IMPACT OF GYMNASTICS TRAINING ON THE HEALTH-RELATED PHYSICAL FITNESS OF YOUNG FEMALE AND MALE ARTISTIC GYMNASTS

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Abstract

Artistic gymnastics can be practised from an early age and develops the main components of physical fitness. The aim of this study was to assess the physical fitness of young competitive artistic gymnasts from Bulgaria. A total of 161 gymnasts (81 females and 80 males), who were divided into three groups (from 5-8, 9-11, and 12-15 years of age), with sports experience from 12 to 180 months, took part in this study. All of the participants completed the extended version of the Alpha-Fit physical fitness test battery, with European norms being applied to calculate percentile scores for each fitness test. The height-for-age percentile scores in the groups between the ages of 9-11 and 12-15 were significantly lower from the 50th percentile of the international norms, both for male and female gymnasts. Gymnasts showed substantially lower body fat, and only one gymnast was assessed as overweight, with two being classified as obese. The percentile scores of the standing long jump and the 4x10 m SRT in the groups were significantly greater than the 50^{th} percentile of the available European norms. The percentile scores of the VO_2max in all female groups were also higher than the 50^{th} percentile of the European norms, while those for males did not differ from the 50^{th} percentile, except in the 5-8 age range. Artistic gymnastics improves the physical fitness components and positively influences children's physical development. Both female and male artistic gymnasts had better physical fitness in most parameters, in comparison with their peers.

Keywords: *physical fitness, artistic gymnasts, gymnastics, alpha-fit.*

INTRODUCTION

Artistic gymnastics is one of the few sports which can be practised from a very young age, and which develops different components of physical fitness. Pupils learn basic elements which are of great significance, especially for children's orientation in space, such as jumps and leaps, hanging, rotating, crawling, rolling, etc. (Pajek, Cuk, Kovac, & Jakse, 2010).

Health-related physical fitness is a major factor in children's health, and it has a multidimensional structure consisting of the following components: body composition, musculoskeletal fitness, motor fitness (speed, agility and coordination), and cardiorespiratory fitness (ALPHA, 2009; Artero et al., 2011; Ruiz et al., 2009; Ruiz et al., 2010). There are different fitness test batteries, such as Alpha-fit, Eurofit, FitnessGram, etc., which are applied around the world in order to assess physical fitness in children and adolescents (Kolimechkov, 2017). Based on many longitudinal and cross-sectional studies, a wide range of authors define the Alpha-fit test battery as an ideal tool, encompassing a valid, reliable and safe set of tests for the assessment of physical fitness in children and adolescents (Cvejic, Pejovic, & Ostojic, 2013; Romero et al., 2010; Ruiz et al., 2010; Santos & Mota, 2011).

Optimal health and level of physical fitness are essential for all gymnasts in order to be able to effectively and accurately perform varied elements and routines. The physical fitness assessment can provide information which allows us to track the impact of the sport on each gymnast's health (British Gymnastics, 2015).

There are currently around 700 artistic gymnasts who are registered with the Bulgarian Gymnastics Federation, and more than 600 of them are under the age of 17. Therefore, the aim of this study was to assess the physical fitness levels of a representative sample of young competitive artistic gymnasts from different regions in Bulgaria, and show the impact of the training on the gymnasts' health by using the Alpha-Fit test battery.

METHODS

This study included a representative sample of 25% of all registered young artistic gymnasts. Thus, this study involved the participation of 161 artistic gymnasts (81 females and 80 males) who regularly took part in, or were preparing for, competitions. The gymnasts were between the ages of five and fifteen, from four different cities in Bulgaria (Sofia, Blagoevgrad, Veliko Tarnovo and Ruse) representing nine different gymnastics clubs which are registered with the Bulgarian Gymnastics Federation. The average sports experience of all participants in artistic gymnastics was 3.6 years (from 1 to 15 years).

The gymnasts were divided into three age groups (from 5 to 8, 9 to 11, and 12 to 15 years of age) and according to gender.

Institutional ethics approval for this research was granted by the National Sports Academy in Sofia, and informed consent was obtained from the parent/guardian of each gymnast.

All artistic gymnasts completed the extended version of the Alpha-Fit physical fitness test battery (ALPHA, 2009), which included the following anthropometric measurements and tests: height, weight, waist circumference, triceps and subscapular skinfolds to assess body composition; handgrip strength and standing long jump to assess musculoskeletal fitness; the 4x10 m shuttle run test (4x10 m SRT) to assess motor fitness; and the 20 m shuttle run test (20 m SRT) to assess cardiorespiratory fitness.

Stature was measured to the nearest 0.1 cm with a stadiometer, body mass was recorded to within an accuracy of 0.1 kg by using the Omron BF511 electronic scale, and waist and arm circumferences were measured to the nearest 0.1 cm with the Lufkin W606PM tape measure. All of the measurements were recorded by following the anthropometric procedures thoroughly (NHNES, 2007; Piwoz & Viteri, 1985). Body mass index (BMI) was calculated as: body mass in kilograms/stature in metres squared. In addition, the percentile scores for each gymnast's height, weight and BMI were computed and assessed by using the WHO AnthroPlus specialised software, provided by the World Health Organisation (WHO, 2011). The following classification of the BMI percentile scores (PRs) for children and adolescents between the ages of 5 and 19, provided by the WHO, was applied:

BMI > 85th PRs is classified as 'overweight'; BMI > 97th PRs is 'obese'; BMI < 15th PRs is 'thinness'; and BMI < 3rd PRs is 'severe thinness' (WHO, 2007a).

Waist-to-height ratio (WHtR) was calculated by dividing waist circumference (cm) by height (cm), and the simple cut-off of WHtR = 0.500 was used to assess increased health risk in children relating to an excessive accumulation of body fat on the upper body (Ashwell & Hsieh, 2005; McCarthy & Ashwell, 2006).

The triceps and subscapular skinfolds were measured with the Lange Skinfold Caliper, Beta Technology Inc, Cambridge to an accuracy of 1 mm. Body fat percentage (%Fat) was determined by the sum of the two skinfolds, using Slaughter's equations (Heyward & Stolarczyk, 1996; Slaughter et al., 1988), which are highly recommended for children and adolescents because of the accuracy and simplicity of this method (ALPHA, 2009; Boye et al., 2002; Laurson, Eisenmann, & Welk, 2011). Body fat percentile scores were computed by using the recent international norms for Caucasian children and adolescents (McCarthy, T.J. Cole, T. Fry, S.A. Jebb, & Prentice, 2006). In order to classify %Fat the following cut-offs were applied: %Fat > 85th PRs is classified as 'overweight'; %Fat > 95th PRs is 'obese'; and %Fat < 2nd PRs is 'underfat' (McCarthy et al., 2006).

The upper arm muscle area (UAMA) was calculated from the arm circumference and the triceps skinfold by using the following formula (Addo, Himes, & Zemel, 2017):

$$UAMA = [\text{Arm circumference} - (\pi \times \text{triceps skinfold})]^2 \div 4 \times \pi$$

Percentile scores for the UAMA were computed for each gymnast by using the recent norms for children and adolescents (Addo et al., 2017). In addition, the relative UAMA (cm^2/kg) was also calculated by dividing the UAMA (cm^2) by body mass (kg).

Handgrip strength was measured for both hands by using the SH5001 Hydraulic Hand Dynamometer to assess upper body isometric strength. The elbow of the tested hand was fully extended and the testing procedure was strictly followed (ALPHA, 2009; NHANES, 2013). The relative handgrip strength for each participant was also calculated by dividing the average handgrip strength (kg) by the body mass (kg).

The standing long jump test was performed to assess lower body explosive strength on a non-slippery hard surface, and the test was recorded to within an accuracy of 1 cm. The distance was measured from the take-off line to the point where the back of the heel, nearest to the take-off line, lands on the ground (ALPHA, 2009).

Percentile scores for the average handgrip strength and the standing long jump were computed by using the available European norms for children (Miguel-Etayo et al., 2014) and adolescents (Ortega et al., 2011). Linear interpolations and extrapolations between the existing European norms were applied in order to compute percentile scores for those ages which were not published, these being 5, 10, 11 and 12-year-old children (Kolimechkov, Petrov, & Alexandrova, 2018).

The 4x10m SRT at maximum speed was performed to measure speed of movement, agility and coordination, in accordance with the standard procedure described in the Alpha-fit test battery (ALPHA, 2009). The test was recorded in seconds by using a stopwatch to an accuracy of 0.1 sec. The percentile scores of the results were calculated by using the available European norms for children (Roriz De Oliveira, Seabra, Freitas, Eisenmann, & Maia, 2014) and adolescents (Ortega et al., 2011). Percentile scores for the missing years (5, 11 and 12-year-old children), in which there was a gap in the norms, were computed by using linear interpolations and extrapolations of the existing

European percentiles (S. Kolimechkov et al., 2018).

The estimated maximal oxygen uptake (VO_2max) was calculated by using a modified version of the 20 m SRT in order to assess the cardiorespiratory fitness of the artistic gymnasts. The modified test required running between two lines which were 10 m apart, in time with an audio signal, instead of the original 20 m. This modification made the administration of the test more convenient when conducted inside the gymnastics centres (on the gymnastics floor 12x12 m). An extended specialised version of the BeepShuttle Junior software (Kolimechkov, Petrov, Alexandrova, & Cholakov, 2018) was applied in order to administer the 10 m SRT. The software applies the original 1-minute protocol, which starts at a speed of 8.5 km/h and increases in speed by 0.5 km/h after each minute, as described by Leger et al. (Leger, Lambert, Goulet, Rowan, & Dinelle, 1984). Moreover, the software calculated the predicted VO_2max by using Leger's equation (Leger, Mercier, Gadoury, & Lambert, 1988) in addition to the percentile score for each participant based on age- and gender-specific international norms (Miguel-Etayo et al., 2014; Tomkinson et al., 2016).

All anthropometric measurements were taken twice, and the mean was used in the analyses, as recommended in the test manual of the Alpha-fit battery. The handgrip strength test, standing long jump test and 4x10 m SRT were performed twice, and the better score was used in the analyses, whilst the cardiorespiratory test was performed once (ALPHA, 2009).

The statistical analyses were conducted with SPSS Statistics 19 software, using descriptive statistics and One-way ANOVA with the Bonferroni *post hoc* test. Statistically significant differences between the average values were evaluated at $p < 0.05$, and all data in the text are presented as mean ± SD. In addition, the percentile scores of the parameters were compared to the 50th percentile by using one sample t-test. Cohen's effect size was calculated for those parameters which differed significantly from the 50th percentile, and the following classification was applied: d (0.01) = very small, d (0.20) = small, d (0.50) = medium, d (0.80) = large, d (1.20) = very large, and d (2.00) = huge (Sawilowsky, 2009).

RESULTS

The anthropometric parameters, their percentile scores and their effect size vs the 50th percentiles (PRs) of the female artistic gymnasts, divided into three age groups, are presented in Table 1. The group which included gymnasts between the ages of 12 and 15 has the greatest average sports experience (7 years and 6 months). Therefore, the outcomes on physical development and physical fitness from practising artistic gymnastics should be clearly evident in this group. The average frequency of the gymnastics training ranged from 4 to 5 sessions per week. The height-for-age percentile scores in the groups between the ages of 9-11 and 12-15 were significantly lower than the 50th percentile of the international norms for children and adolescents at this age provided by the World Health Organization (WHO, 2006). The average weight of the gymnasts increased gradually with age and did not differ from the average international standards. However, it should be taken into account that the World Health Organization (WHO) does not provide weight-for-age reference data for children over 10 years of age, because this indicator cannot distinguish between height and body mass at an age when many children are experiencing the pubertal growth spurt (WHO, 2007b). The body mass index (BMI) did not show significant differences from the international percentile scores, except with the first age group (5-8 years), where the Cohen's effect size was small (d=0.41). The average waist-to-height ratio in all three age groups was below the boundary of 0.500, which distinguishes children at risk as far as their health is concerned (Ashwell & Hsieh, 2005; McCarthy & Ashwell, 2006). The %Fat percentile scores in all groups were greatly lower than the 50th percentile of the international norms for children and adolescents (McCarthy et al., 2006), and the Cohen's effect size was large (d=1.05) for 5-8-year-old gymnasts, very large (d=1.37) for 9-11-year-old gymnasts, and huge (d=3.17) for 12-15-year-old gymnasts, in accordance with the benchmarks provided by Cohen and Sawilowsky (Lakens, 2013; Sawilowsky, 2009). The upper arm muscle area (UAMA) percentile scores for all three groups are lower than the 50th percentile, but this difference was significant only in the group with gymnasts between the ages of 9 and 11 with a medium effect size (d=0.50).

Table 1
Anthropometric parameters, their percentile scores and effect size vs the 50th percentile (PRs) of the female artistic gymnasts divided into three age groups (mean ± SD).

	5-8 years (n=28)	9-11 years (n=39)	12-15 years (n=14)
Age (years)	7.45 ± 0.92	10.25 ± 0.95	13.52 ± 1.28
Sports experience (months)	23.71 ± 12.91 C	36.76 ± 23.07 C	79.57 ± 38.77
Sessions per week	4.05 ± 0.88 B[c]	4.86 ± 0.80	4.94 ± 0.85
Height (cm)	123.96 ± 8.26 BC	138.38 ± 8.98 C	153.13 ± 6.57
Height – percentile score	51.53 ± 31.56	39.98 ± 29.35	32.96 ± 25.07
Effect size vs 50th PRs	NS	0.01 a	0.68 a
Weight (kg)	25.73 ± 5.87 BC	33.22 ± 6.25 C	44.50 ± 7.55
Weight – percentile score	58.18 ± 29.20 B	50.54 ± 23.33**	-*
Effect size vs 50th PRs	NS	NS	
BMI (kg/cm^2)	16.54 ± 1.99 [c]	17.23 ± 1.86 c	18.84 ± 1.90
BMI – percentile score	61.09 ± 27.29	53.93 ± 25.70	44.81 ± 22.96
Effect size vs 50th PRs	0.41 a	NS	NS
Arm circumference (cm)	18.31 ± 2.05 BC	20.02 ± 1.70 C	22.16 ± 1.59
Waist circumference (cm)	53.66 ± 5.87 [b]C	57.99 ± 3.79 c	61.84 ± 4.45
Waist-to-height ratio	0.43 ± 0.04 c	0.42 ± 0.03	0.40 ± 0.02
Subscapular skinfold (mm)	6.95 ± 3.00	7.13 ± 2.61	7.88 ± 1.67
Triceps skinfold	10.52 ± 3.72	11.38 ± 4.21	9.61 ± 3.29
% Fat	16.27 ± 4.60	17.14 ± 4.73	16.54 ± 3.88
% Fat - percentile score	21.04 ± 27.53	17.32 ± 23.77	10.39 ± 12.51
Effect size vs 50th PRs	1.05 A	1.37 A	3.17 A
UAMA (cm^2)	18.07 ± 3.42 BC	21.67 ± 3.77 C	29.34 ± 4.64
UAMA – percentile score	43.20 ± 26.64	38.29 ± 23.25	39.61 ± 23.94
Effect size vs 50th PRs	NS	0.50 [a]	NS
Relative UAMA (cm^2/kg)	0.71 ± 0.10	0.66 ± 0.11	0.67 ± 0.12

* WHO does not provide weight-for-age reference data for children older than 10 years of age (WHO, 2007b).
** n=19 because 20 out of 39 female gymnasts were older than 10 (see *).
a – p < 0.05 vs 50th PRs; a – p < 0.01 vs 50th PRs; A – p < 0.001 vs 50th PRs;
b – p < 0.01 vs 9-11 years; B – p < 0.001 vs 9-11 years;
c – p < 0.05 vs 12-15 years; c – p < 0.01 vs 12-15 years; C – p < 0.001 vs 12-15 years;
NS – not significant

Table 2

Results of the handgrip strength test, standing long jump, 4x10 m SRT, 20m SRT, their percentile scores and effect size (vs 50th percentile) of all female artistic gymnasts (mean ± SD).

	5-8 years (n=28)	9-11 years (n=39)	12-15 years (n=14)
Musculoskeletal Fitness: Upper body strength			
Handgrip strength test* (kg)	8.87 ± 2.91 BC	13.72 ± 4.24 C	20.05 ± 4.18
Handgrip strength test (percentile score)	32.32 ± 30.27	31.65 ± 28.57	26.88 ± 21.09
Effect size vs 50th PRs	0.58 a	0.64 A	1.10 a
Relative handgrip strength (kg/ kg body weight)	0.34 ± 0.08 bc	0.41 ± 0.11	0.45 ± 0.06
Musculoskeletal Fitness: Lower body strength			
Standing long jump (cm)	129.46 ± 17.95 BC	160.83 ± 20.92 C	195.71 ± 15.29
Standing long jump (percentile score)	83.45 ± 20.27	88.65 ± 16.06	96.26 ± 4.65
Effect size vs 50th PRs	1.65 A	2.41 A	9.95 A
Motor Fitness			
4x10 m shuttle run test (sec)	13.81 ± 0.94 BC	12.76 ± 1.12 C	11.57 ± 0.64
4x10 m shuttle run test (percentile score)	74.38 ± 17.44	69.26 ± 25.45	83.30 ± 14.05
Effect size vs 50th PRs	1.40 A	0.76 A	2.37 A
Cardiorespiratory Fitness			
VO_2max (ml/kg/min)	49.06 ± 1.99 bC	46.48 ± 2.92 C	43.25 ± 3.49
VO_2max (percentile score)	79.23 ± 14.90 B	61.19 ± 22.35	72.42 ± 16.48
Effect size vs 50th PRs	1.96 A	0.50 a	1.36 A

* - values expressed as average of right and left hands
a – p < 0.01 vs 50th PRs; A – p < 0.001 vs 50th PRs;
b – p < 0.05 vs 9-11 years; b – p < 0.01 vs 9-11 years; B – p < 0.001 vs 9-11 years;
c – p < 0.01 vs 12-15 years; C – p < 0.001 vs 12-15 years;
NS – not significant

Table 3

Anthropometric parameters, their percentile scores and effect size vs the 50th percentile (PRs) of the male artistic gymnasts divided into three age groups (mean ± SD).

	5-8 years (n=35)	9-11 years (n=28)	12-15 years (n=17)
Age (years)	7.45 ± 1.09	10.29 ± 0.93	13.48 ± 1.10
Sports experience (months)	27.66 ± 14.60 BC	49.57 ± 16.70 C	84.94 ± 31.23
Sessions per week	4.51 ± 0.68 bc	5.06 ± 0.62	4.98 ± 0.61
Height (cm)	122.64 ± 8.28 BC	135.11 ± 7.60 C	148.06 ± 9.67
Height – percentile score	41.71 ± 27.49 C	31.36 ± 23.04 c	11.99 ± 9.54
Effect size vs 50th PRs	NS	0.81 A	3.10 A
Weight (kg)	23.98 ± 3.65 BC	30.73 ± 4.95 C	38.66 ± 8.71
Weight – percentile score	47.43 ± 25.90 B	39.22 ± 27.61**	-*
Effect size vs 50th PRs	NS	NS	
BMI (kg/cm^2)	15.88 ± 1.31 c	16.74 ± 1.65	17.38 ± 1.76
BMI – percentile score	53.42 ± 25.35 c	48.76 ± 26.52 c	28.64 ± 22.16
Effect size vs 50th PRs	NS	NS	0.96 a
Arm circumference (cm)	17.87 ± 1.58 BC	20.23 ± 1.80 c	21.88 ± 2.13
Waist circumference (cm)	54.79 ± 3.32 bC	57.87 ± 4.83 c	62.14 ± 4.43
Waist-to-height ratio	0.45 ± 0.03 bC	0.43 ± 0.03	0.42 ± 0.02
Subscapular skinfold (mm)	5.49 ± 1.54	5.99 ± 1.70	5.97 ± 1.06
Triceps skinfold	8.15 ± 2.25	8.45 ± 2.99 c	6.43 ± 2.20
% Fat	13.22 ± 3.20 c	13.13 ± 3.76 c	10.31 ± 3.00
% Fat - percentile score	15.56 ± 23.78	15.34 ± 23.46	5.93 ± 9.12
Effect size vs 50th PRs	1.45 A	1.48 A	4.83 A
UAMA (cm^2)	18.81 ± 3.48 BC	24.87 ± 5.29 C	31.80 ± 7.65
UAMA – percentile score	36.52 ± 27.82	51.67 ± 30.42	31.86 ± 22.81
Effect size vs 50th PRs	0.48 a	NS	0.80 a
Relative UAMA (cm^2/kg)	0.79 ± 0.12	0.82 ± 0.18	0.83 ± 0.13

* WHO does not provide weight-for-age reference data for children older than 10 years of age (WHO, 2007b).
** n=14 because 14 out of 28 male gymnasts were older than age of 10 (see *).
a – p < 0.01 vs 50th PRs; A – p < 0.001 vs 50th PRs;

b – $p < 0.05$ vs 9-11 years; b – $p < 0.01$ vs 9-11 years; B – $p < 0.001$ vs 9-11 years;
c – $p < 0.05$ vs 12-15 years; c – $p < 0.01$ vs 12-15 years; C – $p < 0.001$ vs 12-15 years;
NS – not significant

Table 4
Results of the handgrip strength test, standing long jump, 4x10 m SRT, 20m SRT, their percentile scores and effect size (vs 50th percentile) of all male artistic gymnasts (mean ± SD).

	5-8 years (n=35)	9-11 years (n=28)	12-15 years(n=17)
Musculoskeletal Fitness: Upper body strength			
Handgrip strength test* (kg)	9.69 ± 2.66 BC	15.71 ± 4.18 C	25.18 ± 5.89
Handgrip strength test (percentile score)	31.90 ± 24.47	37.29 ± 27.00	36.72 ± 27.77
Effect size vs 50th PRs	0.74 A	0.47 a	NS
Relative handgrip strength (kg/ kg body weight)	0.40 ± 0.09 [b]C	0.51 ± 0.12 C	0.66 ± 0.15
Musculoskeletal Fitness: Lower body strength			
Standing long jump (cm)	140.92 ± 21.18 BC	174.75 ± 21.12 C	208.03 ± 19.08
Standing long jump (percentile score)	87.01 ± 13.03	89.87 ± 14.25	91.82 ± 5.29
Effect size vs 50th PRs	2.84 A	2.80 A	7.91 A
Motor Fitness			
4x10 m shuttle run test (sec)	13.99 ± 1.44 BC	12.22 ± 1.08	11.32 ± 0.72
4x10 m shuttle run test (percentile score)	54.09 ± 22.89	65.66 ± 26.76	71.35 ± 22.45
Effect size vs 50th PRs	NS	0.59 [a]	0.95 [a]
Cardiorespiratory Fitness			
VO_2max (ml/kg/min)	49.13 ± 3.12 c	48.38 ± 4.20	46.14 ± 3.82
VO_2max (percentile score)	65.69 ± 21.20	59.23 ± 26.86	56.93 ± 20.30
Effect size vs 50th PRs	0.74 A	NS	NS

* - values expressed as average of right and left hands
a – $p < 0.05$ vs 50th PRs; [a] – $p < 0.01$ vs 50th PRs; A – $p < 0.001$ vs 50th PRs;
[b] – $p < 0.01$ vs 9-11 years; B – $p < 0.001$ vs 9-11 years;
c – $p < 0.05$ vs 12-15 years; C – $p < 0.001$ vs 12-15 years;
NS – not significant

The results of the handgrip strength test, standing long jump, 4x10 m SRT, 20m SRT, their percentile scores and their effect size (vs the 50th percentile) of all female artistic gymnasts are presented in Table 2. The handgrip strength percentile scores in all groups were lower than the 50th percentile of the international norms for children and adolescents, and the Cohen's effect size was medium for 5-8-year-old gymnasts (d=0.58) and 9-11-year-old gymnasts (d=0.64), and large (d=1.10) for 12-15-year-old gymnasts. The standing long jump percentile scores in all three groups were significantly higher than the 50th percentile of the available European norms for children and adolescents at this age (Miguel-Etayo et al., 2014; Ortega et al., 2011), and the effect size was very large (d=1.65) for those female gymnasts who were from 5 to 8 years of age, and huge for the older ones (d=2.41 for the 9-11-year-old gymnasts and d=9.95 for the 12-15-year-old gymnasts). The 4x10 m SRT percentile scores were also significantly higher than the 50th percentile in all groups, and the effects sizes were: very large (d=1.40 for the 5-8-year-old gymnasts), medium (d=0.76 for the 9-11-year-old gymnasts), and huge (d=2.37 for the 12-15-year-old gymnasts). The percentile scores of the VO_2max obtained by the modified 20 m SRT in all three groups were also higher than the 50th percentile of the European norms, and the effect size was very large (d=1.96 for the 5-8-year-old gymnasts, and d=1.36 for the 12-15-year-old gymnasts), and medium (d=0.50 for the 9-11-year-old gymnasts).

The anthropometric parameters, their percentile scores and their effect size vs the 50th percentiles (PRs) of the male artistic gymnasts, divided into three age groups, are presented in Table 3. As expected, the group which included the oldest male gymnasts had the greatest average sports experience (7 years), which was also registered with the female gymnasts. The average frequency of the gymnastics training ranged between 4 and 6 sessions per week. The height-for-age percentile scores in the groups between the ages of 9-11 and 12-15 were significantly lower than the 50th percentile of the international norms, with a large (d=0.81) and huge effect size (d=3.10), respectively. The average weight of the male gymnasts did not differ significantly from the international standards. The body mass index (BMI) did not show significant differences from the international percentile scores, except in the third group (12-15 years), where the effect size was large (d=0.96). The average waist-to-height ratio in all three age groups was within healthy norms, as was registered with the female gymnasts. The %Fat percentile scores in all male groups were substantially lower than the 50th percentile of the international norms for children and adolescents, and the effect size was very large both for the 5-8-year-old gymnasts (d=1.45) and the 9-11-year-old gymnasts (d=1.48), and huge for 12-15-year-old gymnasts (d=4.83). UAMA percentile scores for two of the groups (5-8-year-old and 12-15-year-old male gymnasts) were significantly lower than the 50th percentile, with a small (d=0.48) and large effect size (d=0.80), respectively.

The results of the handgrip strength test, standing long jump, 4x10 m SRT, 20m SRT, their percentile scores and their effect size (vs the 50th percentile) of all male artistic gymnasts are presented in Table 4. The handgrip strength percentile scores in all groups were lower than the 50^{th} percentile of the international norms for children and adolescents, but differ significantly only in the groups with the younger gymnasts: 5-8 years of age and 9-11 years of age. The effect size was medium (d=0.74) and small (d=0.47), respectively. The standing long jump percentile scores in all three groups were significantly greater than the 50^{th} percentile of the available European norms, and the effect size was huge for all three groups (d=2.84 for 5-8-year-old gymnasts, d=2.80 for the 9-11-year-old gymnasts and d=7.91 for the 12-15-year-old gymnasts). The 4x10 m SRT percentile scores were significantly higher than the 50^{th} percentile in two of the groups: 9-11-year-old male gymnasts with a medium effect size (d=0.59), and 12-15-year-old male gymnasts with a large effect size (d=0.95). The percentile scores of the VO_2max did not differ from the 50^{th} percentile of the European norms, except in the 5-8-year-old male gymnasts, where the PRs scores were significantly higher, and the effect size was medium (d=0.74).

DISCUSION

The progressive decrease of the percentile scores in the height of the gymnasts (Table 1 & Table 3) is probably because of the fact that those of shorter stature are more likely to have an advantage when performing many of the gymnastics exercises. For instance, top level male artistic gymnasts (n=10) from the Swiss National team had an average stature of 168.6 ± 4.5 cm (Hubner & Scharer, 2015), which is below the average height (178.2 cm), in accordance with national norms for Swiss male adults (Grasgruber, Sebera, Hrazdira, Cacek, & Kalina, 2016). Cuk et al. concluded that there was no difference in the height of top level male artistic gymnasts in 1933 and those in 2000, with their average height being 168 cm (Cuk et al., 2007). Similarly, there was no significant difference in the average height of top level male artistic gymnasts in 2000 from those in 2015 (Sibanc, Kalichova, Hedbavny, Cuk, & Pajek, 2017). This lower than average stature is also seen in other studies (Benardot, 2014), where the average values of the height of young gymnasts are similar to those in our study. For instance, the height-for-age in female junior elite gymnasts progressively dropped from the 48^{th} to the 20^{th} percentile as age increased (Benardot & Czerwinski, 1991). However, that does not mean that gymnastics training slows down growth. In a recent review about the role of intensive training on the growth of artistic gymnasts, Malina et al. (2013) concluded that adult height or near adult height of artistic gymnasts of both genders is not compromised by intensive gymnastics training at a young age or during the pubertal growth spurt. Artistic gymnasts are shorter and lighter than average, but gymnastics training does not attenuate growth of upper or lower body segments (Malina et al., 2013). In fact, gymnastics is a unique sport that provides competitive opportunities for the smallest and lightest athletes in a world where many sports are clearly biased in favour of athletes who are tall and/or big (Sands, 1999).

Although the BMI is the most popular method and is widely used for the assessment of body composition (Flegal, Tabak, & Ogden, 2006; Keys, Fidanza, Karvonen, Kimura, & Taylor, 2014; Pekar, 2011), it did not provide correct individual assessment of some of the gymnasts involved in our study, because the BMI does not distinguish between fat and muscle mass. That is why some authors highlight that the BMI is not appropriate for some groups of people, such as professional athletes, body building enthusiasts, people engaged in jobs with strenuous physical activity (Bogin & Varela-Silva, 2012) and adolescent athletes (Lutoslawska et al., 2014). Moreover, the BMI was also shown to be an inadequate indicator of weight and body composition in child athletes with greater muscle mass (Kolimechkov et al., 2013).

The percentage body fat was very low, both in female and male artistic gymnasts, which is normal for children and adolescents involved in gymnastics (Jemni, 2011). The results of %Fat from our study are similar to those reviewed by Benardot, 2014, where the average %Fat for children and adolescents engaged in gymnastics ranged between 8.6% and 21.5%.

The percentile scores for the handgrip strength in both female and male gymnasts were lower than the 50^{th} percentile for their age. On the whole, artistic gymnasts have smaller body sizes (especially in older children), in comparison to those for their age and gender, than the international norms, and, therefore, the evaluation of the strength parameters will be better assessed by relative parameters. In addition, the workload in artistic gymnastics comes mainly from the gymnasts' body weight. Consequently, percentile scores of relative handgrip strength (per kg body weight), as well as percentile scores of relative UAMA (per kg body weight), will be a better way to appropriately assess both the gymnasts' muscle mass and strength. However, to the best of our knowledge, such norms for children are still not available in the literature, and we are of the opinion that these norms should be obtained in future research.

The standing long jump represents the relative lower body strength and, not unexpectedly, this test witnessed better results in artistic gymnasts, because jumps in height and length are included in artistic gymnastics training. The 4x10 m SRT represents the lower body strength, speed and agility, and shows a high correlation with the standing long jump test ($r = -0.73$, $p < 0.001$ and -0.83, $p < 0.001$ for girls and boys, respectively). The results of the 4x10 m SRT were also expected to be better in artistic gymnasts, because of the short distance sprints which precede gymnastic vaults and acrobatic series. Similarly, rhythmic gymnasts between the ages of 7 and 17, who completed the Alpha-fit test battery, also achieved their best results in those two tests (Montosa, Vernetta, & López-Bedoya, 2018). As can be expected, the results from the standing long jump and the 4x10 m SRT in our study showed the largest effect size in the group with the most experience in gymnastics (12-15 years of age), Table 2 and Table 4.

Unfortunately, the Alpha-fit test battery is not fully completed in terms of available percentile scores for the evaluation of the tests results. There are still certain age groups without European percentile scores for the standing long jump test, handgrip strength test, 4x10 m SRT and 20 m SRT. Miguel-Etayo et al. also talk about this reference gap between the ages of 10 and 12 at the European level, which has to be filled in (Miguel-Etayo et al., 2014). Meanwhile, interpolated and extrapolated percentile scores of the existing data can be used in order to evaluate the results of children and adolescents at any age (S. Kolimechkov et al., 2018).

The maximal oxygen uptake (VO_2max) of the female artistic gymnasts decreased significantly with age, but remained significantly higher than the 50th percentile of the international age- and gender-specific norms. The effect size was very large (d=1.36) in the group with the most experience in gymnastics. The VO_2max of the male artistic gymnasts also gradually decreased with age, and the values are similar to those published for artistic gymnasts in the literature, with an average VO_2max of 50 ml/kg/min (Jemni, 2011). Although higher average values were reported for the American elite female gymnasts, around 60 ml/kg/min, (Noble, 1975), Jemni (2011) points out that the VO_2max of international level gymnasts reported over the last 50 years remains the same, around 50 ml/kg/min (Jemni, 2011). Barantsev (1985) found out that VO_2max decreases between adolescence and adulthood, with average values dropping from 53.2 ± 6.3 at age 12 to 47.2 ± 6.7 ml/kg/min at age 25 (Barantsev, 1985). Furthermore, Jemni (2011) highlights that this regression is not evident before puberty, and is associated with the higher volume and intensity of training for the strength and power required for difficult technical exercises, specifically in men's gymnastics (Jemni, 2011). The higher percentile scores for the female gymnasts are probably due to the greater average duration of the gymnastics routines (Jemni, Friemel, Le Chevalier, & Origas, 2000). In addition, on three out of the four female gymnastics apparatuses, the lower body is constantly involved, while the exercises on most of the male apparatuses are predominantly concentrated on the upper body.

CONCLUSIONS

Artistic gymnastics improves all health-related components of physical fitness and positively influences children's physical development. Both female and male artistic gymnasts had better physical fitness in most parameters, in comparison to the international norms for their peers.

The results suggest that body fat percentage should be used instead of BMI for gymnasts in order to accurately assess their body composition. Percentile scores of relative handgrip strength and relative upper arm muscle area (UAMA) should be obtained in future research and applied in order to appropriately assess artistic gymnasts.

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