Cardiorespiratory capacity and body composition in girls and adolescents practitioners of Rhythmic Gymnastics

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Summary

Introduction: Aerobic capacity is one of the qualities to be developed in rhythmic gymnastics sport which requires huge physical and technical demands, with high loads of training.
Objective: To analyze cardiorespiratory capacity and VO_2max and its relation to body composition: body mass index (BMI), fat percentage, waist circumference in girls and adolescents practicing rhythmic gymnastics
Method: Descriptive, comparative, cross-sectional study involving 116 competition gymnasts between 8 and 17 years old (48.3% were girls and 51.7% were adolescents). For the evaluation of the cardiorespiratory ftness, the Navette Course test was applied, calculating the VO_2max with the results obtained. Body weight, height, waist circumference, sub-scapular folds and triceps were measured. The body mass index (BMI) was calculated with weight and height, with the measures of the folds the percentage of fat and with the waist circumference the waist height ratio (WHR).
Results: 13.8%, and 23.3% of the total sample showed very high aerobic capacity, and high respectively. Significant differences were found between the two age groups for the Course-Navette test (U = 1214.0 p =.009 r = 2.60) and for VO_2max (U = 300.0 p =.000 r = 7.60). The adolescents gymnasts presented greater aerobic capacity than the girls. Adolescents showed a correlation with BMI (p =.006) and weight (p=.014). The gymnasts showed a WHR lower than 0.55, all factors related to a better cardiovascular profile
Conclusions: Gymnasts in general have good aerobic capacity. The Adolecents showed higher levels of aerobic capacity than girls. All have a BMI, waist circumference and fat percentage below the referenced values.

Key words:
Cardiovascular capacity. VO_2max. Body mass index. Fat percentage. Rhythmic gymnastic.

Capacidad cardiorrespiratoria y composición corporal en niñas y adolescentes practicantes de gimnasia rítmica

Resumen

Introducción: La capacidad aeróbica es una de las cualidades a desarrollar en gimnasia rítmica, deporte que requiere grandes exigencias físicas y técnicas, con elevadas cargas de entrenamiento.
Objetivo: Analizar la capacidad cardiorrespiratoria y el VO_2Max y su relación con la composición corporal: índice de masa corporal (IMC), porcentaje graso, perímetro de cintura en niñas y adolescentes practicantes de gimnasia rítmica.
Método: Estudio descriptivo, comparativo, de corte transversal donde participaron 116 gimnastas de competición entre 8 y 17 años (el 48,3% eran niñas y 51,7 % adolescentes). Para la evaluación de la capacidad cardiorrespiratoria se aplicó el test Course Navette calculándose el VO_2max con los resultados obtenidos. Para la composición corporal se midió el peso, altura, perímetro de cintura, pliegues sub-escapular y tríceps. Con el peso y la altura se calculó el índice de masa corporal, con las medidas de los pliegues el porcentaje de grasa y con el perímetro de cintura la razón cintura estatura (RCE).
Resultados: El 13,8%, y 23,3% de la muestra total mostraron una capacidad aeróbica muy alta, y alta respectivamente. Se encontró diferencias significativas entre los dos grupos de edad para el test Course-Navette (U = 1.214,0 p = 0,009, r = 2,60) y para el VO_2max (U = 300,0 p = 0,000, r = 7,60). Las gimnastas adolescentes presentaron mayor capacidad aeróbica que las niñas. Las adolescentes mostraron una correlación con el IMC (p = 0,006) y el peso (p = ,014). Todas mostraron un RCE menor que 0,55, factores todos relacionados con un mejor perfil cardiovascular.
Conclusiones: Las gimnastas en general presentan buena capacidad aeróbica. Las adolescentes mostraron mayores niveles de capacidad aeróbica que las niñas. Todas tienen un IMC, perímetro de cintura y porcentaje graso por debajo de los valores referenciados.

Palabras clave:
Capacidad cardiovascular. VO_2max. Índice de masa corporal. Porcentaje graso. Gimnasia rítmica.

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Introduction

Aerobic capacity is one of the main health-related components of physical fitness[1] and is key to sports activities.

Rhythmic gymnastics is a highly taxing sport, both physically and technically, which calls for a high level of training[2]. It is, therefore, imperative for gymnasts to be healthy and in optimum overall physical shape in order to pursue it.

For Douda *et al*.,[3] anthropometric characteristics and aerobic capacity are, alongside flexibility and explosive strength, significant determinants of successful performance for these gymnasts.

Several studies have shown that cardiorespiratory fitness is the strongest predictor of mortality and morbidity[4]. It has also been demonstrated that low cardiorespiratory capacity represents the most important cardiovascular risk factor, even surpassing such classics as excess weight or obesity[5].

There exists evidence of a direct relationship between low cardiorespiratory capacity in childhood and adolescence, and an increased risk of cardiovascular diseases in later life[5-8].

Hence the growing interest in improving the cardiovascular fitness of the school population in recent years[9-11]. Numerous studies have found a relationship between levels of cardiorespiratory fitness and different components of physical fitness: body composition, muscular strength, flexibility, speed-agility and coordination[12.13].

Many of these studies also indicate that a build-up of fat in the abdominal region would also appear to be a contributory factor for possible cardiovascular diseases[14.15].

However, few studies have been conducted with gymnasts specializing in this sport[2,3].

The aim of this study, therefore, was to analyse the cardiorespiratory capacity and VO_2max of pre-adolescent and adolescent rhythmic gymnasts and see their relationship with body composition: body mass index and fat percentage.

Material and method

Subjects

A total of 116 female competition gymnasts belonging to 5 clubs in 4 provinces of Andalucía who took part in the 2015 national championship were selected intentionally. 48.3% were pre-adolescents between 8 and 12 years of age, and 51.7% were adolescents of between 13 and 17. They all participated on a voluntary basis with the informed consent of their parents in accordance with the Declaration of Helsinki on ethical principles for research and following current Spanish legislation regulating medical research involving human subjects (Royal Decree 561/1993 on clinical trials).

Procedure

First of all, we spoke with the coaches and parents at the different clubs to inform them about the objective of the study and ask them for their informed consent.

The authors of the work then went to different provinces of Andalucía: Granada, Málaga, Seville and Huelva. The tests were conducted at each gymnast's training facility. Before starting the training session, body composition measurements were taken in the following order: height, weight, waist circumference and subscapular and triceps skinfolds of all the gymnasts. The protocol established by the International Society for the Advancement of Kinanthropometry was followed for all the measurements taken[16]. The body mass or Quetelet index (kg/m^2) was calculated with the weight and height. Because our populations consisted of pre-adolescent - adolescent girls, we used the indicators proposed by Pan and Cole, cited in Cole *et al*. [17]: grade 3 thinness (<16); grade 2 thinness (16.1 to 17); grade 1 thinness (17.1 to 18.5); normal (18.5 to 24.9); overweight (25 to 30); and obesity (≥30). The skinfold measurements (triceps and subscapular) were used to calculate the body fat percentage by application of the formula associated with the *ALPHA-Fitness* test battery. The subjects' waist-to-height ratios (WHtR), obtained by dividing waist circumference by height, both in centimetres, were used as an indication of the build-up of body fat in the central part of the body, a ratio of 0.55 or higher indicating greater cardiometabolic risk (CMR)[18]. The following instruments were used to take the measurements: SECA 861 electronic scales (range: 0.05 to 130 kg; accuracy: 0.05 kg) for weight; a SECA 220 measuring rod with an accuracy of 1 mm for height; Holtain callipers with a constant pressure of 10 g/mm^2 on the contact surface for triceps and subscapular skinfolds; and a non-elastic SECA 200 tape measure (range: 0 to 150 cm; accuracy: 1 mm) for waist circumference.

Subsequently, before the end of the training session, the subjects' aerobic capacity was tested using the multi-stage fitness test, a progressive, indirect test consisting of 20-m. shuttle runs starting at a speed of 8.0 km/h.

Each gymnast was allowed only one attempt. The last level completed was registered for subsequent statistical analysis.

Maximal oxygen uptake (VO_2max) was calculated with the results obtained from this test by applying the following equation: $VO_2max = 31.025 + 3.238 (V) - 3.248 (A) + 0.1536 (AV)$, where V is speed reached in the last level of the multi-stage fitness test in km•h^{-1} and A is age in years. The validity and reliability of this equation to estimate VO_2max in children and adolescents has been widely demonstrated[19].

The measurements were taken by visiting the different clubs in the afternoon training period during the preparatory period of the 2015 annual training plan, in the introductory mesocycle.

Statistical analysis

The normality and homoscedasticity of the distributions were obtained through the Kolmogorov-Smirnov test and Levene's test, respectively. On failing to observe a normal distribution of the aerobic capacity values recorded (multi-stage fitness test) according to the different levels of the age variable, it was decided that nonparametric analysis should be performed. Independent samples were contrasted using the Mann-Whitney U test. The effect size (r) was calculated by applying the formula $Z\sqrt{N}$ (Z by square root of N). Rank correlation was

analysed using Spearman's rho. The data are given in mean ranks. All the forms of analysis were performed using SPSS v 22.0 (SPSS Inc. Chicago IL USA) and the level of significance was 5%.

Results

Table 1 shows the descriptive data of all the variables of the gymnasts who participated in the study which were analysed.

The Pan & Cole Index was calculated according to the composition of the sample (Table 2).

Table 3 shows aerobic capacity for the values of VO_2max recorded by the gymnasts, divided into average, good and excellent according to García-Manso *et al.*, cited in Corral *et al*[20].

The Mann-Whitney U test revealed the presence of statistically significant differences in aerobic capacity between the two age groups considered, U = 1,214.0 p = 0.009, r = 2.60. Similarly, a statistically significant difference was found between the age groups and the maximum volume of oxygen (U = 300.0 p = 0.000, r = 7.60). To be more specific, the adolescent gymnasts gave higher values than the pre-adolescent ones.

Table 1. Anthropometric characteristics of the gymnasts by age group.

	Age (years)		
	8-12 y.o. (n = 56)	13-17 y.o. (n = 60)	Total (n = 116)
Weight (kg)	30.02 (6.11)	44.7 (6.72)	37.64 (9.64)
Height (m)	1.35 (0.17)	1.55 (0.71)	1.45 (0.13)
BMI (kg/m^{-2})	16.20 (1.67)	18.37 (1.68)	17.32 (2.07)
Waist circumference (cm)	56.64 (3.30)	64.96 (1.86)	60.94 (4.94)
Subscapular skinfold (mm)	10.25 (2.43)	9.98 (1.77)	10.11 (2.11)
Triceps skinfold (mm)	8.28 (2.12)	11.9 (2.06)	10.15 (2.76)
Body fat percentage (%)	14.48 (3.13)	20.23 (2.51)	18.91 (3.13)
WHtR (cm)	0.419 (0.03)	0.418 (0.01)	0.419 (0.03)
Multi-stage fitness test (*stage*)	3.45 (1.35)	4.36 (1.13)	3.72 (1.27)
VO_2max (ml/(kg min))	39.11 (3.37)	45.21 (3.23)	42.51 (4.47)

The data are given as mean values (standard deviation).

Table 2. Frequency (and percentage) of the Pan & Cole Index, according to the composition of the sample.

	Age (years)		
	≤ 12 y.o. (n = 56)	≥ 13 y.o. (n = 60)	Total (n = 116)
Pan & Cole Index			
Thinness (Grade 1)	27 (48.21%)	22 (36.6%)	49 (42.24%)
Thinness (Grade 2)	8 (14.3%)	8 (13.3%)	16 (13.8%)
Normal	21 (37.5%)	30 (50%)	34 (43.96%)

Table 3. Frequency (and percentage) of aerobic capacity for VO_2max. values expressed in ml.kg.min.[20]

Age (years)	Average (31-37 ml.kg.min)	Good (38-48 ml.kg.min)	Excellent (> 48 ml.kg.min)
≤ 12	16 (26.7%)	44 (73.3%)	
≥ 13		43 (76.8%)	13 (23.2%)
Total	16 (13.8%)	87 (75%)	13 (11.2%)

Table 4. Level of aerobic capacity according to the Multi-stage fitness test using reference values.[21]

Aerobic capacity	Age (years) 8-12 (n=56)	13-17 (n=60)	Total (n=116)
Very low	9 (16.07%)		9 (7.76%)
Low	22 (39.28%)	10 (16.66%)	32 (27.58%)
Average	8 (14.28%)	24 (40.00%)	32 (27.58%)
High	11 (19.64%)	16 (26.67%)	27 (23.28%)
Very high	6 (10.71%)	10 (16.67%)	16 (13.79%)

The data are presented as frequencies (percentage).

Table 4 shows the level of aerobic capacity according to the multi-stage fitness test using the reference values[21], dividing them into very low, low, average, high and very high.

Table 5 shows the results of correlation analysis between the different variables according to the different age groups using Spearman's rho. Considering the sample as a whole, the correlation study reveals a statistically significant correlation (p <0.05 y p <0.01) between the variables weight, height, BMI, waist circumference, body fat percentage and VO_2max.

Discussion

The principal findings of the study showed that adolescent gymnasts are more aerobically fit than younger gymnasts. They all had low BMI, waist circumference and body fat percentage values, these being more pronounced in the pre-adolescent gymnasts. Correlations were found between weight, height, BMI, waist circumference, body fat percentage and VO_2max. WHtR was lower than 0.55 in both age groups.

The percentages of very high, high and average cardiorespiratory capacity scores obtained by the gymnasts were 10.7%, 19.6% and 14.2% for the pre-adolescents, and 16.6%, 26.7% and 40% for the adolescents[21].

Contrasting these data with normal populations in the same age range, it was found that the pre-adolescent gymnasts registered a mean value of 3.45 in the multi-stage fitness test, slightly higher than pre-adolescents between 8 and 11 years of age[22,23], who have values of 2.9 and 3, respectively. Meanwhile, the adolescent gymnasts obtained results slightly higher than those reported by Cuenca *et al.*[8], and Delgado *et al.*[23], with values of 3.84 and 4.

Table 5. Correlation analysis by age group. Spearman's rho.

		Weight	Height	BMI	Waist circumference	Body fat percentage	Multi-stage fitness test	VO_2max
Weight	Rho de Spearman		0.716**	0.805**	0.646**	0.284*	-0.070	-0.316*
	Sig. (2-tailed)		0.000	0.000	0.000	0.028	0.596	0.014
	N		60	60	60	60	60	60
Height	Rho de Spearman	0.807**		0.223	0.362**	0.012	0.005	-0.183
	Sig. (2-tailed)	0.000		0.087	0.004	0.928	0.967	0.162
	N	56		60	60	60	60	60
BMI	Rho de Spearman	0.642**	0.106		0.598**	0.384	-0.150	-0.354**
	Sig. (2-tailed)	0.000	0.438		0.000	0.002	0.254	0.006
	N	56	56		60	60	60	60
Waist circumference	Rho de Spearman	0.360**	0.189	0.403**		0.246	0.142	-0.048
	Sig. (2-tailed)	0.006	0.164	0.002		0.058	0.278	0.714
	N	56	56	56		60	60	60
Body fat percentage	Rho de Spearman	-0.074	0.068	-0.171	0.078		0.230	0.136
	Sig. (2-tailed)	0.558	0.616	0.208	0.568		0.077	0.300
	N	56	56	56	56		60	60
Multi-stage fitness test	Rho de Spearman	0.419**	0.471**	0.082	0.069	0.142		0.868**
	Sig. (2-tailed)	0.001	0.000	0.549	0.612	0.297		0.000
	N	56	56	56	56	56		60
Vo_2max	Rho de Spearman	0.109	0.217	-0.100	-0.169	0.067	0.808**	
	Sig. (2-tailed)	442	0.108	0.462	0.214	0.624	0.000	
	N	56	56	56	56	56	56	

**The correlation is significant at the 0.01 level (2-tailed). *The correlation is significant at the 0.05 level (2-tailed)

Age group: Adolescents (≥13 y.o.) Age Group: pre-adolescents (≤12 y.o.)

As for VO_2max, the adolescent gymnasts gave slightly higher percentages (45.21 (±3.23) ml/(kg min)) compared to the percentages from Spanish studies carried out on populations in a similar age range suggested by other authors[6,23,24]. The total sample had average, good and excellent VO_2max values (13.8%, 75% and 11.2%) according to the reference values[20] (Table 3).

Adding these percentages together, 44.6% of the pre-adolescent girls and 63.4% of the adolescents had healthy levels. These values are lower than those found for Spanish adolescent girls, 82.7%[25], but higher than the 53% of Portuguese girls26 aged from 10 to 18.

On comparing our results with the referential values of the ALPHA battery[21], we note that most of the gymnasts aged between 13 and 17 years gave average, high and very high values in terms of aerobic capacity, but that the pre-adolescent girls did not (Table 4).

In fact, significant differences existed between the two age groups, the adolescent gymnasts showing greater aerobic capacity (U = 1,214.0, p = 0.009, r = 2.60) and VO_2max (U = 300.0 p = 0.000, r = 7.60) than the pre-adolescents.

In the ≥13 age group, the sum of the very high and high aerobic capacity percentages exceeded the average percentages, no gymnast giving very low results in the test. However, in the ≤12 group, the percentage of high and very high aerobic capacity was lower than the average, with 16.07% and 39.28% of the sample giving values categorised as very low and low[21] (Table 4). These results do not support the relationship found by Tomkinson *et al.*[27] between an increase in age and a decrease in aerobic capacity in the normal population. After conducting a meta-analysis with 55 reports studying the trend of cardiovascular fitness (multi-stage fitness test) in children and adolescents from 1980 to 2000, these authors affirmed that aerobic capacity declines as students grow, pointing to a 0.41% drop in aerobic fitness per year for girls, with a much more marked decline in adolescents than in children. Malina[28] reports similar results for the American population. These trends are not observed in this study. Adolescent gymnasts do a greater volume of physical activity than the normal population due to the training they carry out, thereby exercising and enhancing this variable. There exist studies which describe the importance of physical activity and its influence on this characteristic[29,30].

In the ≤12 group, however, low and very low aerobic capacity results are observed. Being gymnasts in younger categories, the competitive level required of them is lower and so their training loads are lighter, allowing us to imagine that the aerobic work they perform is less specific

than that of the adolescents. Studies show that the effects of training depend specifically on the exercises done[30].

With regard to the body composition variables, the average BMI was 17.32 kg.m^{-2}, most of the gymnasts having normal or slightly low weights; "Grade 1 thinness" (Tables 1 and 2) according to the values of Cole *et al*[17]. These results are similar to those reported in studies with rhythmic gymnasts by Di Cagno *et al.*[31] and Vernetta *et al.*[32], but lower than the results obtained by Avila-Carvalho *et al.*[33], 18.75 kg/m^2, and Rutkauskaitė *et al.*[2], 18.5 kg/m^2, and slightly higher than the 16.9 kg/m^2 registered by Soric *et al.*[34] and the 16.82 kg/m^2 recorded by Poliszczuk *et al*[35].

No significant differences were found between groups of pre-adolescents and adolescents with regard to the categorisation of BMI. However, there is a greater percentage of adolescent gymnasts with a normal BMI and a higher percentage of pre-adolescent gymnasts with Grade 1 thinness (Table 2).

Similarly, the mean waist circumference in the total sample was 60.94 cm, this value being lower than those of Avila-Carvalho *et al.*[33] and D'Alessandro *et al.*[36], with 67.05 cm and 66.8 cm respectively, and very similar to the 58.66 cm found in Roman *et al*[37].

As for body fat percentage, most of the gymnasts were in the middle and low percentiles according to the reference values[21]. They also gave low BMI values, coinciding with other studies[3,31,33,38].

In general, the lower BMI and waist circumference results of these gymnasts compared to the normal population is correlated with the importance that these athletes give to their weight as part of their body image, rhythmic gymnastics being an aesthetic sport where thinness and good presence are important factors when it comes to succeeding and winning[32,39].

Regarding the association between the multi-stage fitness test and VO_2max (Table 5), the existence of a positive relationship between the test and the VO_2max ($p = 0.000$) calculation was found for the total sample. Meanwhile, a negative relationship was found between the VO_2max, BMI ($p = 0.006$) and weight ($p = 0.014$) values in the adolescent gymnasts. However, no statistically significant relationship was found between aerobic capacity and the other anthropometric variables (weight, height, BMI, body fat percentage and waist circumference) paired independently with each of the age groups.

The data obtained from our adolescent gymnasts do not substantiate the relationship between performance in the aerobic multi-stage fitness test and BMI shown in the child-adolescent population[40,41]. The fact that our gymnasts have good aerobic capacity and a BMI at or slightly below normal weight in both groups may be why no relationship can be found like that in studies which report an inverse relationship between nutritional status or levels of body fat and aerobic capacity in overweight and obese girls[40].

However, significant relationships have been discovered between maximum oxygen volume, BMI and weight in the adolescents. The relationship is inverse, i.e. the greater the VO_2max, the lower the Body Mass Index and weight. These results resemble those reported by other authors[7,15,41], who showed that children and adolescents with a lower BMI had greater VO_2max compared to those who were overweight/obese. Similarly, Ross *et al.*[42] report that high cardiorespiratory capacity is associated with lower BMI, while Ara *et al.*[43] describe how active children who are more aerobically fit accumulate less fat during growth both all over the body and in the trunk region.

In our study, all the gymnasts had a low body fat percentage, waist circumference and BMI, and a WHtR of less than 0.55, all factors related to a better cardiovascular profile[7,44].

In conclusion, the results of this study show that, in general, the gymnasts had good aerobic capacity when held up against the standard reference values. The adolescent gymnasts had higher aerobic capacities and VO_2max than the pre-adolescents. They all had low BMIs, waist circumferences and body fat percentages. A relationship existed between the VO_2max, BMI and weight of the adolescent girls.

In terms of practical application, we can say that in this discipline, which requires early initiation, the evaluation of aerobic capacity as a physical health-related characteristic should be considered a fundamental tool when it comes to identifying fitness and controlling training properly. Aerobic capacity should be worked on at every stage of training, with a special emphasis on the preparatory period, where developing good aerobic capacity is essential to achieving the sport's specific performance objectives. The high percentage of adolescent gymnasts with good aerobic capacity shows that they are specifically working on this variable with some success. However, the percentage of pre-adolescent gymnasts with a low and very low aerobic capacity highlights the need for improvement by including specific aerobic exercises in their training microcycles.

Finally, in terms of limitations, our data cannot be extrapolated beyond the ranges observed in the study sample. It would, therefore, be good to increase and vary the sample of participants by applying this battery in other Spanish communities. Similarly, considering that gymnasts start rhythmic gymnastics at a young age, other age bands, including younger gymnasts who are just starting and gymnasts at different levels of competition, could be considered. It is also important to understand that the interpretation is based on the measurements taken compared with the reference values established for the non-athlete school population. Consequently, "high" and "very high" AC values may have been obtained with the adolescent gymnasts as a result of using these tables.

Looking ahead, it would be interesting to conduct longitudinal follow-up research on the VO_2max needs required over gymnasts' sporting careers and potential variations in aerobic capacity over a training macrocycle in order to establish specific reference values for this gymnastic discipline.

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