



Behavior of physiological variables in synchronized swimming athletes during a training session preparing for the Athens 2004 Olympic Games

Marina Guimarães Antunes Pazikas^{1,2}, Andréa Curi¹ and Marcelo Saldanha Aoki^{2,3}

ABSTRACT

The purpose of this study was to evaluate the behavior of physiological variables during a synchronized swimming training session performed in athletes preparing for the Athens 2004 Olympic Games. **Materials and methods:** The sampling used was constituted by the duet (24 ± 0 years) who was representing Brazil in the Athens 2004 Olympic Games. Data collection was performed during a 198 minute training session. The training started with the physical portion, followed by the technical portion. In order to determine the glycemia and the β-hydroxybutyrate, it was used an Optium® monitor with its respective stripes. The cortisol and the dehydrogenase lactate enzymes (LDH), concentrations, as well as the kinase creatine (KC) concentration were determined through the radioimmunoassay (RIA[®]) and through commercially available kits (CELM[®]), respectively. The follow-up of the heart rate (HR) was performed using an Advantage Polar® heart rate monitor. **Results:** It was noted a reduction (~2%) in the body weight. The glycemia also presented a fall (~30%) compared to the value attained in the beginning of the training session. Otherwise, it was observed an elevation in the cortisol concentration (salivary, 22%, and plasmatic, 29%) and in the β-hydroxybutyrate (~340%). No significant changes in the plasmatic concentration of the KC and LDH were observed. The follow-up of the HR showed that from all 198 minutes of the training session, 36.5 ± 0.7 minutes were performed at a light intensity; 103.5 ± 0.7 minutes at a moderate intensity, 54.0 ± 2.1 minutes at a high intensity, and 4.0 ± 0.0 minutes at a very high intensity. **Conclusions:** The weight loss indicates that the hydric reposition was not adequate. The reduction in the glycemia and the increase in the ketonic bodies and cortisol concentrations reinforce the importance of a carbohydrate supplement during the long endurance training. The HR behavior shows that the training session was performed at a moderate intensity, but having fast moments of high intensity, in which routines were performed.

INTRODUCTION

The synchronized swimming was firstly presented in the 1951 Panamerican Games, and it has been admitted as integrant sports in 1955. Since 1952, the modality was shown several times in the Olympic Games, but the synchronized swimming was officially integrated to the Olympic Games program⁽¹⁾ only in 1984. Initially, the competition was composed by the accomplishment of mandatory

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figures and free routines. As the sport evolved, the competition was divided in two steps: technical and free routines. The technical routine is composed by mandatory elements stipulated by the International Swimming Federation (FINA)⁽¹⁾. As the own name suggests, the free routine is based on each team's creativity⁽¹⁾.

Routines, also called choreography, are performed within a given time stipulated by FINA for each type of presentation: solo, duet or team, and they may vary from at least 2 minutes up to a 5 minutes maximum, depending on the type of the choreography and on the athlete's age⁽¹⁾.

Gemma and Wells⁽²⁾ described the synchronized swimming as a gymnastic, ballet and dance mix containing elements of the artistic skating. Figura and co-workers⁽³⁾ defined the synchronized swimming as a combination of swimming and rhythmic gymnastic associated to the music.

Under a physiological perspective, this sports poses unique challenges. The majority of its movements is performed having the face submersed into the water and in apnea^(2,3). Furthermore, Gemma and Wells⁽²⁾ pointed out that the synchronized swimming is composed by technical performances that demand power and resistance, but performed with elegance and style.

According to them, for this to happen, athletes must completely master the swimming skills, as well as to have a complete breathing control, time accuracy, motor coordination, and muscular power^(2,4).

In the synchronized swimming, athletes must also handle opposite forces, such as the gravity and the drag force exerted by the water. During the accomplishment of the routines, there are moments of symmetrical and stable back or frontal fluctuation. As the athlete moves her body, the drag force is enlarged by the asymmetric movements demanded by each specific part of the routine⁽³⁾. All these challenges show the complexity and difficulty of such sports.

Some studies available in the literature evaluated the behavior of the physiological variables in the synchronized swimming. Gemma and Wells⁽²⁾, as well as Figura and co-workers⁽³⁾ followed the physiological responses during the execution of the mandatory figures. More recently, Yamamura and co-workers⁽⁵⁾ reported the blood lactate behavior during the execution of the free and technical routines.

In this report, it was evaluated the physiological parameters during a whole synchronized swimming training session. The follow-up of such parameters along the whole training session will supply valuable information for technicians, physical coaches, nutritionists and physiologists, and they may use such information with the purpose to improve specific strategies to improve the athlete's performance.

Therefore, the purpose of this study was to evaluate the behavior of the physiological variables (weight, glycemia, ketonic body concentration, cortisol concentration in the saliva and in the plas-

1. Paineiras do Morumby Club, SP, Brazil.

2. Physiology of the Exercise Laboratory, College of Physical Education, UniFMU – SP, Brazil.

3. Institute of Biomedical Sciences, São Paulo University, SP, Brazil.

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Correspondence to: Prof. Dr. Marcelo Saldanha Aoki, College of Physical Education – Building No. 20 – UniFMU, Physiology of the Exercise Laboratory, Rua Galvão Bueno, 707, Liberdade – 01506-000 – São Paulo, SP, Brazil. E-mail: saldanha@fmu.br

ma, kinase creatine concentration in the plasma, dehydrogenase lactate concentration in the plasma, and heart rate profile) during a training session performed while preparing athletes to the Athens 204 Olympic Games.

MATERIALS AND METHODS

Sampling

The sampling was composed by the duet (two 24 years old, 179 cm, 63.3 ± 0.8 kg women) who was representing Brazil in the Athens 2004 Olympic Games. Following specific resolutions stipulated by the National Health Council (No. 196/96), participants received detailed information on the procedures adopted, and they agreed in voluntarily participate in the study signing an informed consent and privacy protection term. The participants were instructed to consume a standard menu⁽⁶⁾, and to follow a controlled 24 hours timetable before the blood collection.

Description of the training session

During the preparation phase to the Athens 2004 Olympic Games, more precisely in the three previous months to the competition, the data collection of a whole training session was performed. That training session had the controlled time of 198 minutes. The temperature of the water was kept constant between 27-29°C. The training session started with a physical portion followed by the technical portion, and both are detailed below.

– Physical portion:

It was performed a quick stretching (15 minutes) followed by 45 minutes of weighted-exercises in the water (accomplishment of parts of the choreography and basic positions).

– Technical portion:

The technical portion was initially subdivided in a 45 minutes performance containing mandatory elements (1. vertical, half spin followed by a twirl in the opposite direction, ending in a descending spin; 2. boost: a rapid head-first rise having two arms outside the water; 3. arm sequence using eggbeater kick with the two arms outside the water; 4. travelling ballet leg combination with the following surface positions: ballet leg, ballet leg double, flamingo; 5. thrust by a twirl; 6. ariana; 7. bent knee vertical position followed by a combined spin with the bent knee extending to meet the vertical leg on the descent and bending to resume a bent knee vertical position on the ascent; 8. rocket split followed by a 360 grades spin). Next, it was performed the routine training that lasted approximately 90 minutes. At that moment, it was emphasized the cleanness of the choreography in executing the segmented of the choreography, in order to adjust the movements' synchronism and the angles of the performance, and finally executing the whole routine.

Determining the concentration of the plasmatic glycosis

To determine the glycemia, an Optium® monitor with its stripes was used, according to its usage instruction. The concentration of the glycosis in the plasma (mmol.L⁻¹) was determined through bio-amprometry, in which the glycosis through the dehydrogenase glycosis is transformed in glycolactone. The glycemia was measured before and after the training.

Determining the plasma concentration of the creatine and dehydrogenase lactate

The plasma sampling was collected before and after the training. To perform the enzymatic determination, the commercially available kits (CELM®) for the dehydrogenase Lactate (LDH), and the kinase creatine (KC) (U.L⁻¹) was used.

Determining the plasmatic concentration of the β-hydroxybutyrate

In order to determine the β-hydroxybutyrate (mmol.L⁻¹) concentration, it was also used the Optium® monitor with its stripes.

Determining the cortisol concentration in the plasma and saliva

After one hour fast, the blood and the saliva were collected at 8:15 am, before the training session began. In order to characterize the resting situation, the athletes remained seat for fifteen minutes before the initial collection.

Right after ending the training session, the collection procedure was repeated. In order to collect the saliva, the oral cavity was previously cleaned with filtered water. The saliva sampling was centrifuged for five minutes at 2000 rpm, and the overflowing was separated and stored at -20°C to later determine the cortisol content. The collected blood was conditioned in -20°C heparinized tubes to later determine the cortisol concentration in the plasma.

In order to evaluate the cortisol concentration, the COAT-A-COUNT®, DPC radioimmunoassay kits were used. The hormone contents were determined at the USP Biomedical Sciences Institute.

Description of the heart rate behavior

The follow-up of the heart rate was performed through the Polar Accurex Plus (Interface Polar Plus®/software version 1.02®) with five second recording intervals. Athletes were monitored while performing a 198 minute training session. The classification criterion for the HR used in this study was proposed by the ACSM⁽⁷⁾. Such classification is based on six categories:

Intensity	%HR _{max}
Very light	Light below 35%
Light	Between 35 and 54%
Moderate	Between 55 and 69%
High	Between 70 and 89%
Very high	Equal or above 90%
Maximal	100%

The foreseen HR_{max} for that age level is 196 beating per minute. In order to evaluate the behavior of the heart rate, the null records in the monitor were not taken into account.

Records which were lower than the basal heart rate found in the evaluations, as well as the serial values that were continuing repeated in the records, and that seemed to indicate any kind of failure in the recording device, or even sequences of values that showed quite distant decreasing recording intervals adopted (5 seconds) were also disregarded.

Experimental procedure

In the previous day to the trial, athletes kept their normal training and feeding routine. At the day of the trial, athletes consumed ~60 grams of low to moderate glycemic-index carbohydrate, 60 minutes before the initial data collection. During the training, the water consumption was *ad libitum*. The mean water consumption was of 430 ± 40 mL. The initial collection was performed at 8:15 am. The training session began immediately after the collection, and it lasted 198 minutes. During the training, it was performed the (technical and free) routines presented in the Athens 2004 Olympic Games. Upon ending the training, it was performed the final collection.

RESULTS

Through the follow-up of the HR, it was possible to verify that from the 198 minutes training session, 36.5 ± 0.7 minutes were performed at light intensity (35-54% of the HR_{max}); 103.5 ± 0.7 minutes at moderate intensity (between 55-69% of the HR_{max}), and 54.0 ± 2.1 minutes at high intensity (70-89% of the HR_{max}), and 4.0 ± 0.0 minutes at very high intensity (≥ 90% of the HR_{max}) (table 1). Also, it was evaluated the behavior of the heart rate dur-

ing the (technical and free) routines presented in the Athens 2004 Olympic Games. The intensity in which the routines were performed was classified high (70-89% of the HR_{max}) (tables 2 and 3).

TABLE 1
Distribution of the training time at different intensities related to the maximal heart rate

Intensity	Times of the training (min)
Light (35-54% HR _{max})	36.5 ± 0.7
Moderate (55-69% HR _{max})	103.5 ± 0.7
High (70-89% HR _{max})	54.0 ± 2.1
Very high (≥ 90% HR _{max})	4.0 ± 0.0

Results expressed in mean and standard deviation values.

TABLE 2
Behavior of the heart rate during the technical routine presented in the Athens 2004 Olympic Games

Intensity	Time (min)	HR (bpm)
Light	0:00	90.0 ± 1.4
High	0:15	161.5 ± 0.7
High	0:30	161.5 ± 0.7
High	0:45	165.5 ± 6.4
High	1:00	166.5 ± 0.7
High	1:15	158.0 ± 7.1
High	1:30	160.0 ± 5.7
High	1:45	169.0 ± 5.7
Very high	2:00	177.5 ± 3.5
Very high	2:15	178.0 ± 4.2
High	2:30	169.0 ± 8.5

Results expressed in mean and standard deviation values.

TABLE 3
Behavior of the heart rate during the free routine presented in the Athens 2004 Olympic Games

Intensity	Time (min)	HR (bpm)
Moderate	0:00	120.0 ± 5.7
High	0:15	156.5 ± 0.7
High	0:30	159.5 ± 4.9
High	0:45	158.0 ± 2.8
High	1:00	170.5 ± 3.5
High	1:15	160.0 ± 8.5
Very high	1:30	179.5 ± 4.9
High	1:45	166.0 ± 0.0
High	2:00	166.5 ± 9.2
Very high	2:15	178.0 ± 5.7
High	2:30	164.0 ± 7.1
High	2:45	165.0 ± 2.8
High	3:00	162.5 ± 4.9
High	3:15	162.0 ± 2.8
High	3:30	149.5 ± 0.7

Results expressed in mean and standard deviation values.

It was observed a reduction (~2%) in the body weight (1.3 ± 0.2 kg). The glycemia also presented a fall (30%) compared to the value attained at the beginning of the training (4.8 ± 0.3 x 3.4 ± 0.4 mmol.L⁻¹).

TABLE 4
Evaluation of the body weight, glycemia, β-hydroxybutyrate, cortisol, KC and LDH concentrations at the beginning and end of the training session

Parameter evaluated	Beginning	End
Body weight (kg)	63.3 ± 0.8	62.0 ± 0.6
Glycemia (mmol.L ⁻¹)	4.8 ± 0.3	3.4 ± 0.4
β-hydroxybutyrate (mmol.L ⁻¹)	0.14 ± 0.05	0.48 ± 0.1
Salivary cortisol (nmol.L ⁻¹)	15.2 ± 3.8	18.6 ± 4.5
Plasmatic cortisol (nmol.L ⁻¹)	381.2 ± 57.7	491.6 ± 72.3
KC (U.L ⁻¹)	179.5 ± 40.4	185.3 ± 47.2
LDH (U.L ⁻¹)	210 ± 38.4	205 ± 29.6

Results expressed in mean and standard deviation values.

Parallel to the fall in the glycemia, it was noted a 22% and 29% increase in the salivary and plasmatic concentrations, respectively. At the end of the training session, the kinase creatine dehydrogenase lactate enzymes did not present any alteration in their final value compared to the resting value (table 4).

DISCUSSION

The heart rate (HR) is the parameter used to determine the exercise intensity⁽⁸⁾. Nevertheless, using the HR as an intensity indicator to aquatic sports has some limitations. The body immersion increases the pressure on its lowest portion, thus facilitating the venous feedback. Such optimization in the venous feedback reduces the overload on the cardiovascular system.

Furthermore, the immersion of the face into the water promotes a bradycardiac response associated to a higher vagal tonus^(9,10). According to Takamoto and Mutoh⁽¹¹⁾, such physiological response makes difficulty to use the HR as an accurate parameter to synchronized swimming intensity. Al-Ani and co-worker⁽¹²⁾ observed that the immersion of the face has promoted a significant reduction in the HR (-21 in women, and 19 ± 2 bpm in men). Nevertheless, whenever the immersion was associated to the physical strength, it was noted a mild elevation in the HR (+9 ± 3 bpm in women, and 11 ± 3 bpm in men)⁽¹²⁾.

Therefore, the bradycardia induced through the immersion seems to be attenuated by the physical strength⁽¹²⁾.

Anyhow, upon analyzing the results related to the HR monitoring, it is important to consider the possibility that the intensity of the activity may be underestimated. According to Yamamura and co-workers⁽⁵⁾, another possible approach to determine the intensity of the routines would be to trace the behavior of the blood lactate.

Despite such limitations, the evaluation of the HR behavior in the (free and technical) routines suggests that the performance intensity of these routines may be considered high. Upon the observation of the HR behavior during the whole training, it is possible to assert that in the major part of the training, the HR was kept at a moderate intensity interval. During every training session, it is performed several intervals, in which the athletes stay aside the swimming pool, in order to receive technical instructions and corrections. This characterizes the training session as an intermittent activity, in which there are high intensity moments as in the routines, but having several pauses in order to receive instructions.

Researches have shown that the high intensity exercise especially in activities involving eccentric contractions are frequently associated to muscular lesions^(13,14). In order to check the stress imposed by the training on the skeletal muscle, the plasmatic concentration of the KC and LDH enzymes was determined. It was detected no differences in the concentration of those enzymes after the training session. Nevertheless, it is important to point out the existence of an adaptation that seems to minimize the elevation of such muscular lesion markers in highly trained individuals. It was already reported that the elevation of the KC enzyme in the athletes' plasma is lower than in sedentary individuals submitted to the same activity^(15,16).

Furthermore, the concentration of such enzymes (KC and LDH) not always reflects the level of the muscular lesion⁽¹⁴⁾. So, the absence of alterations in the concentration of the lesion markers does not assure that the muscle has not been stressed during the training.

Among the main limiting factors of the prolonged exercise, it can be pointed out: reduction of the glycemia, commitment of the carbohydrate and dehydration endogen stocks⁽¹⁷⁾. Despite the training is performed in aquatic medium, in which the loss of heat due to the convection is quite efficient, it was observed a considerable hydric loss (~2% of the body weight) by part of athletes.

During the prolonged exercise, the muscular glycogen and the blood glycosis are important energetic substrates. The exercise is a powerful stimulus to the transportation of the glycosis, draining it from the blood to the muscle⁽¹⁸⁾. The consequence of this in the long endurance exercise will be a reduction in the glycemia. In the present study, it was observed a remarkable decrease (~30%) in the concentration of the glycosis after 198 minute of the training session.

The blood glycosis is the main energetic substrate to the nervous system. This way, the glycemia maintenance during the exercise is an important challenge to the homeostasis. As consequence, when the glyceimic homeostasis is changed, several physiological mechanisms begin, such as releasing of the counter regulating hormones (glucagon, catecholamines, GH and cortisol).

The effects in the concentration of the glycocorticoids while performing exercises have been focused in several studies for more than forty years⁽¹⁹⁾. Through these studies, it is known that the secretion of the cortisol depends on the exercise's intensity and endurance^(20,21). It has been well established that the elevation in the cortisol concentration induced by the exercise is associated to the immunosuppression as well^(22,23).

Nevertheless, the physiological role of the cortisol during the exercise in humans is not well known⁽²⁴⁾. In the resting, the cortisol exerts several important functions to the energetic homeostasis maintenance, such as: increase in the production of the glycosis; increase in the synthesis of the enzymes involved in the hepatic glycogenesis, proteolysis (aiming to perform the anaplerosis of the Krebs cycle and the glycogenesis); lipolysis; ketogenesis and reduction in the insulin-mediated glycosis absorption, thus assuring the glycosis offering in the nervous system⁽²⁵⁻³¹⁾.

Therefore, it would be feasible that while performing long endurance exercising, this hormone also exerts a relevant role mainly related to the availability of the substrate. In fact, this could be observed in the present study. The significant elevation in the (salivary and plasmatic) cortisol concentration opposed to the fall in the glycemia levels reinforces its importance in the energetic metabolism modulation during prolonged exercises.

It is worthwhile to remember that the training initiated approximately at 8 am, two hours after the athletes woke up. As the peak value of the cortisol has relationship with the awakening, this would explain the high cortisol concentration before the beginning of the training. In resting conditions, the concentrations in the cortisol presented a reduction trend after attaining its peak value. However, even though, after the 198 minute training, it was noted an increase in the concentration of such hormone both in the saliva and in the plasma.

This increasing cortisol was also associated to the increase in the β -hydroxybutyrate. In those situations where the glycosis offering is reduced, the partial degradation of the free fatty acid lead to the formation of ketonic bodies (acetoacetate, β -hydroxybutyrate, and acetone)⁽³²⁾.

These compounds reduce the usage of the glycosis, attenuate the proteolysis, acting also as an alternative substrate to the nervous system⁽³²⁾.

Similar to other researches^(26,31), the results found in this study suggest a positive relationship between the concentration of the cortisol and the β -hydroxybutyrate.

According to what was previously shown, the ketose suppresses the generation of oxygen-reactive specimens in the human neutrophils, probably through the inhibition of the NADPH-oxidase⁽³³⁾. These results indicate that the antimicrobial inhibition exerted by the neutrophils can be related to a higher athletes' susceptibility to infections, once both the cortisol and the ketonic bodies have their respective concentrations elevated after an extenuating exercising. Confirming such hypothesis, Fukatsu and co-workers (1996) observed that the endurance exercise (50 miles racing) damages the neutrophils' function⁽³⁴⁾. According to these authors,

such inhibition is consequence of the cortisol and ketonic bodies increase⁽³⁴⁾.

Other studies reinforce the idea that the immunosuppression observed in athletes submitted to extenuating training is related to an increase in the cortisol concentration^(35,36). Also, there is strong evidences that the consumption of carbohydrates during exercising can attenuate the increase in the cortisol, and the consequent immunosuppression^(6,35-37). These scientific evidences show the importance of the neuroendocrine modulation on the immunological system during extenuating exercising.

FINAL CONSIDERATIONS

The behavior of the HR shows that the training was performed at moderate intensity (aerobic predominance), but having brief moments at high intensity. It is worthwhile to mention that during the accomplishment of the (free and technical) routines, the heart rate remained at a high intensity interval, indicating a major participation of the glycolytic system.

The weight loss observed during the training indicates the need of a hydric reposition strategy during the training, once a 2% hydric loss in the body weight can compromise the performance. The reduction in the glycemia reinforces the importance of a supplementary carbohydrate ingestion during the long endurance exercising. Based on these data, it is suggested the ingestion of a carbohydrate solution during the training, in order to keep the glycemia and the hydric balance.

Therefore, it can be concluded through these data that the synchronized swimming training session, despite of being of moderate intensity, changes important physiological variables that maintain the homeostasis, such as the glycemia and hydric balance, probably due to its long endurance. These changes affect the endocrine parameter, as the concentration of counter regulator hormones, such as cortisol. By its turn, this last one is an important indicator of the level of the stress imposed by the exercising, and it is further able to modulate the activity of the immunological system.

The information found in this study on the physiological changes induced by a whole synchronized swimming training session are extremely valuable in order to better understand such sports. This information may help technicians, physical coaches, nutritionists, and physiologists to elaborate the strategies to attenuate the limiting factors of the activity, thus promoting a better performance. Nevertheless, it is necessary to perform further studies in order to characterize the physiological profile of this fascinating sport, mainly in different moments of the periodization of the training.

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