International Journal of Applied Exercise Physiology
2322-3537 www.ijaep.com
Vol.10 No.1

Artistic Gymnastics Improves Biomarkers Related to Physical Fitness and Health at Primary School Age

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ARTICLE INFORMATION
Original Research Paper
Doi:
Received November. 2020
Accepted January. 2021

Keywords:
Alpha-fit,
BMI,
children,
gymnasts,
health.

ABSTRACT

Artistic gymnastics requires the performance of a variety of technical elements on different apparatuses where gymnasts have to overcome their body mass. Maintaining optimal health and a good level of physical fitness is crucial in order to successfully perform the routines. The aim of this study was to assess health and physical fitness related biomarkers in young gymnasts, whilst estimating the benefits of regular gymnastics practice at primary school ages. The study included 90 children, 49 of whom (mean age 9.5 years) were practising artistic gymnastics for at least 2 years with an average of 6 hours per week, and a control group of 41 children (mean age 8.9 years). The participants completed the Alpha-Fit physical fitness test battery (BMI, %Fat, handgrip strength, standing long jump, 4x10m shuttle run test and 20m multistage fitness test). Percentile scores were calculated for the results of each test. The height, body mass, BMI, and %Fat of the male and female gymnasts were significantly lower than those of the control groups ($p<0.001$, with very large effect size $d>1.20$). All gymnasts had their body fat within the norms. The results from the standing long jump test, 4x10m shuttle run test, as well as the 20m shuttle run test, were significantly greater in favour of the gymnasts in comparison to the control groups for both genders ($p<0.001$, $d>1.20$). These findings show that practising artistic gymnastics has a positive impact on the health-related biomarkers of children's physical fitness, and it contributes to sustaining a normal health status.

1. Introduction

Nowadays, millions of children are involved in gymnastics all over the world, and that requires detailed understanding of the health-related benefits in both genders, and particularly at a young age. Unlike other sports, artistic gymnastics requires the performance of a variety of technical elements on different apparatuses where gymnasts have to overcome their body weight and mostly multiply it several times when tumbling and dismounting [22]. Maintaining optimal health and a good level of physical fitness is crucial in order to successfully perform the routines. Assessing the gymnast's physical fitness level, as well as identifying the exact components which need to be developed are both important goals in the coaching practise. Measuring and tracking the biomarkers related to physical fitness can provide information on the impact of the sport on each gymnast's health [10].

The health-related physical fitness has been described in the literature as a multidimensional structure, which includes body composition, musculoskeletal fitness, motor fitness, and cardiorespiratory fitness [2, 3, 51, 52]. It has also been shown in both, cross-sectional and longitudinal studies in Europe, that the health-related physical fitness is a major factor in children's health [50, 52]. The modern field-based test batteries are created on the basis of assessing the biomarkers related to physical fitness and health, and there are more than fifteen physical fitness test batteries for children and adolescents applied around the world [11, 26]. One of the most used fitness test batteries applied in longitudinal and cross-sectional studies on health biomarkers in relation to physical fitness in children, is the Alpha-fit test battery, which has been shown to be valid, reliable and safe [13, 15, 52, 55].

Gymnastics is one of the sports activities which can be practised from a very young age, and children involved in gymnastics are introduced to foundational elements, such as jumping, hanging, rotating, crawling, and rolling [47]. Further understanding of the health-related benefits on both genders in primary school children can benefit not only the coaches involved in gymnastics, but also the physical education teachers, parents and gymnasts as well. Therefore, the aim of this study was to assess health-related biomarkers of physical fitness at primary school age whilst estimating the benefits of regular gymnastics practice at young ages.

2. Methods

2.1. Participants

The study included 49 primary school children (19 boys and 30 girls) who were practising artistic gymnastics with a minimum of 2 years and an average of 4 hours per week, and a control group consisted of 41 children (18 boys and 23 girls). All participants were from the United Kingdom. The gymnasts were from five gymnastics clubs in three different areas (London, Bexhill-On-Sea, and Basingstoke) all registered with British Gymnastics Federation. The control group was from primary school children in London who were not seriously engaged (not more than one session per week) in any sports, apart from their Physical Education lessons.

An informed consent form was obtained from the parents/guardians of all participants prior to this study.

2.2. Health-related physical fitness assessment

All participants completed the Alpha-Fit test battery [2], which includes different anthropometric measurements, such as height, weight, BMI, waist circumference, skinfolds (%Fat), and field-based fitness tests (handgrip strength test, standing long jump, 4x10 m shuttle run test, and the 20 m shuttle run test), which are all related to the children's health. The anthropometric measurements were taken twice, and the mean was used in the analyses, as described in the test manual of the Alpha-fit battery. The handgrip strength test, standing long jump test and 4x10 m shuttle run test were performed twice, and the better score was used in the analyses, whilst the 20 m shuttle run test was performed once [2].

2.2.1. Body composition

Height was measured by using the Leicester Height Measure to the nearest 1 mm. This height measure has become the standard in practice, and has been used extensively and over a period of time in the National Child Measurement Programme in England [19]. Body weight and body fat percent (%Fat) were registered by using Tanita BF-689 Children's Body Fat Monitor, within an accuracy of 50 g. This scale applies the bioelectrical impedance method to assess body composition and has a specialised application for anthropometric measurements of children between the ages of 5 and 18. In addition, two skinfolds (triceps and subscapular) were measured to an accuracy of 1 mm by using the Lange Skinfold Caliper, produced by Beta Technology Inc, Cambridge. The sum of the skinfolds was used to obtain %Fat by applying Slaughter's equations [20, 57], which are recommended for children, as this method is both simple and accurate [2, 9, 35]. Furthermore, recent international norms for Caucasian children [41] were applied to calculate percentiles scores (PRs) of %Fat for each participant, and the following cut-offs were used: %Fat > 85^{th} PRs is classified as 'overweight'; %Fat > 95^{th} PRs is 'obese'; and %Fat < 2^{nd} PRs is 'underfat' [41].

The body mass index (BMI) was calculated as: body mass/height^2 (kg/m^2). The WHO AnthroPlus specialised software, produced by the World Health Organisation [62], was applied in order to calculate the percentile scores of height, weight and BMI of the children. The following classification of the BMI percentile scores was used: BMI > 85^{th} PRs is classified as 'overweight'; BMI > 97^{th} PRs is 'obese'; BMI < 15^{th} PRs is 'thinness'; and BMI < 3^{rd} PRs is 'severe thinness' [60].

Waist and arm circumferences were measured with the Lufkin W606PM tape measure to the nearest 0.1 cm. Waist-to-height ratio (WHtR = waist circumference/height) was calculated, and the recommended cut-off of 0.500 was applied to assess increased health risk in children [4, 40]. The upper arm muscle area (UAMA) was calculated in accordance with two parameters (arm circumference in cm and triceps skinfold in cm) by applying the following formula [1]:

$$\text{UAMA (cm}^2\text{)} = (\text{Arm circumference} - \pi \times \text{triceps skinfold})^2 / 4\pi$$

Furthermore, the percentile scores for the UAMA were also calculated for each participant by using the recent norms for children [1]. In addition, the relative UAMA (cm^2/kg) was obtained by dividing the UAMA (cm^2) by body mass (kg).

Lean body mass (kg) was calculated by subtracting the body fat (kg) from the body weight.

2.2.2. Musculoskeletal fitness

Handgrip strength was measured for both hands by using the TKK digital hand dynamometer (TKK 5101 Grip-D, Takey, Tokyo, Japan) to assess upper body isometric strength. The individual optimal grip span was determined for each participant prior to testing by using the equations for girls and boys between the ages of 6 and 12 [14]. The elbow of the tested hand was fully extended, as this position had been shown to be the most appropriate protocol in order to evaluate maximal handgrip strength in children [27] and in adolescents [16]. The tested hand was free of the body, and the testing procedure was strictly followed [2, 45]. In addition, the relative handgrip strength was also calculated by dividing the average handgrip strength of both hands (kg) by the body weight (kg).

The standing long jump test was recorded to within an accuracy of 1 cm, in order to assess lower body explosive strength. The distance was measured from the take-off line to the point where the back side of the heel lands on the ground, as described in the Alpha-Fit test [2].

Percentile scores for the average handgrip strength and the standing long jump tests were calculated from the existing norm for European children [42, 46]. Unfortunately, there is still a reference gap between 9.9 and 12.9 years without percentile scores in the published norms for those tests, which has to be filled in, in order to appropriately assess children's physical fitness [42]. Therefore, the recently proposed values for the tests from the Alpha-Fit battery [29], which had been obtained by means of a linier interpolation from the existing norms [42, 46, 49, 59] were used in order to calculate the missing percentile scores.

2.2.3. Motor fitness

The 4x10 m shuttle run test (4x10 m SRT) at maximum speed was applied to measure speed of movement, agility and coordination, in accordance with the procedure described in the Alpha-fit test battery [2]. The test was recorded in seconds by using the Fastime 4 Stopwatch, to an accuracy of 0.1 sec. The percentile scores of the results from this test were calculated by using the existing norms [46, 49], and the interpolated values of the 4x10 m SRT [29] for the missing norms between the ages of 9.9 and 12.9.

2.2.4. Cardiorespiratory fitness

The BeepShuttle Junior software for children [32] was applied to administer the 20 m shuttle run test (20 m SRT) with the original 1-minute protocol, which starts at a speed of 8.5 km/h and increases by 0.5 km/h after each minute, as described by Leger et al. [36]. This software facilitates the administration of the 20 m SRT by applying audio signals and visualisation, and calculates the estimated maximal oxygen uptake (VO_2max) by using Leger's equation [37]. In order to assess the VO_2max of the participants, BeepShuttle Junior computed the percentile score for each individual based on age- and gender-specific international norms [42, 59].

2.3. Statistical Analyses

The statistical analyses were conducted by using SPSS Statistics 19, IBM, USA software, using descriptive statistics and the Kolmogorov-Smirnov test of normality. All parameters with a normal distribution were compared by using the independent t-test, and those with an abnormal distribution by utilising the non-parametric Mann-Whitney U 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. Percentile scores were compared to some fixed percentile values, such as 25th, 35th, 40th, 50th, 75th, 85th, and 90th, by using one sample t-test in order to support the results analyses. Cohen's effect size was calculated for the parameters which showed significant differences, and was classified as follow: $d > 2.00$ - huge (H), $d > 1.20$ - very large (VL), $d > 0.80$ - large (L), $d > 0.50$ - medium (M), $d > 0.20$ - small (S), and $d > 0.01$ - very small (VS), [12, 56].

3. Results

The female and male participants in all groups included children from different ages between 7 and 11, and therefore, the comparison between the mean values of the parameters, as well as the calculation of the effect size between the groups, has been analysed by using the percentile scores.

The anthropometric parameters with their corresponding percentile scores (PRs) of the primary school female gymnasts and the female control group are presented in Table 1. There was no significant difference between the mean ages of both groups. The mean percentile scores of the height, weight, BMI and %Fat in the female gymnasts were significantly lower than those in the control group. Moreover, the gymnasts' percentile scores were also lower than the WHO international norms in girls at the same age, significantly lower than the 40th percentile for height (28.9 PRs, $p < 0.05$), and the 50th percentile for weight (37.7 PRs, $p < 0.05$) and BMI (39.2 PRs, $p < 0.05$). The World Health Organization does not produce weight-for-age percentile scores for children over 10 years of age, due to the fact that this indicator cannot distinguish between height and body mass at an age when many children are experiencing the pubertal growth spurt [61].

The mean percentile scores for %Fat in the female gymnasts (12.0 PRs where the %Fat was calculated by Slaughter's equations, and 15.2 PRs where the %Fat was calculated by using the bioelectrical impedance method) were significantly lower than the 25th percentile ($p < 0.05$) in girls at the same age, in accordance with the international norms [41]. In addition, the female gymnasts had significantly lower mean values in comparison with the control group in relation to their arm circumference (20.1 cm vs 23.0 cm, $p < 0.01$), upper arm muscle area (24.4 cm^2 vs 27.2 cm^2, $p > 0.05$), and lean body mass (23.6 kg vs 29.0 kg, $p < 0.01$). This is probably due to the fact that the gymnasts had significantly smaller body sizes, such as height, weight and circumferences. On the other hand, the female gymnasts had significantly higher relative upper arm muscle area (0.91 cm^2/kg vs 0.73 cm^2/kg), which is probably a reflection of their higher muscle mass per unit weight.

The mean waist-to-height ratio (WHtR) of the female gymnasts, as well as the individual values of WHtR for all 30 girls engaged in artistic gymnastics, were below the boundary of 0.500, which distinguishes children at risk as far as their health is concerned [4, 40]. In contrast, five of the twenty-three girls from the control group had their WHtR above the value of 0.500.

The individual percentile scores of the anthropometric parameters in the group of female gymnasts showed that there are no 'obese' children, and only one gymnast was below the normal limits for her age (BMI < 3rd PRs, 9.8% Fat, %Fat > 2nd PRs). Additionally, only one of the 30 female gymnasts was assessed as 'overweight' (BMI = 91.7 PRs, 27.4% Fat assessed by the bioelectrical impedance method, %Fat = 85.5 PRs). However, the same gymnast showed lower values of those parameters when assessed by Slaughter's skinfold method (20.5% Fat calculated by Slaughter's equations, %Fat = 60.2 PRs), and the WHtR was not above the boundary of 0.500. Furthermore, her upper arm muscle area (37.0 cm^2) was the greatest in the group, and her relative upper arm muscle area (0.96 cm^2/kg) was above the mean for the group of female gymnasts. Therefore, the BMI did not provide an adequate assessment, due to the large amount of muscle mass in this individual, and probably the body fat monitor for children (Tanita BF-689) did not adequately assess the %Fat in some children with greater muscle mass.

Table 1. *Anthropometric parameters and the corresponding percentile scores (PRs) of the female artistic gymnasts (n=30) and the control group of primary school girls (n=23), (mean ± SD), in addition to the effect size vs the control group*

	Female gymnasts (n=30)	**Control group Females** (n=23)	p	Effect size vs Control group
Age (years)	**9.37** ± 1.35	**9.03** ± 0.54	p > 0.05^x	
Sports experience (months)	**44.90** ± 17.96	**-**	-	
Sessions per week	**2.93** ± 1.05	**-**	-	
Height (cm)	**130.60** ± 7.36	**139.92** ± 9.07	**p < 0.001***	
Height – percentile score	**28.88** ± 23.45	**75.07** ± 30.76	**p < 0.001^x**	**1.72** VL
Weight (kg)	**27.18** ± 4.61	**37.81** ± 10.01	**p < 0.001***	
Weight – percentile score (n=21; 23)[a]	**37.71** ± 22.81	**80.93** ± 25.94	**p < 0.001^x**	**1.76** VL
BMI (kg/cm^2)	**15.83** ± 1.45	**19.08** ± 3.51	**p < 0.001***	
BMI – percentile score	**39.18** ± 23.55	**74.37** ± 26.37	**p < 0.001^x**	**1.42** VL
Arm circumference (cm)	**20.11** ± 1.57	**22.97** ± 3.31	**p < 0.01^x**	
Waist circumference (cm)	**55.28** ± 3.19	**64.22** ± 8.53	**p < 0.001***	
Waist-to-height ratio	**0.41** ± 0.03	**0.47** ± 0.06	**p < 0.001^x**	
Subscapular skinfold (mm)	**5.32** ± 1.62	**11.94** ± 6.26	**p < 0.001^x**	
Triceps skinfold (mm)	**8.42** ± 1.76	**14.68** ± 5.59	**p < 0.001^x**	
%Fat (Slaughter)	**13.21** ± 2.47	**22.13** ± 5.99	**p < 0.001***	
%Fat (Slaughter) percentile score	**12.02** ± 14.00	**63.31** ± 33.98	**p < 0.001^x**	**2.08** H
%Fat (TANITA for children)	**16.48** ± 3.99	**26.09** ± 7.42	**p < 0.001***	
%Fat (TANITA) percentile score	**15.15** ± 20.05	**63.55** ± 35.66	**p < 0.001^x**	**1.74** VL
UAMA (cm^2)	**24.42** ± 4.42	**27.18** ± 6.38	p > 0.05^x	
UAMA - percentile score	**66.46** ± 23.38	**78.14** ± 22.19	**p < 0.05^x**	**0.51** M
Relative UAMA (cm^2/kg)	**0.91** ± 0.12	**0.73** ± 0.09	**p < 0.001^x**	
Lean Body Mass (kg)	**23.56** ± 3.82	**29.02** ± 6.09	**p < 0.01***	

[a] - WHO does not provide weight-for-age reference data for children older than 10 years of age [61]

** - compared by using the t-test for independent samples*

[x] - compared by using the Mann-Whitney U test for independent samples

H – huge effect size, VL - very large, M - medium

The mean percentile scores for height, weight and BMI in the control group are above the average for this age (significantly higher than the 50th PRs, $p < 0.001$), but within the WHO norms. Moreover, the mean percentile score of %Fat is also within the norm (> 2nd PRs and < 85th PRs), as provided for children [41], and the mean WHtR is below the boundary of 0.500.

The individual percentile scores of the anthropometric parameters in the control group showed that nine of the primary school girls (39.1%) were 'overweight' (BMI > 85th PRs, %Fat > 85th PRs), one of whom had her WHtR above 0.500. Four of the girls (17.4%) in this group were assessed as 'obese' (BMI > 97th PRs, %Fat > 95th PRs), three of whom had their WHtR above the boundary of 0.500, which is linked to a risk as far as their health is concerned.

Table 2. *Results from the Alpha-Fit health-related physical fitness tests, and the corresponding percentile scores of the female artistic gymnasts (n=30) and the control group of primary school girls (n=23), (mean ± SD)*

	Female gymnasts (n=30)	**Control group Females** (n=23)	p	Effect size vs Control group
Musculoskeletal Fitness: Upper body strength				
Handgrip strength test† (kg)	**14.18** ± 2.97	**16.45** ± 4.13	p > 0.05^x	
Handgrip strength test (percentile score)	**54.10** ± 29.24	**75.83** ± 26.44	**p < 0.01^x**	**0.77** M
Relative handgrip strength (kg/kg body weight)	**0.52** ± 0.07	**0.45** ± 0.11	**p < 0.01^x**	
Musculoskeletal Fitness: Lower body strength				
Standing long jump (cm)	**154.61** ± 16.81	**123.48** ± 21.70	**p < 0.001***	
Standing long jump (percentile score)	**92.25** ± 11.65	**55.55** ± 31.00	**p < 0.001^x**	**1.66** VL
Motor Fitness				
4x10 m shuttle run test (sec)	**11.97** ± 0.71	**13.88** ± 1.25	**p < 0.001***	
4x10 m shuttle run test (percentile score)	**91.01** ± 10.31	**52.37** ± 28.04	**p < 0.001^x**	**1.93** VL
Cardiorespiratory Fitness				
VO_2max (ml/kg/min)	**52.06** ± 4.17	**45.88** ± 2.08	**p < 0.001^x**	
VO_2max (percentile score)	**89.26 ± 17.08**	**54.12** ± 22.34	**p < 0.001^x**	**1.80** VL

† - values expressed as average of right and left hands

** - compared by using the t-test for independent samples*

^{x} - compared by using the Mann-Whitney U test for indipendent samples

VL - very large effect size, M - medium

The results from the health-related physical fitness tests, as well as the corresponding percentile scores of the primary school female gymnasts and the control group, are presented in Table 2. The female gymnasts showed approximately equal values of handgrip strength in their left and right hands (14.1 ± 3.15 kg vs 14.2 ± 3.05 kg, $p > 0.05$). The girls from the control group showed a greater difference in handgrip strength between their left and right hands (16.8 ± 4.18 kg vs 16.1 ± 4.31 kg, $p > 0.05$). The female gymnasts had a lower average (of both hands) handgrip strength in comparison with the control group (14.2 ± 2.97 kg vs 16.5 ± 4.13 kg, $p > 0.05$), as well as a lower percentile score relating to handgrip strength (54.1 ± 29.24 kg vs 75.8 ± 26.44 kg, $p < 0.01$), as shown in Table 2. This is due to the greater weight and height of the girls in the control group. However, the female gymnasts had a significantly higher relative handgrip strength of both hands (0.52 ± 0.07 kg/kg body weight for the gymnasts vs 0.45 ± 0.11 kg/kg body weight for the control group, $p < 0.01$, Table 2), as well as a significantly higher relative upper arm muscle area (0.91 cm^2/kg vs 0.73 cm^2/kg, $p < 0.001$, Table 1), which confirms that the gymnasts had better strength parameters in relation to their body weight.

The lower body strength, assessed with the standing long jump, was significantly higher in favour of the female gymnasts in comparison with the control group (154.6 ± 16.81 cm vs 123.5 ± 21.70 cm, respectively, $p < 0.001$). The mean percentile score of this parameter is also significantly higher in favour of the gymnasts (92.3 ± 11.65 vs 55.6 ± 31.00, $p < 0.001$), and it is even significantly higher than the 85th percentile ($p < 0.01$) than the European norms for girls at the same age. The individual results showed that 24 out of the 30 female gymnasts had percentile scores higher than 90.

The motor fitness, assessed with the 4x10 m shuttle run test, showed significantly better results in favour of the female gymnasts in comparison with the girls from the control group (12.0 ± 0.71 sec vs 13.9 ± 1.25 sec, respectively, $p < 0.001$). The mean percentile score of the 4x10 m shuttle run test was significantly higher in the girls engaged in gymnastics (91.0 ± 10.31 vs 52.4 ± 28.04, $p < 0.001$), and similarly to the standing long jump test, the gymnasts had significantly higher percentile score ($p < 0.01$) than the 85th percentile of the European norms. The individual results revealed that 21 of the 30 gymnasts had percentile scores higher than 90, which is probably due to the develop motor skills from the gymnastics training.

The cardiorespiratory fitness, assessed with the 20 m shuttle run test, showed significantly better maximal oxygen uptake (VO_2max) in favour of the female gymnasts in comparison with the control group (52.1 ± 4.17 ml/kg/min vs 45.9 ± 2.08 ml/kg/min, respectively, $p < 0.001$). The mean percentile score of the VO_2max was also significantly higher in the group of the gymnasts (89.3 ± 17.08 vs 54.1 ± 22.34, $p < 0.001$), and it was significantly higher ($p < 0.01$) than the 80th percentile of the European norms for girls at that age.

The individual results of the VO_2max, showed that 25 out of 30 gymnasts had percentile scores higher than 80, which suggests that in spite of the anaerobic nature of this sport, the artistic gymnastics training in young age (7-11-year-old gymnasts) improves the aerobic fitness in girls.

Table 3. *Anthropometric parameters and their percentile scores (PRs) of the male artistic gymnasts (n=19) and the control group of primary school boys (n=18), (mean ± SD), in addition to the effect size vs the control group*

	Male gymnasts (n=19)	**Control group Males** (n=18)	p	Effect size vs Control group
Age (years)	**9.69** ± 1.49	**8.79** ± 0.52	**p < 0.05***	
Sports experience (months)	**48.42** ± 21.01	**-**	-	
Sessions per week	**3.05** ± 1.08	**-**	-	
Height (cm)	**133.26** ± 7.62	**136.56** ± 6.96	p > 0.05*	
Height – percentile score	**33.94** ± 18.60	**73.13** ± 19.38	**p < 0.001***	**2.06** H
Weight (kg)	**28.88** ± 4.39	**37.09** ± 6.86	**p < 0.001***	
Weight – percentile score (n=10; 18)[a]	**41.01** ± 19.97	**88.58** ± 14.45	**p < 0.001ˣ**	**2.87** H
BMI (kg/cm^2)	**16.17** ± 1.02	**19.83** ± 2.97	**p < 0.001***	
BMI – percentile score	**43.42** ± 21.26	**86.94** ± 17.63	**p < 0.001ˣ**	**2.22** H
Arm circumference (cm)	**20.27** ± 1.66	**22.84** ± 2.50	**p < 0.01***	
Waist circumference (cm)	**57.65** ± 3.71	**66.19** ± 6.78	**p < 0.001***	
Waist-to-height ratio	**0.42** ± 0.04	**0.49** ± 0.05	**p < 0.001ˣ**	
Subscapular skinfold (mm)	**4.45** ± 0.89	**13.11** ± 6.31	**p < 0.001ˣ**	
Triceps skinfold (mm)	**7.12** ± 1.88	**14.22** ± 9.07	**p < 0.01***	
%Fat (Slaughter)	**10.69** ± 2.85	**23.72** ± 8.63	**p < 0.001***	
%Fat (Slaughter) percentile score	**23.04** ± 20.20	**82.82** ± 23.29	**p < 0.001ˣ**	**2.75** H
%Fat (TANITA for children)	**14.88** ± 2.09	**25.08** ± 7.21	**p < 0.001***	
%Fat (TANITA) percentile score	**23.17** ± 21.17	**78.88** ± 29.32	**p < 0.001ˣ**	**2.19** H
UAMA (cm^2)	**25.95** ± 3.85	**27.12** ± 5.41	p > 0.05*	
UAMA - percentile score	**67.30** ± 18.88	**80.91** ± 24.66	**p < 0.05ˣ**	**0.62** M
Relative UAMA (cm^2/kg)	**0.91** ± 0.08	**0.77** ± 0.17	**p < 0.01ˣ**	
Lean Body Mass (kg)	**25.72** ± 3.58	**27.83** ± 3.18	p > 0.05*	

[a] - WHO does not provide weight-for-age reference data for children older than 10 years of age [61]

** - compared by t-test for independent samples*

ˣ - compared by Mann-Whitney U test for indipendent samples

H – huge effect size, M - medium

The anthropometric parameters and their percentile scores of the male gymnasts vs the control group are presented in Table 3. Although, there is a difference of nearly one year between the mean age of the groups, they were compared based on the calculated age- and gender-specific percentile scores for each parameter. Similarly, to the female gymnasts, the mean percentile scores of the height, weight, BMI and %Fat in the male gymnasts were significantly lower from those of the control group. Moreover, the mean percentile scores (PRs) of those parameters in the male gymnasts were also lower than the 50th percentile of the WHO norms for boys in the same age (weight PRs = 41.0, $p > 0.05$; BMI PRs = 43.4, $p > 0.05$; height PRs = 33.9, $p < 0.01$).

The mean percentile scores of %Fat in the male gymnasts (23.0 based on the results from the skinfold method, and 23.3 based on the bioelectrical impedance) were significantly lower than the 35th percentile ($p < 0.05$) in boys at the same age as provided by the international norms in children [41].

Similarly, to the female gymnasts, the male gymnasts had lower mean values of their arm circumference (20.3 cm vs 22.8 cm, p < 0.01), upper arm muscle area (26.0 cm^2 vs 27.1 cm^2, p > 0.05), and body lean mass (25.7 kg vs 27.8 kg, p > 0.05) in comparison with the control group. This is due to the smaller body sizes (weight and circumferences) in the children engaged in artistic gymnastics. However, the male gymnasts had significantly greater relative upper arm muscle area in contrast to the control group (0.91 cm^2/kg vs 0.77 cm^2/kg, respectively, p < 0.01). Those findings show that the children practising gymnastics have greater muscle mass of their arms per unit of weight.

The individual percentile scores of the BMI in male gymnasts showed that none of the boys was classified as 'obese', and only one gymnast had a percentile score of 85 which is in the lower 'overweight' cut off. However, this gymnast had low %Fat (14.1% calculated with the bioelectrical impedance method, and 13.9% calculated by the skinfold method), low percentile scores of %Fat (9.0 and 8.7, respectively), and the WHtR was not greater than the accepted 0.500 cut off. Moreover, he had the highest upper arm muscle area in the group of the male gymnasts (33.4 cm^2), and his relative upper arms muscle area was 0.86 cm^2/kg, which was close to the mean of his group. In this case, the BMI score was not accurate, due to the greater muscle mass, which cannot be assessed appropriately in athletes from the strength sports [8].

The mean percentile score of the BMI in the control group (87.0) was assessed as 'overweight' and was significantly higher than the 50^{th} percentile of the WHO norms for boys. The individual results showed that 5 of the 18 boys (2.8%) in the control group were 'overweight' (BMI > 85^{th} PRs), and 3 of those 5 boys had high %Fat (%Fat > 85^{th} PRs). Moreover, 7 boys (38.8%) from the control group were assessed as 'obese' (BMI > 97^{th} PRs), 6 of whom had %Fat > 95^{th} PRs.

Table 4. *Results from the Alpha-Fit health-related physical fitness tests, and their percentile scores of the male artistic gymnasts (n=19) and the control group of primary school boys (n=18), (mean ± SD)*

	Male gymnasts (n=19)	**Control group Males** (n=18)	p	Effect size vs Control group
Musculoskeletal Fitness: Upper body strength				
Handgrip strength test† (kg)	**16.91** ± 3.44	**15.42** ± 2.90	p > 0.05*	
Handgrip strength test (percentile score)	**58.60** ± 18.62	**66.37** ± 24.34	p > 0.05*	NS
Relative handgrip strength (kg/kg body weight)	**0.58** ± 0.08	**0.42** ± 0.08	**p < 0.001***	
Musculoskeletal Fitness: Lower body strength				
Standing long jump (cm)	**176.78** ± 22.44	**124.56** ± 23.04	**p < 0.001***	
Standing long jump (percentile score)	**96.24** ± 4.36	**45.72** ± 30.28	**p < 0.001**^{x}	**2.37** H
Motor Fitness				
4x10 m shuttle run test (sec)	**11.18** ± 0.89	**13.36** ± 1.08	**p < 0.001***	
4x10 m shuttle run test (percentile score)	**92.41** ± 6.09	**49.44** ± 25.25	**p < 0.001***	**2.37** H
Cardiorespiratory Fitness				
VO_2max (ml/kg/min)	**53.98** ± 3.93	**46.36** ± 2.67	**p < 0.001**^{x}	
VO_2max (percentile score)	**88.63** ± 15.89	**43.13** ± 21.56	**p < 0.001**^{x}	**2.41** H

† - values expressed as average of right and left hands

** - compared by t-test for independent samples*

^{x} *- compared by Mann-Whitney U test for indipendent samples*

H – huge effect size;

NS – not significant

The results of the health-related physical fitness tests and their corresponding percentile scores in the male gymnasts and the control group are presented in Table 4. The male gymnasts showed 1 kg non-significant difference in the handgrip strength values of left vs right hands (16.4 ± 3.54 kg vs 17.4 ± 3.42 kg, respectively, $p > 0.05$), with the highest individual difference of 2.5 kg. The control group also showed a difference of 1 kg between left and right hands (14.9 ± 3.11 kg vs 15.9 ± 2.92 kg, respectively, $p > 0.05$), but those boys had greater individual differences reaching 4.8 kg.

There were no significant differences between the mean handgrip strength expressed as average of right and left hands (16.9 ± 3.44 kg for the gymnasts vs 15.4 ± 2.90 kg for the control group, $p > 0.05$) and their mean percentile scores (58.6 ± 18.62 kg for the gymnasts vs 66.4 ± 24.34 kg for the control group, $p > 0.05$), as shown in Table 4. However, the male gymnasts had significantly higher relative handgrip strength (0.6 ± 0.08 kg/kg body weight vs 0.4 ± 0.08 kg/kg body weight, $p < 0.001$).

As it was the case with the female gymnasts, the lower body strength, assessed with the standing long jump, was also significantly higher in favour of the male gymnasts in comparison with the control group (176.8 ± 22.44 cm vs 124.6 ± 23.04 cm, respectively, $p < 0.001$). The mean percentile score of the standing long jump test was also significantly higher in favour of the male gymnasts (96.2 ± 4.36 vs 45.7 ± 30.28, $p < 0.001$), and it was significantly higher than the 90th percentile ($p < 0.001$) of the European norms for boys at the same age. The individual results showed that 17 out of the 19 male gymnasts had percentile scores higher than 90.

The 4x10 m shuttle run test showed significantly better results in favour of the male gymnasts in comparison with the boys from the control group (11.2 ± 0.89 sec vs 13.4 ± 1.08 sec, respectively, $p < 0.001$). The mean percentile score of the 4x10 m shuttle run test was significantly higher in the boys practising gymnastics (92.4 ± 6.09 vs 49.4 ± 25.25, $p < 0.001$), and the male gymnasts also had significantly higher percentile score ($p < 0.001$) than the 85th percentile of the European norms. The individual results of the motor fitness showed that 14 of the 19 male gymnasts had percentile scores higher than 90.

The cardiorespiratory fitness, assessed by the 20 m shuttle run test, using the BeepShuttle Junior software [32], showed significantly higher maximal oxygen uptake (VO_2max) in favour of the male gymnasts in comparison with the control group (54.0 ± 3.93 ml/kg/min vs 46.4 ± 2.67 ml/kg/min, respectively, $p < 0.001$). The mean VO_2max percentile score was also significantly higher in the group of the gymnasts (88.6 ± 15.89 vs 43.1 ± 21.56, $p < 0.001$), and it was significantly higher ($p < 0.01$) than the 75th percentile of the norms for boys at that age. The individual results of the 20 m shuttle run test, showed that 15 out of 19 male gymnasts had percentile scores higher than 80.

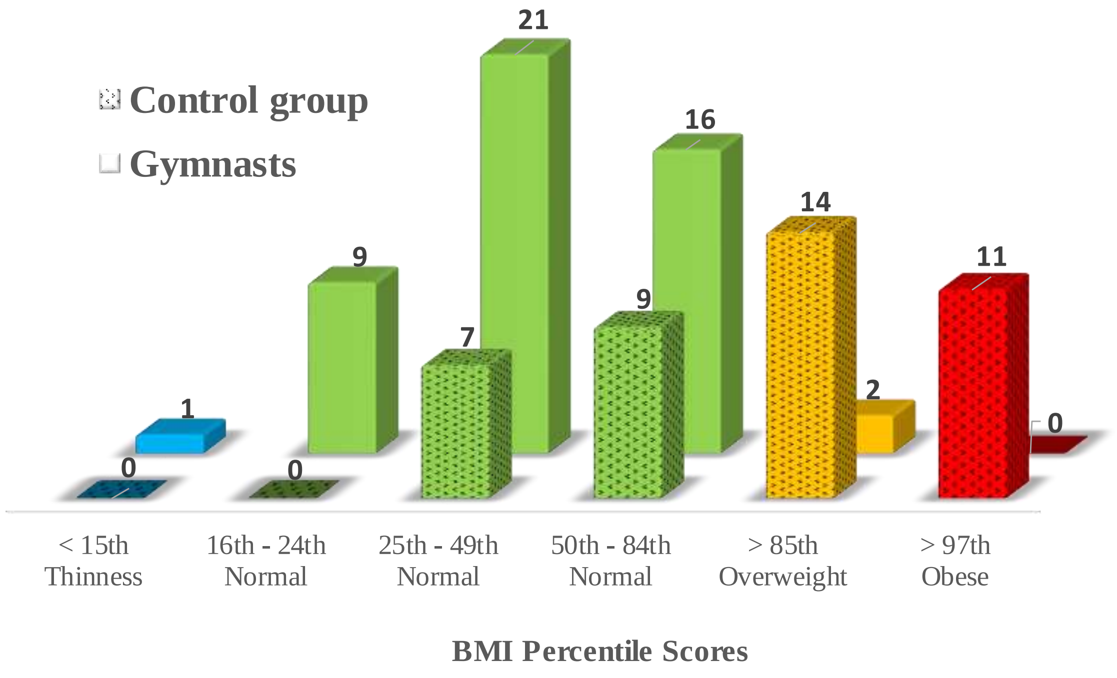

***Figure 1.** Distribution of the BMI percentile scores in the artistic gymnasts (boys and girls together, n=49) and the control group (n=41)*

The distribution of the BMI percentile scores for all gymnasts (boys and girls, n=49) and the control groups (boys and girls, n=41) are presented in Figure 1. The results showed that 46 out of the 49 artistic gymnasts had their BMI within the norms, and the other 3 gymnasts have been discussed in this article. These findings show that the gymnastics training in childhood, both in boys and girls, contributes to maintaining a normal weight, and thereby sustaining a normal health status.

Sixteen out of the forty-one primary school children in the control group had their BMI within the WHO norms. The percentile scores of the other 25 children were above the 85th percentile (14 children were assessed as 'overweight', and 11 as 'obese'), and 10 of those children had their WHtR above the 0.500 cut off, and the %Fat was greater than the 95th PRs, all of which identified them as children at risk, as far as their health is concerned.

4. Discussion

The percentile scores of the main anthropometric parameters, including height, weight, BMI, arm and waist circumferences, and %Fat in the male and female gymnasts were significantly lower than those of the control groups (Table 1 and Table 3). Moreover, the mean percentile scores (PRs) of height and %Fat in the gymnasts were also lower than the 50th percentile of the WHO norms for children at the same age and from the same gender. However, such lower mean values are within the published results in children engaged in gymnastics [6, 21, 25, 31, 34]. Although gymnasts are shorter on average and their height-for-age progressively decreases as the age increases [7, 25], review on the role of training on the growth of the gymnasts concluded that 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 [39].Thus, artistic gymnastics plays an unique role as a sport which provides opportunities for those with smaller body sizes in a world where many sports are biased in favour of tall or big athletes [54]. Although having smaller body sizes, the boys and the girls practising gymnastics showed significantly higher relative upper arm muscle area in comparison with the control groups (Table 1 and Table 3), which highlights their greater muscle mass per unit of body weight.

On the whole, the percentile scores of the BMI provided an accurate assessment of the groups (Figure 1), but failed to appropriately evaluate the body composition of individual gymnasts with greater muscle mass. Although widely used for the assessment of body composition [17, 24, 48], the BMI has shown to be inappropriate for professional athletes [8], adolescent athletes [38], and individual cases of child athletes with greater muscle mass [28, 31, 33]. Therefore, the %Fat and strength parameters (relative upper arm muscle area and relative handgrip strength) should be mainly used in the anthropometric analyses of artistic gymnasts.

The gymnastics training contributes to the maintaining of normal weight (Figure 1), and helps sustaining a normal health status both in boys and girls involved in this sport. The %Fat was very low, both in female and male artistic gymnasts (Table 1 and Table 3), which is normal for children and adolescents involved in gymnastics [21]. The values of %Fat from our study are similar to those reviewed by Benardot (2014), where the average %Fat for children and adolescents practising gymnastics ranged from 9% to 22% [6].

The results showed that around 61% of the children in the control groups were 'overweight' or 'obese', which is even higher than the 30-45% overweight/obesity rate reported in the literature [18, 53]. This high percent of children with excess weight in the control groups is probably due to the lack of engagement in enough physical activities in their lifestyle.

The wide application of the physical fitness test battery 'Alpha-Fit' provided an excellent opportunity to compare the health-related fitness levels between the groups in this study, as well as the participants and children from different countries around the world based on age- and gender-specific international norms.

The artistic gymnasts showed approximately equal values of their handgrip strength in left and right hands, which was more evidently in the female gymnasts (14.1 ± 3.15 kg for left vs 14.2 ± 3.05 kg for right hand, $p > 0.05$). These findings of body symmetry are in accordance with our previous study in children engaged in artistic gymnastics [30, 33]. Although, there were no significant differences between the mean handgrip strength (expressed as average of right and left hands) between the gymnasts and the control group for both genders in our study, the gymnasts actually had significantly higher relative handgrip strength, as well as relative upper arm muscle area (Table 1 and Table 3). These findings show that the children practising artistic gymnastics have better relative strength parameters in addition to a greater muscle mass per unit body weight. Percentile scores of such parameters (relative handgrip strength and relative upper arm muscle area) should be obtained in future research in order to appropriately assess artistic gymnasts.

The lower body strength, assessed by the standing long jump test, was significantly greater in favour of the gymnasts in comparison with the control groups for both genders, and 84% of all artistic gymnasts had percentile scores higher than the 90^{th} percentile of the international norms, which is probably due to the well-developed muscles of their lower limbs from the gymnastics training (especially from the exercises on floor and vault), as well as the familiarisation of the standing long jump technique, which is often used in testing gymnasts [21].

The motor fitness, assessed with the 4x10 m shuttle run test, was also significantly better in favour of the gymnasts in comparison with the control group for both genders (Table 2 and Table 4), and 71% out of all artistic gymnasts had percentile scores higher than the 90^{th} percentile of the international norms. These findings suggest that children from both genders develop better motor fitness, including agility, coordination, and speed of movement, as a result of practising artistic gymnastics. The 4x10 m shuttle run test has shown to have a high correlation with the standing long jump test in a sample of young artistic gymnasts, who completed the Alpha-Fit test battery ($r = -0.73$, $p < 0.001$ and -0.83, $p < 0.001$ for girls and boys, respectively), and those gymnasts showed the largest registered Cohen's effect size for these two tests in the groups with greater experience in gymnastics [25]. Additionally, children and adolescents practising rhythmic gymnastics also achieved their best results in those two tests, after completing the Alpha-fit battery [44].

The cardiorespiratory fitness, assessed with the 20 m shuttle run test, showed significantly better absolute results and percentile scores in favour of the gymnasts for both genders in comparison with the control groups (Table 2 and Table 4). The mean VO_2max for the female and male gymnasts in our study (52.1 ± 4.17 ml/kg/min and 54.0 ± 3.93 ml/kg/min, respectively) were close to the published values of VO_2max for gymnasts (around 50 ml/kg/min) in different studies in the literature [5, 23, 43, 58]. Moreover, Jemni (2011) found out that the VO_2max values in elite and non-elite gymnasts (50 ml/kg/min on average) have not changed in the last few decades [21]. Furthermore, Barantsev (1985) registered VO_2max values of gymnasts at different ages, and found out that the VO_2max values gradually decrease from 53.2 ± 6.3 ml/kg/min for 12-year-old gymnasts to 50.9 ± 6.2 ml/kg/min for 14-15-year old gymnasts, and to 47.2 ± 6.7 ml/kg/min for 25-year-old male gymnasts [5]. According to Jemni (2011), this decrease in VO_2max, which is visible after puberty in gymnasts, is due to the prevalence of intense strength training, required to master the complex technical elements from the routines of the male gymnasts [21].

The individual results of the 20m shuttle run test in the gymnasts showed that 82% of all gymnasts had percentile scores higher than 80, which suggests that in spite of the anaerobic nature of this sport, the artistic gymnastics training in young age (7-11-year-old gymnasts) improves the cardio-respiratory fitness both in boys and girls compared to non-particularly active children. Although most of the literature confirm that gymnastics practice doesn't improve maximal oxygen uptake in adult gymnasts [23], the difference we found in our study could be because of the young age of our groups, hence these gymnasts were still in young developmental stages.

5. Conclusions

Practising artistic gymnastics maintains children's weight in the normal limits, and has a positive impact on all of the health-related biomarkers of their physical fitness. The children engaged in gymnastics (both boys and girls) had significantly better physical fitness variables, in comparison with the control groups, as well as the international norms for children in the same age and from the same gender.

The skinfold method using Slaughter's equations, as well as the bioelectrical impedance method (by using Tanita BF-689 for children) are both appropriate for the assessment of %Fat in children, but the body fat monitor (Tanita) might not take into consideration the specific nature of the body composition in child athletes in separate cases. Body fat percentage should be used as part of anthropometric assessments, as well as relative parameters for strength per unit of body weight (relative handgrip strength and relative upper arm muscle area) should be applied for gymnasts instead of the absolute ones, in order to accurately assess their health-related physical fitness. Percentile scores for relative handgrip strength and relative upper arm muscle area in children should be obtained in future research.

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