THE RESPONSE TO THE TRAINING LOAD IN THE AQUATIC ENVIRONMENT IN TERMS OF THE STIMULATION OF THE REFLECTIVE CAPABILITIES OF ELITE SYNCHRONIZED SWIMMERS

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Summary: The youngest swimming sport included in the Summer Olympic Games since 1984 is synchronized swimming. Since the synchronized swimming is still growing popularity and professionalization, it is important to search for ways to improve sports performance. There are few scientific studies focusing also on the biological and motor indicators of top athletes. The present study examined biological and motor variables of elite synchronized swimmers (SYN, N = 13) in ages of 16.5 ± 3.23 years and compare the frequency of Angiotensin Converting Enzyme (ACE) gene genotypes among elite female synchronized swimmers and the non-athletic control group (CON, N = 30) in ages of 16.0 ± 0.6 years. The motor variables were measured using Optojump system before and after water training session. All measurements were collected by trained data collection staff. The ACE I/D variation differences between groups were identified by Chi-Square test. The results of motor variables obtained were evaluated statistically using the Wilcoxon Signed-Rank Test. The strength of association between selected biological and motor variables was measured by Spearman's correlation. We provided evidence for significant differences of variation of the ACE I/D polymorphism between observed groups. A significant correlation among biological and motor parameters of SYN was demonstrated among the percentage of fat and the time of reflection ($p = 0.042$), the basal resting heart rate and the jump height ($p = 0.006$) and among the basal resting heart rate and the power ($p = 0.012$). The SYN significantly increased only their contact time in jumping ($p < 0.016$) after the training session. Based on the results we state that the effect of intervention in the stimulation of the reflective capabilities due to the training session in the aquatic environment was not confirmed in the study.

Key words: aquatic environment, training load, synchronized swimming, anthropometric characteristics, jump

Introduction

The youngest swimming sport included in the Summer Olympic Games since 1984 is synchronized swimming. Nowadays, the Olympic Games competitions in the discipline duet (two competitors) and discipline team events (eight competitors) (FINA 2017). Synchronized swimming according to the type of sports performance belongs to technical-aesthetic sports. Sport performance combines power, speed and endurance with precise synchronized movements and acrobatic movements (Ghiani et al. 2016). The aim of the athletic performance is accurate execution of conditioning-coordination movement-demanding movement with flawless technique. The athlete's effort is to perform a specific movement task as rationally as possible (Labudová 2011). Sports performance in synchronized swimming is realized in the water environment, therefore respecting and using its specific water laws is one of the basic prerequisites for the success of athletes. Homma (1994) states that almost half of the total duration of the competition routine for athletes is in dynamic apnea. The growing popularity and professionalization of synchronized swimming emphasize the importance of searching for ways to improve sports performance. There are few scientific studies focusing also on the biological and motor indicators of top athletes (Homma et al. 1999; Chatard et al. 1999; Yamamura et al. 1999, 2000; Alentejano et al. 2010; Rodriguez-Zamora et al. 2014). Systematic review of physiological parameters of athletes in the age category of juniors and seniors in the years 2006 to 2016 presented Ponciano et al. (2018). The protocols used analyses of physiological responses in synchronized swimmers during competitions or laboratory tests, lactate measurements, heart rate, rates of perceived exertion, VO_2 and lung volume. The authors recommend to carry out more measurements of physiological parameters in the conditions of competition. It can contribute to the expansion of knowledge about the conditionality of sport performance by the monitored parameters. They also attend to focus on men who have been competing in the World Championships in mixed duet since 2015. Several studies examined anthropometric parameters of top synchronized swimmers as body composition Poole et al (1981), Kirkendall et al. (1982), Moffat et al. (1982), Evans et al. (1985), Petkov et al. (1988), Labudová (2011), metabolism and nutrition D'alessandro et al. 2016 and Ghiani et al. (2016). Besides the training and nutrition, the genetic factors influence mostly the variance between individual athletes (Grznár et al. 2017).

Nowadays, more than 200 genetic variants are associated with physical performance (Eynon et al. 2011). The first described genetic polymorphism affecting sports performance was *ACE* gene polymorphism (Montgomery et al. 1998). Angiotensin Converting Enzyme (ACE) is a crucial part in Renin Angiotensin System and plays a central role in the regulation

of blood pressure. It maintains the circulatory homeostasis. *ACE* gene polymorphism is located in the intron 16 and consists of either an insertion (I) allele or a deletion (D) allele leading to three genotypes: II, ID and DD. The I allele leads to lower ACE activity in serum and tissue. It is associated with a higher proportion of slow type I muscle fibers, higher efficiency of aerobic performance, better fatigue resistance, higher oxygenation of peripheral fibers during activity and more pronounced aerobic response to training (Shenoy et al. 2010). The D allele is associated with a higher percentage of fast muscle fibers type II b, which are essential for maximum strength performance in a short time (Zhang et al. 2003). In general, the frequency of genotype II is higher in athletes practicing high aerobic activity sports. The DD genotype is more frequent in strength and power athletes (Puthuchear et al. 2011). Several studies deal with the comparison of monitored indicators with athletes related to sports (Zemková et al. 2009; Kyselovičová et al. 2016; Grznár et al. 2017). The area of the content of the training load in the aquatic environment and its response to the stimulation of selected motor abilities, as well as the genetic conditionality of performance in synchronized swimming is still less explored.

The aim of the study is to describe biological and motor variables of elite synchronized swimmers and accurate the knowledge about the response to the training load in the aquatic environment in terms of the stimulation of the reflective capabilities of elite synchronized swimmers.

Methods

Subjects

Thirteen elite female synchronized swimmers (SYN; age 16.54 ± 3.23 years) and thirty age-matching non-athletic control group (CON; age 16.0 ± 0.6 years) participated in the study. All subjects had competed at national and international level and they spent an average $20 \pm 3,4$ hours in training weekly. Additionally, one of them participated on Olympic Games in 2016, six of them had taken part in FINA World Championships and two of them are actually preparing on Qualification Tournament for OG 2021. The study was approved by the Ethics Committee of FPES CU in Bratislava.

Biological variables assessment

Body weight was measured to the nearest 0.1 kg using an electronic digital scale (model Omron BF511). Standing height, was measured to the nearest 0.5 cm. The head, shoulder blades, buttock and heels (without the shoes) were touching the wall, to which the tape was

fixed (NHANES 2007). Body fat was measured by OMRON BF511 bioimpedance analysis. We established body mass index (BMI) before the training session. An integrated telemetric monitor was used for the measurement of baseline resting heart rate. The data were measured in the mornings of the same week, in a controlled environment with constant temperature. Subjects were asked to abstain from physical exercise the day before testing days and encouraged to rest the evening prior. Genomic DNA was extracted from the buccal swabs and standard protocol with Chelex (Bio-Rad). Genotypes were determined using regular PCR with primers: forward, CTGGAGACCACTCCCATCCTTTCT; reverse, GATGTGGCCATCACA TTCGTCAGA. PCR was performed in thermocycler (Biometra) for 30 cycles at denaturing temperature 95°C for 1 min, annealing temperature 58 °C for 45 s and extension temperature 72 °C for 45 s. PCR products were visualized using 2 % agarose gels stained with ethidium bromide. The sizes were 490 bp for I allele and 190 bp for D allele.

Motor variables assessment

The reflective capabilities as vertical jump height [cm] without upper limbs counter-movement, the contact time [s] and the power of the vertical jump [W] was determined by Optojump system. The OptoJump system consists of two optical sensors (each 100 × 4 × 3 cm) based on photocells (transmitting and receiving rods, placed in parallel). The OptoJump system detects time parameters with a frequency of 1 000 Hz and spatial parameters with an accuracy of 1cm. Each rod contains 96 LEDs (a light-emitting diodes), located 3mm from ground level at 1.04 cm intervals between them. The LEDs communicate via infrared transmission. The rods communicate continuously with light emitting diodes (LEDs). The rods acting as transmitting and receiving units for LED signals. Subjects had the task of jumping repeatedly, as high as possible for 10 s, with their hands on their hips. They were asked to have the shortest contact time with the pad and the highest jump during the jump test. The basic information was followed by a test demonstration (Amann et al. 2016). The motor tests were measured two times before and after training session in the same day. All pre- and post-measurements used the same techniques and identical equipment for all subjects.

Training session load in the water

The duration of the training session in the water was 90 min. The total swimming volume was 3 600 m. The swimming part was focused on the development of fitness skills. It accounted for approximately 2/3 of the total training volume (2 600 m). The special part was focused on the development and improvement of special motor abilities and skills of synchronized swimming. It accounted for approximately 1/3 of the total training volume (1 000 m). The training took place in a 50 m pool.

Statistical Analysis

Processing and evaluation of the collected data was completed using basic mathematical and statistical methods. The results obtained were evaluated statistically using the Wilcoxon Signed-Rank Test for dependent variables - to opinion of differences between average in group before and after training session. The Mann-Whitney U Test for independent variables was used to opinion the differences between averages of SYN and CON groups. The ACE I/D variation differences between groups were identified by Chi-Square test. Results are reported as means and standard deviations. Differences at the level of $p < 0.05$ were accepted as significant. Effect size (ES) were calculated and defined as follows: small $r = 0.1- 0.29$, medium $r = 0.3 - 0.49$ large $r = 0.5 - 1$ (Cohen 1992). The strength of association between two variables (selected biological and motor variables) was measured by Spearman's correlation, where the value $r = 1$ meant a perfect positive correlation and the value $r = -1$ meant a perfect negative correlation. The SPSS (version 23.0) statistical software package was used to analyze all data.

Results

Biological variables

As shown in Table 1, the synchronized swimmers showed significantly lower average of body weight, of BMI, of body fat percentage and of resting heart rate variables than CON, that are associated with the structure of sport performance of synchronized swimming.

Table 1
Biological variables of SYN and CON

	SYN	CON	
	Mean $\pm$ SD	Mean $\pm$ SD	P value
Body height [cm]	163.585 $\pm$ 2.931	164.1 $\pm$ 3.921	0.859
Body weight [kg]	53.408 $\pm$ 4.805	60.36 $\pm$ 6.9	0.004*
BMI [kg.m ⁻²]	19.908 $\pm$ 1.441	22.5 $\pm$ 1.2	< 0.001**
Body fat (%)	15.492 $\pm$ 3.157	23.18 $\pm$ 4.91	< 0.001**
Resting heart rate (bpm)	62.154 $\pm$ 10.542	69.25 $\pm$ 6.06	< 0.001**

** $p < 0.001$ between SYN and CON; * $p < 0.05$ between SYN and CON

The frequencies of *ACE* genotype in synchronized swimming group (SYN) as well as control group (CON) met HWE criterion. There were significant differences in genotype frequencies between SYN and CON groups ($p=0.01$) in *ACE* I/D.

Table 2

Group	ACE DD	ID	II	P value
SYN (n=13)	46.1%	15.4 %	38.5%	0.01
CON (n=30)	23.3%	56.7 %	20%	

*p < 0.05 between SYN and CON

Effects of intervention in motor variables

As shown in Table 3, the SYN significantly increased their contact time in jumping ($p < 0.016$, $r = 0.425$) after the training session. Height and power of jumps did not prove significant changes after the training session and show trivial effect size.

Table 3
Changes in motor variables of SYN

Dependent variables	Pre-Test Mean $\pm$ SD	Post-Test Mean $\pm$ SD	P value	ES r
Contact time [s]	0.21 $\pm$ 0.02	0.23 $\pm$ 0.03	0.016*	0.425
Jump height [cm]	21 $\pm$ 3.44	20.58 $\pm$ 3.93	0.959	0.009
Power [W.kg⁻¹]	29.49 $\pm$ 4.77	27.57 $\pm$ 5.09	0.056	0.338

ES – Effect Size; SD - Standard Deviation; *p < 0.05 between Pre-Test and Post-Test;

Based on the results, we state that a significant correlation among biological and motor parameters of SYN was demonstrated between the percentage of fat and time of reflection ($r = 0.571$, $p = 0.042$). The significant correlation was shown also among basal resting heart rate and jump height ($r = 0.718$, $p = 0.006$) and among basal resting heart rate and power ($r = 0.672$, $p = 0.012$). As we stated earlier, other measures of biological and motoric parameters of SYN showed no correlations among themselves (contact time correlating with body height: $r = 0.251$, $p = 0.408$, body weight: $r = 0.167$, $p = 0.585$, basal resting heart rate: $r = 0.163$, $p = 0.595$ and ACE: $r = 0.225$, $p = 0.461$; jump high correlating with body height: $r = 0.226$, $p = 0.459$, body weight: $r = 0.039$, $p = 0.899$, percentage of fat: $r = 0.11$, $p = 0.72$ and ACE: $r = 0.063$, $p = 0.839$; power correlating with body height: $r = 0.109$, $p = 0.723$, body weight: $r = 0.109$, $p = 0.723$, percentage of fat: $r = 0.091$, $p = 0.301$ and ACE: $r = 0.043$, $p = 0.888$).

Discussion

Accessible researches and studies indicated similar outcomes that aesthetic-technical sports prefer athletes who are taller with more body mass (Claessens et al. 1999; Monsma et al. 2005; Alessandra di Cagno et al. 2008; Kyselovičová et al. 2012; Chren 2015; Grznár et al.

2019). These studies correspond with our results, where the synchronized swimmers showed significantly lower selected biologic variables than CON. We state that this fact is associated with the specific requirements of sports performance in synchronized swimming in terms of anthropometric and physiological variables (Evans et al. 1985; Petkov et al. 1988; Ponciano et al. 2017). Our results of SYN anthropometry parameters of body height, body weight and body are identical with previous studies (Homma et al. 1994; Yamamura et al. 2000; Peric et al. 2012; Rodriguez-Zamora et al. 2012). Moreover, authors investigated the possible link between levels of body fat and hydrostatic properties of synchronized swimmers because better buoyancy in the water can have positive influence on movements on and under the surface (Lundy 2011). In comparison to the findings of several studies we conclude that the physiological parameter - the basal resting heart rate, which indicates the adaptation to the training load, have the Slovak elite synchronized swimmers (62.15 ± 10.5 bpm) comparable values with foreign elite synchronized swimmers (Ponciano et al. 2018). One of the most observed gene polymorphisms associated with sport performance is ACE I/D gene polymorphism. In cardiac muscle *ACE* genotype variants influence the left ventricular mass changes in response to stimulus. In skeletal muscle, the D allele is associated with greater strength gains in response to training. DD genotype is more frequent in strength and power athletes (Puthuchear, et. al. 2011). Our results are in accordance with Nazarov et al. (2001) that found an excess of the D allele in short distance swimmers and of the I allele in middle distance swimmers. The frequency of genotypes II and ID is higher in athletes practicing sports requiring a high aerobic activity.

The results of several authors who have examined the effect of different types of training load on the stimulation of rebounding abilities of athletes on dry land are different. Romero-Franco and Jiménez-Reyes (2015) found that the vertical jump improved after warming up, but subsequently worsened after heavy plyometric training. On the other side Fortier et al. (2013) investigated that due to the short-duration isolated static stretching or combined with dynamic exercises, the acute effect did not occur before and after training in athletic sprinters. The area of the content of the training load in the aquatic environment and its response to the stimulation of selected motor abilities of performance in synchronized swimming is still insufficiently researched. We assume, that these findings are related to the external environment conditions where is the sport performance realized. The physical activity preformed on the land is influenced by gravity which is reduced in the aquatic environment (Rýžková et al. 2018). Even in our study, we did not find the significant effect of training load in the water in terms of the stimulation of the reflective capabilities of synchronized swimmers.

Conclusion

Every sport has specific requirements that can be considerably different to other sports. The sport of synchronized swimming requires low body weight associated with a lower percentage of body fat. In accordance with previous studies we conclude, that the biological characteristics and motor variables of the elite synchronized swimmers may play an important role during competition and can be considered as bases for success in this sport. We provided evidence for significant differences of variation of the ACE I/D polymorphism between observed groups. The response to the training load in the water in terms of the stimulation of the reflective capabilities of synchronized swimmers did not assume significant relations. This may be caused due to the specific environment, because on the land sport performance is influenced by gravity that is reduced in the aquatic environment.

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