RESEARCH ARTICLE

DOI: 10.26524/ijpefs1915

International Journal of
PHYSICAL EDUCATION, FITNESS AND SPORTS

Biological Maturation of Portuguese Rhythmic Gymnasts in Different Competition Levels of Performance

Received 14th February 2019
Accepted 27th March 2019

www.ijpefs.com

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Abstract: The aims of the present study were: (1) identify and compare the biological maturity in Portuguese gymnasts across competitive levels; (2) investigate how morphological variables and training volume behave in the different status and indicators of maturity and (3) determinate if the maturity status influences the competitive performance. The sample (n=164) consisted of three competition levels (Base, 1st division and Elite) from Portugal. Anthropometric measurements and body composition were performed. For analysis of biological maturation, the sexual and somatic maturation were evaluated. For the statistical analysis, Mann-Whitney and Kruskal-Wallis tests, Pearson correlation and Linear Regression were used. In total, 63.4% of gymnasts had not yet reached menarche and the higher competition level, lower the number of gymnasts with menarche. On mean, all groups had reached the age at peak height velocity. The higher the competition level, higher the chronological age and age at peak height velocity. Thus, the maturation indicators showed a delay in pubertal development in all competition levels and the elite gymnasts seem present a later pubertal development. The chronological age, the values of body mass, height, BMI and body fat increased with the maturity status according all maturity indicators. However, gymnasts with different maturity status revealed similar training volume. Finally, the maturational status explained 11.5% of competition success with higher advantage in the competitive performance to prepubertal gymnasts. Thus, the premenarcheal status and a higher age at peak height velocity contribute to performance in Rhythmic Gymnastics.

Key Words: biological maturation; sexual maturation; somatic maturation; rhythmic gymnastics; gymnasts.

1. Introduction

Rhythmic Gymnastics (RG) requires a high level of development in motor capacities, flexibility, strength, endurance, coordination, agility, rhythm and balance [1, 2] in order to perfectly execute complex body and apparatus elements, harmoniously combining rhythm and movement [3]. Furthermore, the success in this sport is strongly influenced by visual appeal and body aesthetics [4, 5]. Once that elite rhythmic gymnastics should have an appropriate body size and maintain low body fat [2, 6]. However, morphological characteristics of rhythmic gymnasts are determined by different factors, such as genetic aspects, training level and specific nutritional plans, [7] which favor the optimum physical condition for the sport [2]. But can also be associated to alterations in the biological maturation [4, 5, 8-13].

Biological maturation refers to the progress towards a mature state [14] and most often is viewed in the context of skeletal (skeletal age), sexual (pubertal stages of development and age at menarche) and somatic (age at peak height velocity) maturation [15]. Malina et al. [16] explain that maturation is a process, while maturity is a state. This maturation process consists of two components: timing and tempo. Timing refers to the chronological age at which specific maturational events occur, while tempo refers to the rate at which maturation progress, and both vary considerably among individuals [16].

The training in RG begins at the early age of 5–6 years and continues throughout childhood and adolescence [17-19]. The high-level athletes in RG achieve international status long before they become adults [20]. Thus, the late menarche is common among rhythmic gymnasts [4, 6, 21, 22]. Therefore, gymnasts with same chronological age and belonging in the same age category of competition can have a high variation in the growth and biological maturation [1, 16].

Thus, the aims of this study were: (1) identify and compare the biological maturity in Portuguese gymnasts across competitive levels; (2) investigate how morphological variables and training volume behave in the different status and indicators of maturity and (3) determinate if the biological maturity status influences the competitive performance.

2. Materials and methods

Subjects: 164 Portuguese gymnasts who participated in the district and/or national competitions in the sport season 2013/2014, in three different levels: Base, 1st division and Elite.

Ethical Considerations: Ethics Committee of the Faculty of Sport, University of Porto (Portugal) and Scientific Committee of the Portugal Gymnastics Federation approved the study protocol. The assessments were performed in accordance with the ethical standards of the Helsinki Declaration.

Morphological characteristics: Anthropometric measurements were obtained according to the protocol established in Anthropometric standardization reference manual [23]. All anthropometric measurements were performed at the beginning of each training session by the same trained anthropometrist. Body mass (kg) was measured with a portable bio-impedance scale (Tanita BC-558 Ironman Segmental Body Composition Analyzer) with a 0.1 kg precision. Height (cm) and sitting height (cm) were determined to the nearest 0.1 cm using the portable stadiometer Personal Sanny. Triceps and calf skinfolds were measured with a Holtain Skinfold Caliper (0.2 mm precision). The values verified in the assessments were within acceptable limits of technical error of measurement and therefore, the quality control of the information determined a high precision and reliability of the data.

Relative body fat (%BF) was calculated using the equation proposed by Slaughter et al. [25]: $[(0.610 * \Sigma SKF) + 5.1]$, where, ΣSKF is the sum of triceps and calf skinfolds. Body mass index (BMI) was calculated from the equation: body mass (kg) / height^2 (m).

Biological maturation: For analysis of sexual maturation, menarcheal status and age at menarche (retrospective method) were obtained by questionnaire. To infer, indirectly, the somatic maturation, we used the maturational offset, that it is an estimate of the distance to which an individual is of age at which will occur the peak height velocity (PHV) [26]. The value is expressed in years, for more (+) or for less (-). To prediction of age of PHV the following variables are required: gender, date of birth, date of measurement, height, sitting height and weight. The predicted age at PHV was the difference between age and maturity offset.

Additional data: Chronological age, age of training onset and training volume were collected using questionnaires. Scores in the Portuguese National Championship determined the competitive performance in the sport season 2013/2014.

Statistical Procedures: Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS 23.0). The significance level was set at 5%. Descriptive statistics were performed using the mean and standard deviation. Mann-Whitney and Kruskal-Wallis nonparametric tests were used to compare competition levels in different analysis and maturity status. Pearson correlation and linear regression were used to verify the influence of biological maturity status in performance.

3. Results

Table 1 shows the training and morphological characteristics of Portuguese gymnasts and this group separated by competition levels.

Table 1: Training and morphological characteristics in complete sample and separated by competition levels.

Competition Level Variables	General (n=164)	Base (n=83)	1st division (n=72)	Elite (n=9)	Proof value
	x̄±sd	x̄±sd	x̄±sd	x̄±sd	
Age (years)	13.5±2.0	13.3*±1.9	13.6±2.1	14.8*±1.8	p=0.016 [b]
Training onset (years)	6.9±2.4	7.3±2.6	6.5±2.2	6.0±1.5	p=0.082
Training volume (h/week)	16.9±7.5	13.9*±6.4	18.7*±6.2	31.2*±6.2	p<0.001 [a,b,c]
Body mass (kg)	43.7±9.3	45.1±9.4	42.1±9.5	42.6±6.1	p=0.094
Height (cm)	152.6±8.9	152.7±7.8	152.1±10.3	155.8±6.6	p=0.489
BMI (kg/m²)	18.5±2.4	19.1*±2.6	17.9*±2.1	17.5*±1.5	p=0.008 [a,b]
Body fat (%)	17.5±4.1	19.4*±4.2	18.2*±4.3	14.6*±2.8	p<0.001 [a,b,c]

Legend – BMI: body mass index; x̄: mean; sd: standard deviation; * p≤0.05: significant differences – a) base versus 1st division; b) base versus elite; c) 1st division versus elite.

Table 2: Summary table of biological maturation of Portuguese gymnasts by competition levels

		Sexual maturation (Menarche)		Somatic Maturation (Maturational Offset)	
Competition levels	**Chronological age**	**Number and % of gymnasts**	**Age at menarche**	**Distance of PHV**	**Predicted age at PHV**
Base (n=83)	13.3±1.9 years	36 (43.4%)	12.4*±1.0 years	0.7±1.4 years	12.6*±0.7 years
1st division (n=72)	13.6±2.1 years	22 (30.6%)	14.0*±1.2 years	0.8±1.7 years	12.9*±1.6 years
Elite (n=9)	14.8±1.8 years	2 (22.2%)	13.5±0.7 years	1.6±1.3 years	13.3*±0.6 years
Total (n=164)	13.5±2.0 years	6 (36.6%)	13.0±1.3 years	0.8±1.6 years	12.7±0.7 years

Legend – PHV: peak height velocity; * p≤0.05: significant differences

We can see in Table 1 that, the higher the competition level, higher was the training volume per week. There were no significant differences in the training onset (age at which each gymnast started RG training), although the higher the competition level, lower the age of training onset.

No significant differences were found in the groups in body mass and height, however we verified that the higher competition level, higher the height the gymnasts. Furthermore, the Elite and 1st division Had similar body mass values and lower than Base.

Significant differences were verified in the body composition variables, except in 1st division versus elite in BMI. The higher the competition level, lower values of body fat and BMI.

Table 2 presents the maturation data of Portuguese gymnasts and this group separated by competition levels. We observed that only 60 (36.6%) from 164 gymnasts had reached menarche (13.0±1.3 years and range of 10.0 to 16.0 years) and 63.4% had not yet begun to menstruate (12.6±1.4 years and range of 10.6 to 18.1 years). Thus, the higher competition level, lower the number of gymnasts with menarche: base (43.4%); 1st division (30.6%); elite (22.2%). The most gymnasts of each group had not yet the menarche. There were significant differences ($p<0.001$) in age at menarche in base (12.4±1.0 years) versus 1st division (14.0±1.2 years). Although without statistical significance, the age at menarche in Elite was lower than 1st division ($p=0.464$) and higher than Base ($p=0.139$). 88.8% of Elite gymnasts had not yet the menarche.

Furthermore, the predicted age at PHV by competition level also was presented in Table 2. On mean, all groups had reached the age at PHV. The higher the competition level, higher the chronological age, higher the distance of the PHV (+) and higher the age at PHV. However, significant differences were verified in the age at PHV in all groups: Base versus 1st division ($p=0.002$), Base versus Elite ($p=0.003$) and 1st division versus Elite ($p=0.046$).

Table 3 shows the analysis of morphological and training variables (age, body mass, height, BMI, %BF and training volume) of Portuguese gymnasts according to two maturation indicators: 1. menarche (absence or presence of menarche) and 2. PHV status (-2 to +5).

Table 3: Variables of growth, body composition and training by maturation indicators

Variables / Maturation Indicators			n (%)	Age (yrs)	BM (kg)	Height (cm)	BMI	%BF	Volume (h)
				x̄±sd	x̄±sd	x̄±sd	x̄±sd	x̄±sd	x̄±sd
1	Premenarcheal		104 (63.4%)	12.6*±1.4	38.8*±7.0	148.7*±8.0	17.4*±1.8	16.2*±3.5	16.7±7.8
	Menarcheal		60 (36.6%)	15.1*±1.9	52.0*±6.6	159.4*±5.8	20.4±2.1	19.8*±4.1	17.2±7.0
2	PHV status	-2	4 (2.4%)	11.1±0.2	26.6±1.2	134.6±2.1	14.7±1.1	13.3±2.6	14.0±8.7
		-1	38 (23.3%)	11.5±0.6	33.8±3.4	142.4±3.7	16.7±1.4	16.4±3.4	15.9±8.1
		0	33 (20.2%)	12.3±0.6[h]	40.0±4.5[h]	149.7±5.1[h]	17.8±1.5[a,e]	17.1±2.9[h]	15.3±6.3
		+1	35 (21.3%)	13.4±0.5	45.7±5.2	155.8±4.1	18.8±1.9	17.5±3.5	18.1±7.8
		+2	29 (17.7%)	14.5±0.7	50.4±6.3	159.6±4.9	19.8±2.1	18.5±4.9	18.8±5.6
		+3	14 (8.5%)	16.5±0.7	55.0±6.4	161.4±3.8	19.9±6.0	20.5±5.3	15.2±10.5
		+4	9 (5.5%)	17.9±0.6	56.0±4.0	162.2±3.8	21.3±1.4	18.8±5.5	18.6±6.5
		+5	2 (1.2%)	18.2±0.1	57.8±9.9	173.1±0.2	19.3±3.4	18.5±3.5	24.0±0.0

Legend –x̄: mean; sd: standard deviation BM: Body Mass; BMI: Body mass index; %BF: % body fat; Volume: training volume in hours per week; 1: Menarche – *$p\leq0.05$: significant differences; 2: PHV status – Significant differences in the variables analyzed when comparing the gymnasts with PHV=0 versus the others PHV status ($p\leq0.05$: significant differences): a) PHV-2; b) PHV-1; c) PHV+1; d) PHV+2; e) PHV+3; f) PHV+4; g) PHV+5; h) differences in PHV0 and all PHV status.

In the analysis of Menarche in Table 3, we observed that the chronological age, the values of body mass, height, BMI, %BF and training volume were higher in menarcheal than premenarcheal gymnasts. However, significant differences were verified in all variables (p <0.001), except in training volume (p=0.425).

Table 3 shows also that the PHV occurred (PHV0) at a predicted age of 12.3±0.6 years (n=33). The values of each variable increased with age and somatic maturation status, except the training volume. However, the BMI and %BF in the PHV status +4 and +5 did not follow this trend, probably by reduced sample in these groups and thus, the power of the statistical test and the general analysis of mean values were compromised. There were significant differences (p≤0.05) in the value of variables at PHV0 and other somatic maturity status in age (PHV-2 to +5), body mass (PHV-2 to +5), height (PHV-2 to +5), BMI (PHV-2 to +5) and %BF (PHV-2 and PHV+3). On the other hand, no significant differences were found in the value of variables at PHV0 and other somatic maturity status in training volume.

According to Linear Regression, we observed that the maturational status explained 11.5% of competitive performance (F=5.921; p=0.001; R^2 adjusted = 0.115). The regression equation was y= 15.571 +3.366 * age at PHV – 5.573 * menarcheal status (where 0 corresponds to premenarcheal and 1 to menarcheal gymnasts).

4. Discussion

Portuguese gymnasts from different competition levels presented different training volume. Elite gymnasts had significantly higher training volume than the remaining groups probably due to high training and competition requirements, essential to maintain this higher level of sport performance [4]. According to Misigoj-Durakovic [6], the training programs in RG can be described as of high intensity, high frequency and long duration. Ávila-Carvalho et al. [4], explain that to achieve the necessary preparation for a good performance, elite gymnasts train 25-30h/week and in some cases, 40h/week due to the high physical and technical requirements in RG. During the seventies and eighties the requirement was 15h and 20h per week, respectively [18]. The gymnasts who participated in the European Championship of 1986 had a training volume of 21.7h/week and in 2008, 36h/week [27]. These data demonstrate a tendency to increase the training volume over the recent years. Thus, Portuguese elite gymnasts in our study presented number of hours of training per week (31.2±6.2h/week) according to international records and higher than training volume of 25.0h±0h/week found by Batista-Santos et al. (2015) in Portuguese junior elite gymnasts (13.6±0.3 years) [28].

Regarding to age of initiation in RG, Portuguese gymnasts presented age of training onset (6.8±2.4 years) according to previous studies: 6.8±1.9 years [9], 7.7±2.2 years [21], 7.4±2.3 year [29], 6.2±1.9 year [27], 6.5±1.4 years [23]. Furthermore, we verified that the higher the competition level, lower the age of training onset: 7.3±2.6 years in Base, 6.5±2.2 years in 1st division and 6.0±1.5 years in Elite, despite significant differences were not found in the groups in this variable.

Information about the training characteristics in RG is essential to understanding the effects of such training on the growth and body development of gymnasts [30]. The elite gymnasts presented higher training volume, lower training onset and lower values of S3SKF, BMI and body fat than other competition levels. These results are in agreement with Claessens et al. [31], that consider the performance of elite gymnasts negatively correlated with the body fat, once that the success in RG is strongly influenced by visual appeal and body aesthetics [5].

Georgopoulos et al. [9] conducted a study with 255 rhythmic gymnasts, aged 14.7±2.1 years, participants in the European Championship in Greece. The gymnasts presented 16.3±1.8kg/m2 of BMI, 16.1±4.1% of % BF and 42.0±7.4kg of body mass. Theodoropoulou et al. [28] studied 423 elite rhythmic gymnasts aged 15.9±2.4 years in the period from 1997-2004 on World and European Championships and verified that the values of BMI and %BF were 16.9±1.8kg/m^2 and 15.5±4.6%

respectively. Del Vecchio et al. [1] observed that Brazilian junior gymnasts had 17.1±1.5kg/m² of BMI. Portuguese gymnasts in our study showed higher values of BMI (18.5±2.4kg/m²) and %BF (17.5±4.1%). When we analyzed the values by competition levels, we verified that only the elite gymnasts presented values of BMI (17.5±1.5kg/m²) and %BF (14.6±2.8%) closer to the studies reported [1, 9, 28].

The height is one of most commonly body dimensions used to monitor growth status [16]. In our study, the Elite showed the higher values of height (155.8±6.6 cm), although statistically the groups had similar height. The Portuguese gymnasts (13.5±2.0 years) presented 152.6±8.9 cm of height, and when compared to gymnasts with similar mean age (13.4±1.6 years) studied by Douda et al. [2]. we verified equivalent height values (151.1±9.5 cm). In other study performed by Camargo et al. [30], the gymnasts with similar mean age (13.4±0.6 years) had 155.9±4.5 cm of height, however, these gymnasts showed a more advanced pubertal stage (PHV+2) than Portuguese gymnasts (PHV-1).

The analysis of biological maturation is also an important procedure to understand the differences in growth and body development of gymnasts [8, 14, 16], once that it has consistently been shown that late maturity is common in Gymnastics, especially elite gymnasts [6, 12, 15] and that late-maturing gymnasts seem to have advantages in motor performance in this sport [32].

Purenović-Ivanović et al. [22] performed a study to determine the potential influence of pubertal development in gymnasts of different age categories on the performance scores and verified a negative relationship of all pubertal development parameters used in their study with the performance scores in senior gymnasts, which according to authors, could indicate that late maturation is desirable in RG. Furthermore, Claessens et al. [33] compared gymnasts from different competitive levels at the same chronological age and verified that premenarcheal gymnasts tend to have higher competitive scores, on average, than post-menarcheal gymnasts.

In our study, we observed similar results, once that the maturational status explained 11.5% of competitive performance with higher advantage in the competition success to prepubertal gymnasts.

The main indicator of maturation used in studies with gymnasts is the age at menarche, probably because it is a less invasive method, more easy application, and without the need for anthropometric measurements. The average age for menarche in non-athlete female population is 12.8 year [34] however, gymnasts tend to attain menarche later than normal population and girls in other sports [11, 31]. Several studies indicate that gymnasts have a late age at menarche and age at peak height velocity (PHV), especially in elite gymnasts [6, 12, 14, 21, 22, 28, 35].

Previously reported studies showed similar age at menarche in gymnasts (in years):15.0±0.9 [36], 14.6±1.5 [29] 15.9±1.3 [27] 15.9±1.4 [23] 14.8±1.1 for young and 16.6±1.2 for adult [4] 15.3±1.3 years [37]. In our study, the mean chronological age of Portuguese gymnasts was 13.5±2.0 years and only 36.6% already had menarche (13.0±1.3 years) [4]. We observed also that the higher the competition level, lower number of gymnasts with menarche: base (43.4%); 1st division (30.6%); elite (22.2%). Purenović-Ivanović et al. [22] verified that the age at menarche in rhythmic gymnasts was 13.6±1.2 years, however, as in our study, only a small part of the sample (33.3%) already had menarche. The authors also verified that the higher the competition level of gymnasts, the later the menarche onset occurred.

The menarcheal Portuguese gymnasts presented higher values of age, body mass, height, BMI and %BF than premenarcheal gymnasts. Klentrou & Plyley [5] found similar characteristics, once that menarcheal gymnasts were significantly taller and heavier, with a higher BMI and %BF than premenarcheal gymnasts.

In addition, to infer, indirectly, the somatic maturation, we used the maturational offset [25] that it is an estimate of the distance to which an individual is of age at which will occur the PHV. Generally, the PHV in girls occurs at about 12 years of age [38]. We observed that on mean, the Portuguese gymnasts in general and all competition levels had reached the age at PHV. Furthermore, the higher the competition level, higher the age at PHV: Base (12.6±0.7 years); 1st division (12.9±1.6 years) and Elite (13.3±0.6 years).

The PHV in Portuguese gymnasts occurred at a predicted age of 12.3±0.6 years (n=33), when the gymnasts showed greater improvement in height. Other studies reported similar predicted age of PHV: 13.0±0.7 years [39]; 12.9±1.5 years [35], (12.5±0.6 years [40] and 12.1±0.8 years [30].

Thus, according to the different analysis of maturation in Portuguese gymnasts in our study, we observed that the gymnasts showed a delay in pubertal development in all competition levels and although without statistical significance in all maturity indicators, we observed the elite gymnasts seem to have a later maturational development.

The elite gymnasts, who represent the higher competition level, are a selected group of girls exposed to intensive training long before menarche [5]. Our data demonstrate its unique characteristics, once that elite Portuguese gymnasts (14.8±1.8 years) presented motivation to maintain low %BF (14.6±2.8%), high training volume regimen (31.2±6.2h/week), high number of years of practice in the sport (8.1±1.9 years) and age of training onset (6.0±1.5 years) in accordance with indications by several authors who suggest that the RG training begins at the early age of 5–6 years and continues throughout childhood and adolescence [17-19]

Several studies have referred that the age of the onset of maturational development varies greatly, and is influenced by several factors as nutrition, heredity, state of health, body fat, high volume and intensity training, chronic psychological stress and other [5, 8-11, 13]. Thus, presently available data, point that the sports training and participation, alone do not likely affect maturation and therefore, do not appear to affect adult height or overall rate of growth [8, 12, 14, 18, 21]. Generally, the gymnasts tend to have a later maturation and therefore, the growth cessation is going to occur at a much later age than girls with average or early maturation [8].

Our study also was aimed at verify how the training volume of gymnasts behave in the different status and indicators of maturity. The analysis of menarcheal status (presence or absence of the menarche) showed that the menarcheal Portuguese gymnasts presented higher training volume than premenarcheal gymnasts, although without significant differences. Klentrou & Plyley [5] verified different results, once that menarcheal gymnasts had lower training volume. In the PHV, there was not a structural pattern in the results found in training volume in the different ages and somatic maturation status. Indeed, before reaching PHV, there was an increase in the training volume with the increase of age and maturity status (PHV-2 = 14.0±8.7h/week; PHV-1 = 15.9±8.1h/week). However, in the PHV0 (15.3±6.3h/week) the training volume was lower than PHV-1. From then, we did not observe no structural patter in the training volume with the increase of age and maturity status. To better understand these results, we analyzed the training volume by age categories of competition (according to rules of Gymnastics Federation of Portugal) and verified that the young gymnasts (11-12 years) had lower training volume (14.8±6.8h/week). However, the other age categories, junior (13-15 years) and senior (16 years and older) presented similar training volume: 18.4±7.2h/week and 18.1±8.5h/week, respectively. So, the gymnasts in the PH0 or more (over 12 years of age), did not necessarily presented a higher training volume.

The analysis of training volume is interesting, once that we observed significant differences in this variable in the three competition levels: Base (13.9±6.4h/week); 1st division (18.7±6.2h/week) and Elite (31.2±6.2h/week), however, when we compared the training volume according to maturity status of the gymnasts, no significant differences were verified. Therefore, gymnasts with different maturity status presented different age, body mass, height, BMI and %BF, but on the other hand, revealed a similar training volume and no sufficiently different at the statistical level. According to Beunen & Malina [14], the variation in maturity status influences body dimensions, composition and proportions, and also the performance. Thus, although the age categories in competition is defined only by chronological age, it is important that the coaches consider the maturity status of the gymnasts in the training requirements [3]. Although there is a great interest in understanding how the stages of growth and maturation can be best utilized in sport development, the available data and studies are extremely limited [16]. We can cite two models to long-term development of young athletes: Long Term Athlete Development (LTAD) [41, 42] and the Youth Physical Development (YPD) [43, 44] which are concept of planned, systematic and progressive system of training, competition and recovery of athletes considering their maturity status. The coaches use information about the PHV as a reference point for the development of individualized training programs during the maturation process, although each model present a different organization in the motor capacities training.

RG can be classified as early specialization sport [41] and we did not find a specific model based on maturity status that could contribute the development of coaches' work. The knowledge and awareness of general patterns of growth and maturation allows that the coaches can recognition of the advantages, risks, and challenges that accompany these biological processes, and thus, to ensure that the training is based on the needs of the individual as opposed to a general approach based a simply on chronological age [44, 16].

However, it is not easy to select the better indicator of the maturational state. In our study were used two maturity indicators and they showed that Portuguese gymnasts had a delay in pubertal development in all competition levels. However, according to Malina et al. [16], measuring maturation can be challenging. The authors explain that there are limitations in all indicators of maturity used in growth studies: skeletal age determination with x-rays exposes children to low dose radiation, is an expensive evaluation and is dependent on experienced individuals to interpret the results; directly observing secondary sexual characteristics is a quite invasive method; surveys questioning breast and pubic hair development have limitations in terms of recall accuracy and possible wrong perception of own body; age at menarche have error associated with recall accuracy and are affected by the tendency to report ages as whole years; age at PHV is an "after-the-fact" indicator. Predicted age at PHV is dependent upon age at prediction and individual differences in actual age at PHV [45].

5. Conclusions

In total, 63.4% of Portuguese gymnasts had not yet reached menarche and the higher competition level, lower the number of gymnasts with menarche. In the PHV, on mean, all groups had reached the age at PHV. The higher the competition level, higher the chronological age, higher the distance of the PHV and higher the age at PHV.

Thus, the maturation indicators used in our study (age at menarche and age at PHV) showed a delay in pubertal development in all competition levels of performance and we observed that the elite gymnasts seem to present a later maturational development.

We observed also that the chronological age, the values of body mass, height, BMI and %BF increased with the maturity status according all maturity indicators, although without significant differences in some maturity status. However, gymnasts with different maturity status revealed a similar training volume (indeed, slightly different training volume but with no statistical significance).

Finally, the maturational status explained 11.5% of competition success with higher advantage in the competitive performance to prepubertal gymnasts. Thus, the premenarcheal status and a higher age at PHV contribute to performance in RG.

References

[1] F. B. Del Vecchio, M. Primeira, H. C. d. Silva, C. Dall'Agnol, L. M. Galliano, Nível de aptidão física de atletas de ginástica rítmica: Comparações entre categorias etárias, *Revista Brasileira de Ciência e Movimento, 22* (2014) 5-13.

[2] H. Douda, A. Toubekis, A. Avloniti, S. Tokmakidis, Physiological and anthropometric determinants of rhythmic gymnastics performance. *International Journal of Sports Physiology and Performance,* 3 (2008) 41-54.

[3] M. Bordalo, M. Portal, S. Cader, N. Perrotta, J. Neto, E. Dantas, Comparison of the effect of two sports training methods on the flexibility of rhythmic gymnasts at different levels of biological maturation, *The Journal of sports medicine and physical fitness, 55* (2015) 457-463.

[4] L. Ávila-Carvalho, P. Klentrou, M. L. Palomero, E. Lebre, Anthropometric profiles and age at menarche in elite group rhythmic gymnasts according to their chronological age, *Science & Sports, 28* (2013) 172-180.

[5] P. Klentrou, M. Plyley, Onset of puberty, menstrual frequency, and body fat in elite rhythmic gymnasts compared with normal controls, *British Journal of Sports Medicine,* 37 (2003) 490-494.

[6] M. Misigoj-Durakovic, (2012). Anthropometry in Premenarcheal Female Esthetic Sports Athletes and Ballerinas, *Handbook of Anthropometry,* New York.

[7] C. Tringali, I. Brivio, B. Stucchi, I. Silvestri, R. Scurati, G. Michielon, G. Alberti, B. Venerando, Prevalence of a characteristic gene profile in high-level rhythmic gymnasts, *Journal of Sports Sciences,* 32 (2014) 1409-1415.

[8] A. Baxter-Jones, N. Maffulli, R. L. Mirwald, Does elite competition inhibit growth and maturation in some gymnasts? Probably not, *Pediatric Exercise Science, 15* (2003) 373-382.

[9] N. Georgopoulos, K. Markou, A. Theodoropoulou, P. Paraskevopoulou, L. Varaki, Z. Kazantzi, M. Leglise, , & Vagenakis, A.. Growth and pubertal development in elite female rhythmic gymnasts, *The Journal of Clinical Endocrinology & Metabolism,* 84 (1999) 4525-4530.

[10] N. Georgopoulos, K. Markou, A. Theodoropoulou, G. Vagenakis, D. Benardot, M. Leglise, J. Dimopoulos, A. Vagenakis, Height Velocity and Skeletal Maturation in Elite Female Rhythmic Gymnasts, *The Journal of Clinical Endocrinology & Metabolism, 86* (2001) 5159-5164.

[11] L. Maïmoun, N. A. Georgopoulos, C. Sultan, Endocrine disorders in adolescent and young female athletes: impact on growth, menstrual cycles, and bone mass acquisition, *The Journal of Clinical Endocrinology & Metabolism,* 99 (2014) 4037-4050.

[12] R. Malina, A. Baxter-Jones, N. Armstrong, G. Beunen, D. Caine, R. Daly, R. Lewis, A. Rogol, K. Russell, Role of Intensive Training in the Growth and Maturation of Artistic Gymnasts, *Sports Medicine, 43* (2013) 783-802.

[13] M. R. G. Silva, (2007) Avaliação nutricional e composição corporal, *Edições Universidade Fernando Pessoa*, Porto.

[14] G.Beunen, R. M. Malina, (2007) Growth and Biologic Maturation: Relevance to Athletic Performance, *The Young Athlete: Blackwell Publishing Ltd*, UK.

[15] A. Baxter-Jones, A. Thompson, R. Malina, Growth and maturation in elite young female athletes, *Sports Medicine and Arthroscopy Review,* 4 (2002) 2-49.

[16] R. M. Malina, K. E. Ackerman, A. D. Rogol, (2016) Growth and the Young Female Athlete, *The Young Female Athlete*, Switzerland.

[17] D. Caine, S. Bass, R. Daily, Does elite competition inhibit growth and delay maturation in some gymnasts? Quite possibility, *Pediatric Exercise Science,* 15 (2003) 360-372.

[18] N. Georgopoulos, A. Theodoropoulou, N. Roupas, L. Rottstein, A. Tsekouras, P. Mylonas, G. Vagenakis, E. Koukkou, A. Armeni, S G. akellaropoulos, M. Leglise, K. Vagenakis, K. Markou,. Growth velocity and final height in elite female rhythmic and artistic gymnasts, *Hormones,* 11 (2012) 61-69.

[19] M. P. Law, J. Côté, K. A. Ericsson, Characteristics of expert development in rhythmic gymnastics: A retrospective study, *Journal International Journal of Sport and Exercise Psychology, 5* (2007) 82-103.

[20] L. S. Menezes, J. Novaes, J. Fernandes-Filho, Somatotipo de atletas y practicantes de gimnasia rítmica prepubescentes y postpubescentes, *International Journal of Morphology,* 32 (2014) 968-972.

[21] N. Georgopoulos, K. B. Markou, A.Theodoropoulou, D. Benardot, M. Leglise, A. G. Vagenakis,. Growth retardation in artistic

compared with rhythmic elite female gymnasts, *The Journal of Clinical Endocrinology and Metabolism,* 87 (2002) 3169-3173.

[22] T. Purenović-Ivanović, R. Popović, L. Moskovljević, The contribution of pubertal development to performance scores in high-level rhythmic gymnasts, *Acta Gymnica,* 47 (2017) 122-129.

[23] L. Ávila-Carvalho, P. Klentrou, M. L. Palomero, E. Lebre, Body composition profile of elite group rhythmic gymnasts, *Science of Gymnastics Journal,* 4 (2012) 21-32.

[24] T. G. Lohman, A. F. Roche, R. Martorell, (1988). Anthropometric Standardization Reference Manual, *Human Kinetics Books*, Champaign.

[25] M. Slaughter, T. Lohman, R. Boileau, C.Horswill, R. Stillman, M. Van Loan, D. Bemben, Skinfold equations for estimation of body fatness in children and Youth, *Human Biology, 60* (1988) 709-723.

[26] R. L. Mirwald, A. D. Baxter-Jones, D. A. Bailey, G. P. Beunen, An assessment of maturity from anthropometric measurements, *Medicine and Science in Sports and Exercise,* 34 (2002) 689-694.

[27] G. Berlutti, C. Briganti, T. Pamich, L. Torrisi, A. Franco, G. Morino, G. Caldarone, (2010) Body composition, biological maturation, alimentary habit, anthropometric characteristics in rhythmic gymnastics athletes. From the Florence 1986 European Championships to the Turin 2008 Europian Championships, Twenty years of evolution, Federazione Gimnastica D'Italia.

[28] A. Batista-Santos, M. E. Lemos, E. Lebre, L. Ávila-Carvalho, Active and Passive Lower Limb Flexibility in High Level Rhythmic Gymnastics, *Science of Gymnastics Journal, 7* (2015) 55-66.

[29] A. Theodoropoulou, K. B. Markou, G. A. Vagenakis, D. Benardot, M. Leglise, G. Kourounis, A. G. Vagenakis, N. A. Georgopoulos,. Delayed but normally progressed puberty is more pronounced in artistic compared with rhythmic elite gymnasts due to the intensity of training. *The Journal of Clinical Endocrinology and Metabolism,* 90 (2005) 6022-6027.

[30] C. Camargo, R. Gomez-Campos, M. Cossio-Bolaños, V. Barbeta, M. Arruda, G. Guerra-Junior, Growth and body composition in Brazilian female rhythmic gymnastics athletes, *Journal of Sports Sciences,* 32 (2014) 1790-1796.

[31] A. Claessens, J. Lefevre, G. Beunen, R. M. Malina, The contribution of anthropometric characteristics to performance scores in elite female gymnasts, *The Journal of Sports Medicine and Physical Fitness, 39* (1999) 355-360.

[32] A. Baxter-Jones, P. Helms, Effects of Training at a Young Age: A Review of the Training of Young Athletes (TOYA) Study, *Pediatric exercise Science,* 8 (1996) 310-327.

[33] A. Claessens, J. Lefevre, G. Beunen, R. Malina, Maturity-associated variation in the body size and proportions of elite female gymnasts 14-17 years of age, *European Journal of Pediatrics,* 165 (2006) 186-192.

[34] M. Djordjevic-Nikic, L. Moskovljević, The influence of sports training on the growth and pubertal development in female rhythmic gymnasts, *Physical Culture,* 63 (2009) 10-16.

[35] M. Thomis, A. L. Claessens, J. Lefevre, R. Philippaerts, G. P. Beunen, R. M. Malina, Adolescent growth spurts in female gymnasts, *The Journal of Pediatrics, 146* (2005) 239-244.

[36] Muñoz, M., de la Piedra, C., Barrios, V., Garrido, G., Argente, J. (2004). Changes in bone density and bone markers in rhythmic gymnasts and ballet dancers: implications for puberty and leptin levels. European Journal of Endocrinology, 151 (4) 491-496.

[37] M. Silva, T. Paiva, Low energy availability and low body fat of female gymnasts before an international competition, *European Journal of Sport Science,* 15 (2015) 591-599.

[38] R. Malina, C. Bouchard, O. Bar-Or, (2004) *Growth, maturation, and physical activity*, *Human Kinetics*, Champaign.

[39] J. A. Nurmi-Lawton, A. D. G. Baxter-Jones, R. L. Mirwald, J. A. Bishop, P. Taylor, C. Cooper, S. A. New, Evidence of sustained skeletal benefits from impact-loading exercise in young females: A 3-year longitudinal study, *Journal of Bone and Mineral Research,* 19 (2004) 314-322.

[40] R. M. Malina, A. L. Claessens, K. Van Aken, M. Thomis, J. Lefevre, R. Philippaerts, G. P. Beunen, Maturity offset in gymnasts, *Medicine & Science in Sports & Exercise, 38* (2006) 1342-1347.

[41] I. Balyi, A. Hamilton, (2004) Long-Term Athlete Development: Trainability in children and adolescents. Windows of opportunity. Optimal trainability, *Victoria, BC: National Coaching Institute British Columbia & Advanced Training and Performance Ltd.*

[42] Balyi, I., Way, R., & Higgs, C. (2013). Long-term athlete development. Champaign: Human Kinetics.

[43] R. Lloyd, J. Oliver, the Youth Physical Development Model: A New Approach to Long-Term Athletic Development, *Strength and Conditioning Journal, 34* (2012) 61-72.

[44] R. Lloyd, J. Oliver, (2014) Developing younger athletes. In D. Joyce & D. Lewindon (Eds.), *High Performance Training for Sports, Human Kinetics* Unites States of America.

[45] R. M. Malina, S. M. Kozieł, Validation of maturity offset in a longitudinal sample of Polish girls, *Journal of Sports Sciences,* 32 (2014) 1374-1382.

Acknowledgements

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Competing Interests: The author declares to have no competing interests

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