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ANTHROPOMETRIC AND CARDIOVASCULAR VARIABLES OF ELITE ATHLETES

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Summary: Synchronized swimming and aerobic gymnastics are competitive sports that have grown in popularity throughout the Slovakia and around the world. Unfortunately, a paucity of research exists either on anthropometric and physiological characteristics or physical benefits of these sports. The present study examined anthropometric and cardiovascular characteristics of control group - CO (n = 10) in comparison to competitive synchronized swimmers - SS (n = 11) and aerobic gymnasts – AG (n = 10) between the ages of 13 and 25 years. The physical measures were assessed per the protocols in the following order: height (BH), weight (BW), body mass index (BMI), and % body fat (% BF). The measurements of maximal oxygen consumption (VO_2max) and maximum heart rate (HR_{max}) were examined by spiroergometry via COSMED K4b2. All measurements were collected by trained data collection staff. An analysis of variance (Kruskal - Wallis) with a Mann-Whitney *U* test for the significant effect among the three groups showed that aerobic gymnasts were taller than synchronized swimmers and control group *(p = .02)*. Training and conditioning requirements specific for the two athletic groups caused that AG and SS have higher level of VO_2max *(p = .02)* and $VO_2max.kg^{-1}$ *(p = .00)*, and also lower level of the body weight (p= .01), BMI (*p = .01)* and the % BF *(p = .00)*. These findings confirm that selected parameters are considered the bases for success in elite sports. This information could also help to design specific training and evaluate the adaptation to training stimuli with the aim to maximize sport performance.

Key words: synchronized swimming, aerobic gymnastics, anthropometric characteristics, cardiovascular characteristics

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Introduction

In sports, particularly in aesthetic ones such as gymnastics, synchronized swimming, dancing, figure skating, etc., the athlete anthropometric and physiological characteristics (Claesses et al.1999) play an important role in individual selection (Russel, 1987) and influence the sport success as well (Hume et al. 1993; Miletic et al. 2004; Sedeaud et al. 2014). The anthropometric parameters are also considered the bases for success in gymnastics (Di Cagno et al. 2008; Avilla et al. 2012; Arriaza et al. 2016), together with psychological aspects (Di Cagno et al. 2009; Gregor 2009; Sedeaud et al. 2014), nutrition (D'Alessandro et al. 2007) and maturity (Tringali et al. 2014). Specify and intensity of training generates alteration at a cardiovascular system (Douda et al. 2008). Thus, functional examination assesses the ability to endure the physical load during the sports, and cardiovascular system plays dominant role. Heart rate, as one of the manifestations of cardiac activity, is considered to be one of the most suitable parameters to monitor the workload on the body. In addition, heart rate is well correlated with the load intensity in all physical activities and in this way, it is used when testing performance and effort (Komadel & Thurzová 1994; Hamar & Lipková 2008).

Synchronized swimming combines swimming, dancing and gymnastics. Swimmers in solo, duet, team events and free combination (FINA, 2015) perform synchronized routines of elaborate moves in the water accompanied by music. Contemporary synchronized swimmers need to combine technically, physically, and aesthetically very demanding exercises, lasting about 2 to 4 minutes (duration of the routine differs according to age and competitive category), performed at increasingly higher levels of intensity both breathing freely and holding breath. According to Homma (1994), almost 50 % of this time is spent in apnea. Consequently, the sport seems to require high levels of aerobic and anaerobic endurance, as well as exceptional breath control when upside down underwater (Jamnik 1987). Most studies in synchronized swimming have focused on heart rate (HR) and blood lactate measurements after performing single figures (Gemma 1987; Homma 1994; Homma & Takahashi 1999) or a routine training program (Smith 1988; Chatard et al. 1999). However, barely any of these assessments have been performed during real competition, making it difficult to derive valid information on the physiological demands of the sport and its different events (Jamnik 1987).

Aerobic gymnastics as the youngest and progressively expanding gymnastic sport is defined as an aesthetic-technical discipline with the ability to perform continuous complex and high intensity aerobic movement patterns to music, which originates from traditional aerobic exercises: the routine must demonstrate continuous movement, flexibility, strength and various combinations of seven basic steps, with perfectly executed difficulty elements (FIG 2013). In addition, it combines elements of rhythmic gymnastics, and oftentimes artistic and acrobatics gymnastics along with music, dance and choreography. Thus, aerobic gymnastics routine involves many gymnastics and dance based skill, difficulty elements, with unique technical and artistic requirements. These skills load the body in a variety of ways. Since the aerobic gymnastics performance is characterised by the dynamics of movement with fast direction changes over the competition floor, a short-term persistence has the largest representation during the routine. Gymnasts do not perform more than 105 s (duration of the routine differs according to age and competitive category). Thus, in terms of energy requirements on the body the anaerobic dominance is obvious (Goswami & Gupta 1998). However, during the intense training sessions, gymnasts are asked to perform routines while fatigued, and to find the best compromise among technical effectiveness, safety, and high intensity effort (Sands et al. 2003). The high level of the basic requirements of fitness is necessary for the success in learning of skills. The anaerobic threshold (lactate or ventilatory) also is another approach that determines the level of aerobic endurance (Allen et al. 1985). Previous research suggests that physiological data during actual gymnastics performances due to the nature of the activity and the relatively short duration of the performances required elevated heart rate (Jemmi et al. 2000).

Few studies have been published describing either anthropometric or physiological characteristics of aerobic gymnasts (Rodriguez et al. 1998; Arazi et al. 2013; Alaksandreviciene et al. 2016), and synchronized swimmers (Gemma 1987; Homma 1994; Homma & Takahashi 1999). Despite the different movements patterns as well as the environment both sports - competitive aerobics and synchronized swimming can be considered a sport with high cardiorespiratory and metabolic demands (Kyselovicova & Danielova 2012; Labudova 2011; Aleksandreviciene et al. 2016) with the intense activation of aerobic and anaerobic pathways. Herein we aimed to describe and compare elite level synchronized swimmers and aerobic gymnastics anthropometric and cardiovascular variables.

Materials and methods

Subjects

Eleven (11) synchronized swimmers (age 16.6 ± 2.9 years); ten (10) aerobic gymnasts (age 18.2 ± 4.7 years) and ten (10) non-athletes (age 18.8 ± 0.4 years) volunteered in the study after being informed about the aim and methods of the study. All athletes can be characterized as elite ones, involved in sports more than 10 years, trained for 16 – 25 hours per week. They all had competed at national and international level at least in the previous four years. The subjects delivered a written informed consent, with parental permission when needed. The study was approved by the Ethics Committee of FPES CU in Bratislava.

Anthropometrics

Body height, body weight, and 4 skinfold thickness (biceps, triceps, subscapular and supra iliac regions) were measured. Standing height was measured without shoes to the nearest 1.0 cm. Body weight was measured to the nearest 0.1 kg using an electronic digital scale (model BREMED 7750). Skinfolds thickness was measured to the nearest half millimetre on the right side of the body using Skinfold Caliper FAT-1. The mean of two measurements was taken. Triceps skinfolds were measured on the back of the arm with the elbow extended, exactly halfway between the acromion and the proximal end of the olecranon; biceps skinfolds at the mid-length of the biceps; subscapular skinfolds 1cm below the inferior angle of the scapula, and supra iliac skinfolds about 2.0 cm above the iliac crest and 2.0 cm towards the medial line. Body fat was estimated as described by Slaughter et al. (1988). Body mass index (BMI) was calculated as weight divided by height squared ($kg.m^{-2}$).

Cardiovascular variables

Participants' VO_2max and maximum heart rate (HR_{max}) were continuously monitored and determined through an incremental exercise tests on a treadmill. The tests were carried out under standardised laboratory conditions. The devices calibration was made before each test sessions on a treadmill (Woodway Force 1.0, USA) and with K4b2 (Cosmed Italy). Each subject was given a visual demonstration and was allowed to practice the appropriate technique during walking (at velocity of 5 $k.h^{-1}$) and running (at velocity of 8 $km.h^{-1}$) on the treadmill up to 5 minutes.

Afterwards, the subject sat on a chair for 10 minutes. Chest strap (Polar WearLink W.I.N.D.) was paired with K4b2 for monitoring of heart rate during whole testing protocol. K4b2 clipped on the trunk, measured in telemetry data transmission mode, breath by breath. The test began with subject steady state on the treadmill for 3 minutes while breathing normally. Treadmill inclination was set up at 1 %. Examiner gave an instruction "accelerate" 5 – 10 seconds before velocity was increased automatically. First movement stage was set up at velocity of 5 $km.h^{-1}$ for 3 minutes. Next stages with 1 minute duration were increased at velocity of 1 $km.h^{-1}$ until the subject was unable to maintain the desired velocity for 1 minute. Treadmill was stopped after visual feedback from subject and/or the magnetic safety key interruption by examiner. After exercise cessation, the subject stayed on the treadmill to monitor cardiorespiratory parameters during a recovery phase for 3 minutes.

Statistical Analysis

Descriptive statistics (means and standard deviation, minimum value, maximum value, and range.) were calculated for all variables. A Kruskal-Wallis test was conducted to evaluate differences among the three groups (SS, AG, CO) on median change in all parameters. A chi-square statistic was used for evaluation that the medians are equal across the groups. For the Kruskal-Wallis, we have used the Mann-Whitney *U* test to examine unique pairs. Eta square (η^2) was computed from the reported chi-square value for the Kruskal-Wallis test. We calculated 95 % confidence interval for each anthropometric parameter.

Results

Body height

The test, which was corrected for tied ranks, was significant, $\chi 2$ *(2, N = 31) = 7.55, p = .02.* The proportion of variability in the ranked dependent variable accounted for body height variable was .25, indicating a small relationship between sport and the body height. Follow-up tests were conducted to evaluate pairwise differences among the three groups, controlling for Type I error across tests by using the Bonferroni approach. The results of these tests indicated a significant difference between the AG and the SS group and the CO group. Body height was significantly lower for AG group *(M = 160.70, SD = 6.56, 95 % CI 156.01 – 165.39 cm)* than for the SS group *(M = 167.59, SD = 6.03, 95 % CI 163.79 – 171.39 cm)* and CO group *(M = 167.10, SD = 5.66, 95 % CI 162.79 – 171.41 cm).*

Body weight

The test, which was corrected for tied ranks, was significant, *χ2 (2, N = 31) = 9.88, p = .01 (Figure 1).* The proportion of variability in the ranked dependent variable accounted for body weight variable was .33, indicating a fairly small relationship between sport and the body height. The results of Mann-Whitney *U* test indicated a significant difference between the CO group and the SS group and AG group. Body weight was significantly higher for CO group *(M = 61.50, SD = 5.19, 95 % CI 57.79 - 65.21 kg)* than for the AG group *(M = 51.10, SD = 9.21, 95 % CI 44.51 - 57.69 kg)* and SS group *(M = 54.05, SD = 5.25, 95 % CI 50.53 – 57.58 kg).*

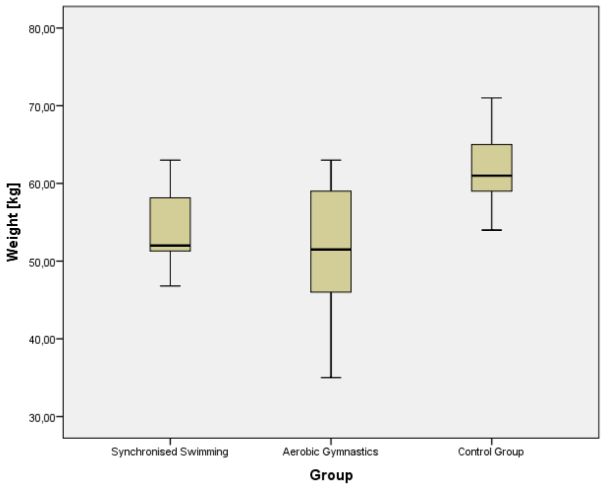

Figure 1

*The results of Mann-Whitney U test between the groups in parameter **weight***

BMI

We have found significant differences between groups, *χ2 (2, N = 31) = 9.83, p = .01 (Figure 2).* The proportion of variability in the ranked dependent variable accounted for BMI variable was .33, indicating a fairly small relationship between sport and the BMI. The results of Mann-Whitney *U* test indicated a significant difference between the AG and the SS group and the CO group. BMI was significantly higher for CO group *(M = 22.05, SD = 1.71, 95 % CI 20.82 – 23.27 kg.m*$^{-2}$*)* than for the AG group *(M = 19.69, SD = 2.56, 95 % CI 17.86 – 21.52 kg.m*$^{-2}$*)* and SS group *(M = 19.22, SD = 1.25, 95 % CI 18.38 – 20.06 kg.m*$^{-2}$*).*

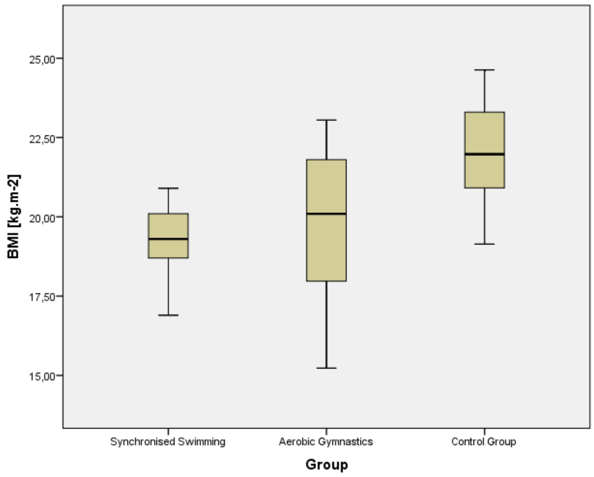

Figure 2

The results of Mann-Whitney U test between the groups in parameter ***BMI***

HR_{max}

We have not found significant differences between groups, *χ2 (2, N = 31) = 2.18, p =. 34.*

VO_2max [ml.min^{-1}]

We have found significant differences between groups, *χ2 (2, N = 31) = 8.76, p = .02.* The proportion of variability in the ranked dependent variable accounted for VO_2max variable was .29, indicating a small relationship between sport and the VO_2max. The results of Mann-Whitney *U* test indicated a significant difference between the AG and the SS group and the CO group. BMI was significantly higher for CO *(M = 2184.16, SD = 507.58, 95 % CI 1821.06 – 2547.27* ml.min^{-1}*)* than for the AG group *(M = 2720.18, SD = 592.71, 95 % CI 2296.18 – 3144.18* ml.min^{-1}*)* and SS group *(M = 2850.75, SD = 340.76, 95 % CI 2621.83 – 3079.68* ml.min^{-1}*)*, as indicated in *Figure 3.*

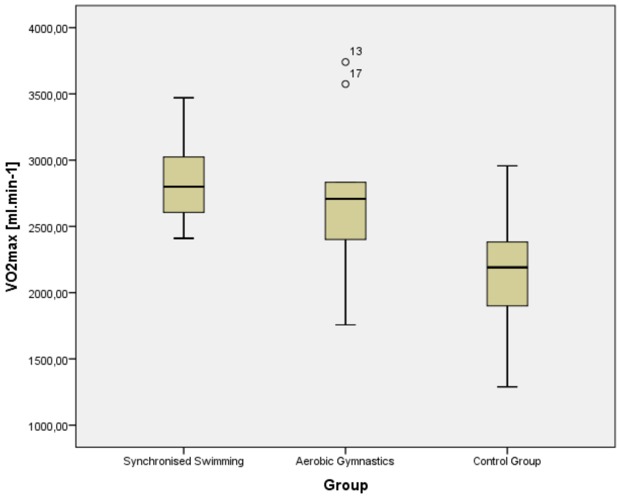

Figure 3
The results of Mann-Whitney U test between the groups in parameter ***VO_2max [ml.kg^{-1}]***

VO_2max [ml.min^{-1}.kg^{-1}]

We have found significant differences between groups, $\chi 2$ $(2, N = 31) = 18.79$, $p = .00$. The proportion of variability in the ranked dependent variable accounted for VO_2max variable was .63, indicating a fairly strong relationship between sports and the VO_2max. The results of Mann Whitney U tests indicated a significant difference between the AG and the SS group and the CO group *(Figure 4)*. VO_2max was significantly higher for CO group *($M = 35.43$, $SD = 7.33$, 95 % CI 30.18 - 40.67* ml.min.kg^{-1}*)* than for the AG group *($M = 54.17$, $SD = 592.71$, 95 % CI 48.20 – 60.13* ml.min.kg^{-1}*)* and SS *($M = 51.35$, $SD = 4.10$, 95 % CI 48.59 - 54.10* ml.min.kg^{-1}*)*.

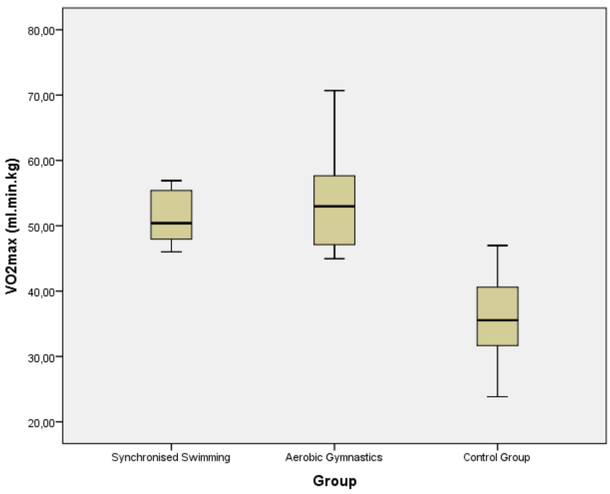

Figure 4
The results of Mann-Whitney U test between the groups in parameter ***VO_2max [ml.min^{-1}.kg^{-1}]***

% BODY FAT

We have found significant differences between groups, *$\chi 2$ (2, N = 31) = 21.50, p = .00.* The proportion of variability in the ranked dependent variable accounted for fat variable was .72, indicating a fairly strong relationship between sport and the fat. The results of Mann-Whitney *U* test indicated a significant difference between the AG and the SS group and the CO group *(Figure 5)*. % BF was significantly higher for CO group *(M = 25.37, SD =2.08, 95 % CI 23.88 – 26.86 %)* than for the AG group *(M = 20.13, SD = 2.85, 95 % CI 18.09 - 22.17 %)* and SS group *(M = 16.73, SD = 2.77, 95 % CI 14.87 – 18.59 %)*.

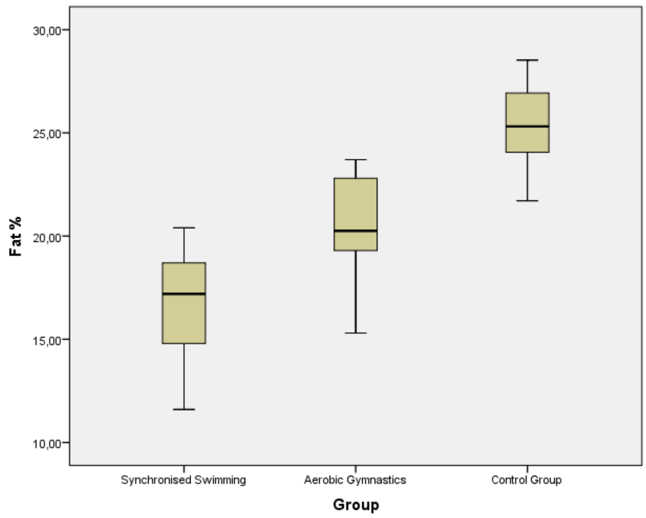

Figure 5
*The results of Mann-Whitney U test between the groups in parameter **% body fat***

Discussion

Anthropometric characteristics

Many sports prefer athletes who are taller with more body mass. However, and particularly in aesthetic-technical disciplines it differs. Rodriguez-Zamora et al. (2012) investigate 34 elite synchronized swimmers. There were no significant differences between juniors (15.9 ± 1,0 years) and seniors (21,4 ± 3,6 years) in height (163.7 ± 5.1 versus 168.9 ± 8.0 cm) and weight (53.2 ± 5.3 versus 54.6 ± 6.3 kg), respectively. In addition, Moffat et al. (1982) found that synchronized swimmers aged 19 to 24.4 years had a body height from 160.4 to 167.5 cm, weight 55.9 to 59 kg and body fat from 21.5 to 29.1 %. In comparison to the findings of several authors we can conclude that the Slovak elite synchronized swimmers have lower % body fat; e.g. Evans et al. (1985) found average value of 22.27 % body fat, similarly, Kirkendall et al. (1982) monitored elite competitors (average age = 17.39 years, % body fat =

20.09). Roby et al. (1983) followed top competitors aged 20.1 years with an average value of % body fat 24. Authors also looked at the possible link between levels of body fat and hydrostatic properties of synchronized swimmers.

In gymnastics, performance is significantly related to height (Sands 1999). Small stature could be beneficial for gymnasts to perform better and avoid injury (Bale & Goodway 1990). Moreover, in gymnastics as body weight is carried, greater mass is not considered an advantage (Benardot 2012). Such findings are supported by research of Shaklina and Zakharchenko (2016) who present the results of questionnaire survey and anthropometric studies in Ukrainian artistic gymnasts: the age of subjects ranged from 14 to 21 years; body mass 36.0 – 55.0 kg, and body height 146.0 – 166.5 cm. In contrary, the average age of artistic gymnasts to achieve high-ranking level is 15.3 years while the age of gymnasts of low-ranking level is 13.7 years (Böhmerová & Hamar 2014).

Physiological characteristics

Despite the different movements patterns as well as the environment both sports – aerobic gymnastics and synchronized swimming can be considered a sport with high cardiorespiratory and metabolic demands (Kyselovičová & Danielová 2012; Labudová 2011; Rodriguez-Zamora et al. 2012; Aleksandreviciene et al. 2016) with the intense activation of aerobic and anaerobic pathways. Better technical skills are correlated with a higher VO_{2max} as well as higher anaerobic threshold (Guidetti et al. 2007). Our findings are similar to results of Baldari & Guidetti (2001), Yamamura et al. (1999) and other. Selected anthropometric characteristics, aerobic power, flexibility, and explosive strength are important determinants of successful performance (Douda et al. 2008).

The importance of monitoring heart rate during the sport performance in synchronized swimming is underlined by research Rodriguez-Zamora et al. (2012). The multiple correlation analysis has showed that the heart rate before and the minimum heart rate during the synchronized swimming competition routine predicted 26% of the variability of the final score. The authors concluded that the cardiovascular response during competition routine is characterized by intense pre-activation and emerging tachycardia up to the maximum level, which alternate with segments of significant bradycardia during exercise performed in dynamic apnea.

Moreover, competition routines are considered very or extremely difficult especially in the disciplines solo and duo.

Methodological difficulty of detection of physiological parameters directly on top competitions highlight several authors (Figure et al. 1993; Yamamura et al. 1999; Bante et al. 2007). Other authors consider that the physiological testing elite of competitors can detect emerging trends demands of the sport sector (Lundy 2001; Pazik et al. 2005; Alentejano 2010). The assessment of physiological and energetic demands during exercise of relatively short duration, changing intensity, and types of muscle activation is rather complicated. Additionally, in aesthetic sports technical parameters of the specific performance play an important role. Competitive requirements has to be characterized in reality, during competition, thus requiring a field study design, with some intrinsic limitations imposed by the competition rules on the one side.

Conclusion

The present study is the first to investigate the physiological and anthropometric characteristics of elite athletes in synchronised swimming and aerobic gymnastics in Slovakia. We found SS were younger, slightly higher and almost the same weight as the elite AG. The BMI and % BF was significantly higher for the CO. Moreover, both groups of elite athletes had higher values in VO_2max. The VO_2max expressed in $ml.min^{-1}.kg^{-1}$ was significantly different between the three groups of subjects. The highest values were found in AG (64.69) followed by the values of SS (56.9) and controls (46.9). At maximal effort VO_2max was significantly higher both in SS and AG (51.35 ± 4.1 $ml.min^{-1}.kg^{-1}$ and 54.17 ± 8.34 $ml.min^{-1}.kg^{-1}$, respectively), than in controls (35.43 ± 7.33 $ml.min^{-1}.kg^{-1}$). The findings of the present study suggest that the anthropometric and cardiovascular characteristics of the elite athletes may play an important role during training and can be considered as bases for success in sports. This information could help in practice to design, plan and organize specific training and evaluate the adaptation to training stimuli with the aim to maximize training effectiveness and specific performance.,

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