purpose of increasing specific endurance for the pommel horse event.

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1. Introduction

Although all three variables of the sports workout, intensity, duration and type of effort have an important role in determining the type of energy system predominant in the effort, the intensity is the variable that determines the energy system to be activated. Although the underlying physiological adaptations associated with improved endurance performance in training are well established, debate abounds regarding how one should train to induce these adaptations and translate them to performance gains. A key issue of debate is the intensity of training and how the day-to-day training intensity should be distributed (Esteve-Lanao, Foster, Seiler, & Alejandro, 2007). For an optimal distribution of the intensity of the training stimuli, in endurance efforts, it is necessary to define and classify the routine-specific effort, according to a set of measurable physiological parameters that will provide coaches with an objective measure of the demands determined by the training-induced effort. Therefore, the planning of the training for specific endurance requires a preliminary phase of knowledge of both the characteristics of the specific effort and the individual characteristics of the athletes.

The knowledge of the characteristics of the specific effort for the competitive routine provides the coaches with the following advantages:

- Correct classification of the effort characteristic of the exercise in a certain area of the metabolic effort.
- Identifying the intensity at which the body of the athletes works during the exercise.
- Identifying the optimal effort intensity for the training of the specific resistance for each athlete.
- Conducting the workouts within each specific (technical/physical) component, according to a scheme objectively designed and adjusted to each athlete;
- Adjusting the recovery programmes according to the individual response to specific training stimuli.

2. Problem Statement

2.1. Description of the specific effort on pommel horse

The intensity and complexity of the specific effort of the competitive routine are determined by the construction of the apparatus and the demands imposed by the regulation regarding the structure of the exercises and the technical execution. According to the *Code of Points* (FIG, 2017), which takes into consideration the general biomechanical characteristics of the elements on this apparatus, these are hierarchized into five groups, from I to V:

“I. Swings and scissors

II. Circles and flairs with or without spindles and handstands

III. Side and cross support travels

IV. Travels forward and backward, flops and combined elements

V. Dismounts” (pp. 54-58)

In each of the five groups, depending on the difficulty, the elements are classified into seven scoring groups, from A to G, the minimum score of the elements being 0.1 points for an A-score element and the maximum score of 0.7 points for a G-score element. Performing a complete high-performance

exercise on pommel horse requires the training of the two basic components of performance, technical training and metabolic adaptation, in an approximately equal ratio. From a technical point of view, the performance of this routine is evaluated by marks which take into consideration the difficulty of the exercise and the accuracy of the execution. An excellent complete exercise at world level has a difficulty of execution higher than a mark of 6.6 points, and the exercise with the highest score is currently the one performed by Max Withlock, who scored 7.4 points at the 2014 European Championships in Sofia.

There are several types of movements on pommel horse, which may be classified as follows:

- a. Pendulum or balance movements
- b. Double circles
- c. Flairs (Thomas)

Depending on the support on the apparatus:

- a. Unilateral, on pommel or leather:
 - on the left arm – with spindles or not,
 - on the right arm – with spindles or not.
- b. Bilateral:
 - on pommel,
 - on pommel (up, down and mixed),
 - on leather,
 - mixed (leather-pommel, pommel-leather).

Depending on the travel on the apparatus:

- forward,
- backward,
- side,
- swindle (flops). (Readhead, 1997, p. 113; Vieru, 1997, p. 217)

From a neuromuscular point of view, the specific demands while performing on this apparatus are located, in particular, in the upper body area. The technique of the specific elements is characterised by balancing and rotation movements, made with side or cross-support, with legs together or apart, in a continuous dynamic without interruptions or movements made out of strength. Looking from the outside, the effort on this apparatus is of high intensity and complexity, maintained at a steady level for 40-50 seconds. The specific physiological demands determined by the competitive routine are difficult to determine because the competition regulations do not allow for the use of measurement tools to evaluate the effort parameters during official competitions. Consequently, in order to determine the specific effort in this routine, the measurements can be organized in the laboratory or during specific workout, in which the athletes perform their own complete competitive exercises. Biochemical measurements made in competitions on elite gymnasts led to lactic acid concentrations higher than 11 mmol/l and heart rate values higher than 180 bpm. (Monèm, 2011) These values suggest that the effort specific to pommel horse in artistic gymnastics is a high-intensity anaerobic lactacid type.

2.2. Description of parameters investigated to determine the specific effort

Unlike the changes made in the field of technical execution, which can easily be noticed from the outside, the functional transformations induced by physical effort can be objectively assessed only on

based on specific measurements conducted in the laboratory, during workouts or competitions. The major mechanism for ATP regeneration involves three distinct chemical reactions and pathways: creatine phosphate hydrolysis (alactic anaerobic energy sources), aerobic (oxidative) metabolism (involves the combustion of a fuel in the muscle cell in the presence of oxygen) and anaerobic glycolysis (anaerobic lactic) (MacDougall, Wenger, & Green, 1990). Planning and conducting workouts for the development of endurance requires knowledge of both the metabolic processes that produce energy in the muscle cell and the characteristics of the cardiorespiratory function, given the importance of oxygen in the development of energy processes. A quick method, applied to assess the degree of stress induced by the training stimuli or even by the effort in competitions, where regulations allow the use of specific measuring tools, is to determine the concentration of capillary lactic acid and heart rate values. "Heart rate primarily reflects the level of cardiovascular system functioning, and the lactate level reflects the energy system involved" (Plowman & Smith, 2014). Heart rate is an easy-to-measure parameter, especially during workouts, so it is often used by coaches in order to get to know the different aspects of the workouts performed. The heart rate values show specific adaptive variations depending on the duration and intensity of the physical exercise performed. The heart rate is directly proportional and linear with the intensity of the physical exercises. As the intensity of the exercise increases, the heart rate continues to increase until it reaches a plateau. At this point, the individual has apparently reached his maximum level. (Chandler & Brown, 2008) Long-term adaptation, the result of a planned physical effort based on concrete goals, achieved over a period of several years of training, is also reflected at the cardiorespiratory level by relatively stable changes, characterised by bradycardia at rest, low systolic volume at rest, low heart rate at rest and high heart rate during effort, increased heart volume and hypertrophy of the ventricular walls (Drăgan, 1989). These adaptive modifications have a specific character depending on the type of effort in the routine or type of sports practised. In parallel to long-term cardiovascular adaptations, there are short-term adaptive variations. This category includes the variations recorded during a workout, but also those characteristic of different training stages in the annual training plan.

Another method commonly used in the athletes' training, in order to determine the adaptive metabolic changes resulting from effort is the measurement of the lactate concentration in the capillary blood. Lactic acid results from the enzyme chain reaction of glucose degradation (lactose anaerobic glycolysis) to produce energy in case of high intensity physical efforts. After exhausting efforts, the intramuscular lactate concentration may exceed 25 mmol/kg, while the lactic acid concentration in the blood is 20 mmol/l. In the case of an increased lactate concentration, an extreme acidosis occurs, the intramuscular pH may decrease to 6.4 and the arterial pH reaches 6.8 (Drăgan, 2002) The values of the lactate concentration measured in different stages of effort and correlated with the recorded heart rate values, allow the assessment of the level of adaptation to effort and ensure the correct daily dosing of the training plans. Thus, the determination of lactate concentration has become an essential method in the athletes' training. By measuring lactic acid, it is possible to determine exactly the methods and the intensity of the workout (Janssen, 2001). Therefore, the evaluation of the effort-induced lactate concentration in blood in conjunction with FC oxygen uptake (VO_2) and training volume are often part of the usual physiological evaluations of high-performance athletes. There are three main reasons for making these determinations: they serve as indicators of the level of adaptation to effort, are correlated with endurance performances and can indicate the optimal training stimuli (Gore, 2000).

There is a clear practical need for dividing up the training intensity continuum into zones. These zones should be anchored in identifiable physiological markers if they are to be meaningful in interpreting the impact of training organization (Esteve-Lanao et al., 2007). At present, in the practice of the athletes' training, there are different effort classification schemes in a various number of "effort zones". The biochemistry laboratory at the National Institute for Sports Research classifies effort depending on the values of the heart rate (HR) and the concentration of lactic acid (LA) in the following zones:

1. Oxygen zone (O₂), with HR = 130 +/- 5b/min and lactic acid concentration of 0-1.5 mmol/l.
2. Stable oxygen zone (O₂S), with HR = 150 +/- 10b/min and lactic acid concentration of 2-3.5 mmol/l.
3. Relative oxygen zone (OR) with HR = 160 +/- 10b/min and lactic acid concentration of 3-5 mmol/l.
4. Lactate – oxygen zone 2 (O₂ LA2) or maximum oxygen uptake zone with HR = 170 +/- 5b/min and lactic acid concentration of 5-12 mmol/l.
5. Lactate – oxygen zone 1 (O₂ LA1) with HR = 180 +/- 5b/min and lactic acid concentration of 12-18 mmol/l.
6. Lactate – oxygen zone (LA O₂), with HR = 190 +/- 5b/min and lactic acid concentration of 18 mmol/l. (Tocitu, 2000)

3. Research Questions

How can the specialists determine the individual metabolic and cardiorespiratory demands, induced by the specific effort made during a complete exercise on pommel horse?

4. Purpose of the Study

The objectives of research are:

- Optimisation of the individual training plans for specific endurance on pommel horse.
- Correlation of the individual training programme for specific endurance training with the metabolic and cardiovascular demands characteristic of the apparatus and with the individual adaptive particularities.

5. Research Methods

5.1. Research method

The research method used for this research was the case study.

5.2. Subjects of research

The study was conducted on a number of six elite gymnasts (S1-S6), aged between 24 and 27 years old. The research was conducted at the request of the coach and with the individual consent of each athlete. The tests were carried out in the gym during a specific workout.

5.3. Parameters measured

In this study, we measured and correlated the values of two parameters, heart rate and lactic acid concentration in the capillary blood.

5.4. Tools used

Polar Team 2 is a system especially designed to measure heart rate during training effort, simultaneously for several athletes. The equipment provides the opportunity to record, store and review the data, both in real time and after the end of the workout.

For the evaluation of lactate concentration in blood, the Lactate Pro 2 Analyser was used (Figure 01). This tool has the advantage of providing quickly, in approximately 15 seconds, the values of the lactate concentration from a small amount of blood from capillary blood samples collected (0.3 μ l) (*Lactate Pro 2 Portable Blood Lactate Analyser*, 2015).



Figure 01. Lactate Pro 2 Analyser

5.5. Presentation of the testing conditions

The demarcation of the characteristics of the specific effort was obtained by measuring the heart rate parameters and lactic acid concentration in three phases of the training:

1. In basal conditions, before the athletes start the warm-up effort, the value of the heart rate and the lactic acid concentration in capillary blood were measured (T1).
2. During a specific effort, while each athlete performed a complete exercise on pommel horse, the heart rate was measured.
3. In a 3-minute time interval, after performing the complete exercise, the heart rate and the lactic acid concentration in capillary blood were measured (T2).

The specific effort was represented by the performance of a complete exercise on pommel horse in similar competitive conditions (Table 01). The evaluation of each athlete was carried out by the coach specialised in this apparatus, according to the *Code of Points* (FIG, 2017), by giving marks for the difficulty of the complete exercise (D) and marks for the accuracy of the execution (E). The difficulty of execution (D) of each individual exercise was D = 6.3 for the athlete S1, D = 6.5 for the athlete S2, D = 5.7 for the athlete S3, D = 5.6 for the athlete S4, D = 5.4 for the athlete S5 and D = 5.4 for the athlete S6. The volume of specific effort (Vef.), measured in seconds, ranged between 36 seconds and 47 seconds. The shortest duration of execution Vef. = 36 sec. was recorded by the athlete S6. The athletes S4 and S5

recorded a volume of 37 sec., the athlete S3 recorded 38 sec. The exercises with the longest duration were those which also had the highest mark for difficulty, namely Vef. = 45 sec. for the athlete S1 and Vef. = 47 sec. for the athlete S2. For the level of execution of the complete exercise, the athletes subject to evaluation received marks between 7.133 and 7.966. The Final Score (F.S.) of an exercise was established by the addition of the “D” and final “E” scores.

Table 01. Characteristics of a complete exercise on pommel horse

Subject	Characteristics of a complete exercise			
	D	E	F.S.	Vef. (sec.)
S1	6.3	7.866	14.166	45
S2	6.5	7.966	14.166	47
S3	5.7	7.733	13,433	38
S4	5.6	7.391	12.991	37
S5	5.4	7.166	12.566	37
S6	5.4	7.133	12.566	36

6. Findings

6.1. Results and discussion

The individual results recorded by each athlete, HR in basal conditions, average HR during the specific effort, maximum HR during the effort and the lactate concentration recorded 3 minutes after the completion of the exercise are presented in Table 02. By correlating the maximum HR values with those of the lactate concentration, the effort zone in which each athlete was included was determined.

Table 02. Values of parameters measured

Subject	Parameters measured				Effort zone
	HR basal b/min	HR max. in effort b/min	Lactate concentration (T1) mmol/l	Lactate concentration (T2) mmol/l	
S1	72	172	0	6.7	Oxygen–lactate 2 (O ₂ LA1)
S2	66	180	0.5	10.3	Oxygen–lactate 2 (O ₂ LA1)
S3	60	167	0	7.9	Oxygen–lactate 2 (O ₂ LA1)
S4	64	162	1	8.5	Oxygen–lactate 2 (O ₂ LA1)
S5	70	172	0.5	10.5	Oxygen–lactate 2 (O ₂ LA1)
S6	58	169	0	8.3	Oxygen–lactate 2 (O ₂ LA1)

The recorded results show that the performance of a complete exercise, of (D) difficulty higher than 5.4 on pommel horse determines physiological demands which allow us to include the specific effort in the oxygen-lactate zone 2 (O₂ LA2), or the maximum oxygen uptake zone. This zone comprises the efforts in which the heart rate has values of 170 +/- 5b/min and lactic acid concentration of 5-12 mmol/l. We consider that in competitive condition, because of the high specific stress, the values of the measured parameters (HR and lactate concentration) can be higher than those recorded in the gym. As a result, we consider that that the specific physiological demands of the performance of a complete exercise on pommel horse, in competitive conditions, range within the limit between the maximum oxygen uptake zone and lactate tolerance zone. Considering these aspects, it is necessary that the training plans of high-

performance gymnasts contain programmes for training of specific endurance in which the athletes are engaged in effort of over 12 mmol/l lactic acid (lactate threshold). The working percentage in this area should be between 2 and 4% of the total working volume in a training year. In addition, the specific efforts in the lactate threshold and the proper training of anaerobic effort zones, called stable oxygen and aerobic/anaerobic threshold. The training of these zones is important to ensure an increased post-effort recovery capacity zone.

Regarding the individual particularities of adaptation to effort (Figures 02 and 03), we notice that only one athlete, the athlete S2, shows a high heart rate value, HR = 180b/min, which indicates a low level of cardiovascular adaptation to effort. All the other athletes obtained an optimal correlation between the HR values and the lactate concentration values, characteristic of the oxygen – lactate 2 zone.

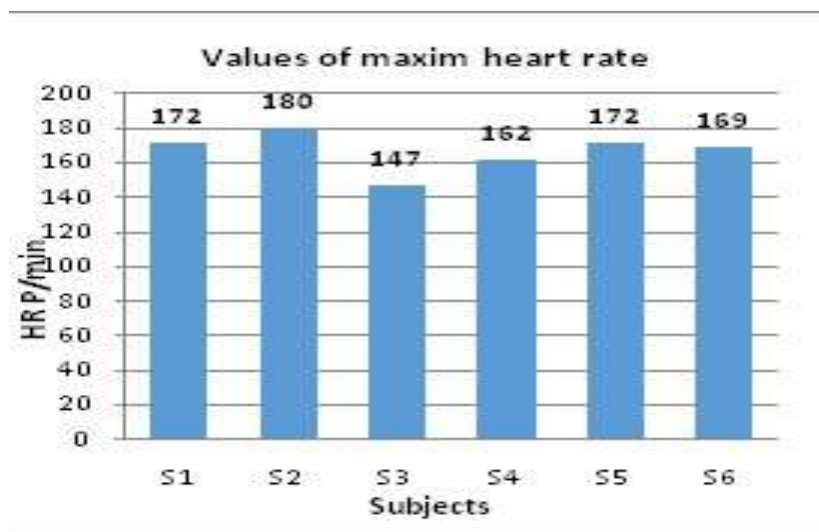


Figure 02. Values of maximum heart rate

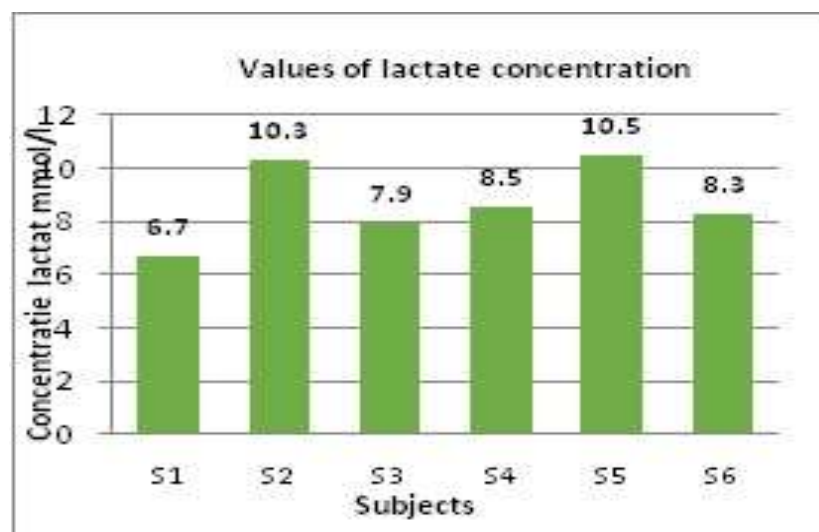


Figure 03. Values of lactate concentration

7. Conclusion

Correlating the values of the parameters measured in this study with the values that define the effort zones established by the biochemistry laboratory at the National Institute for Sports Research, we find that the specific effort on the pommel horse with is in maximum oxygen uptake zone (O_2 LA2), with $HR = 170 \pm 5$ min and lactic acid concentration of 5-12 mmol/l. This information is needed by coaches to effectively plan the training for specific effort.

The correct dosing of the effort according to the training phase and the individual level of adaptation to the specific effort of the training phase cannot be achieved without the knowledge of the following elements:

1. Metabolic demands specific to the competitive routine
2. Basic energy mechanisms that provide specific energy
3. Metabolic products resulting from the specific effort
4. Appropriate methods and means for post-effort recovery
5. Individual level of training of specific endurance in relation to the demands of the routine

The answers to these questions provide the coaches with valuable information for an effective training periodicity and for creating training programmes tailored to the specific demands of the routine and the individual needs (frequency of endurance training in weekly training plans, of training means, duration and intensity of effort, duration and nature of breaks between repetitions, but also important criteria for establishing the recovery, medication and nutrition programmes). In order to determine the metabolic response characteristic of the specific effort of the routine, the following factors should be considered: the complexity and difficulty of the effort, its intensity, duration and the individual characteristics of each athlete. Although the measurement tools for physiological parameters are now available to every team of coaches, their use in competitions is difficult or impossible due to specific competition equipment or regulations. A solution is to determine these indicators in training verification events or in various friendly competitions.

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