Science & Sports (2013) 28, 172—180

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ORIGINAL ARTICLE

Anthropometric profiles and age at menarche in elite group rhythmic gymnasts according to their chronological age

Profils anthropométriques et âge de la ménarque d'un groupe de gymnastes rythmiques en fonction de leur âge chronologique

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Received 7 November 2011; accepted 2 April 2012
Available online 31 October 2012

KEYWORDS
Anthropometric measures;
Body fat;
Training;
Menarche;
Group rhythmic gymnasts

Summary
Aim. — To analyse anthropometric, body composition profile, onset of menarche and training experience of young and adult elite group rhythmic gymnasts (GRG).
Methods. — Eighty-four GRG, who participated in the 2009/2010 RG World Cup were evaluated. Body mass index (BMI) was calculated and relative body fat (% BF), fat mass (FM) and lean body mass (LBM) were estimated from skinfold thickness (suprailiac, triceps, thigh and calf). Age at menarche was recorded using a questionnaire.
Results. — Elite GRG had a similar height, % BF, FM and waist/hip ratio profile no matter their chronological age (20.5 ± 1.7 vs 16.5 ± 0.9 years old), but the values were higher than those reported in previous RG studies. However, the adult elite RG had a higher BMI than younger gymnasts (19.0 ± 1.2 vs 18.5 ± 1.4 kg/m^2) both at the normal range. The absolute and relative LBM (kg; %) were higher in the adult gymnasts with higher training experience level (25.0 ± 2.5 vs 27.5 ± 2.5 kg; 48.4 ± 2.1 vs 50.6 ± 2.1%). The younger gymnasts began training RG earlier (6.1 ± 1.2 vs 6.8 ± 1.7 years old), suggesting nowadays an earlier specific initiation in RG, and had a lower training experience (10.3 ± 1.6 vs 13.4 ± 2.5 years).
Conclusion. — The younger gymnasts recorded earlier onset of menarche (14.8 ± 1.1 vs 16.6 ± 1.2 years old). Years of training before menarche and chronological age were both correlated with age at menarche: the greater the years of training before menarche and the older the chronological age, the later the age at menarche.

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http://dx.doi.org/10.1016/j.scispo.2012.04.005

MOTS CLÉS
Mesures anthropométriques ;
Graisse corporelle ;
Entraînement ;
Ménarque ;
Gymnastique rythmique d'ensemble

Résumé
Objectifs. — Analyser le profil anthropométrique, la composition corporelle, l'âge de la ménarque et l'expérience dans le sport des gymnastes des ensemble d'élite de gymnastique rythmique (EGR).
Méthodologie. — Quatre-vingt-quatre gymnastes d'ensemble, qui ont participé à la Coupe du Monde 2009/2010 de GR ont été évaluées. L'indice de masse corporelle (IMC) est calculé et la graisse corporelle relative (% GC), la masse grasse (MG) et la masse maigre du corps (MMC) sont estimées à partir des plis cutanés (supra-iliaque, triceps, cuisse et mollet). L'âge de la ménarque a été déterminé à partir d'un questionnaire.
Résultats. — Les valeurs de taille, le % GC, la MG, le ratio de taille/hanche sont équivalents entre les groupes quel que soit l'âge ($20{,}5 \pm 1{,}7$ vs $16{,}5 \pm 0{,}9$ ans) et sont plus élevés que dans la plupart des précédentes études en GR. Mais les gymnastes adultes ont un IMC plus élevé que les gymnastes jeunes ($19{,}0 \pm 1{,}2$ vs $18{,}5 \pm 1{,}4\,kg/m^2$), mais toujours dans la normalité. La MMC absolue et relative (kg, %) est plus élevée chez les gymnastes adultes avec plus d'expérience dans le sport ($25{,}0 \pm 2{,}5$ vs $27{,}5 \pm 2{,}5$ kg ; $48{,}4 \pm 2{,}1$ vs $50{,}6 \pm 2{,}1$ %). Les gymnastes jeunes ont commencé plus tôt dans la GR ($6{,}1 \pm 1{,}2$ vs $6{,}8 \pm 1{,}7$ ans), suggérant une tendance actuelle pour un début plus précoce dans la GR, mais ont une expérience d'entraînement moins longue que les adultes ($10{,}3 \pm 1{,}6$ vs $13{,}4 \pm 2{,}5$ ans).
Conclusion. — Les gymnastes jeunes ont une ménarque plus précoce que les adultes ($14{,}8 \pm 1{,}1$ vs $16{,}6 \pm 1{,}2$ ans). L'augmentation des années d'entraînement avant la ménarque et l'âge chronologique expliquent un retard de l'âge de la ménarque parmi les gymnastes élite de GR.

1. Introduction

The prerequisites of athletic success in many sports rely, to a great extent, upon physical characteristics, including anthropometric dimensions and body composition (BC) [1]. Over the last decades, many studies have been conducted in order to define what could be the ideal body shape for different sports. Although the morphological profile does not guarantee a higher level performance in a particular sport, specific morphological traits have been considered as a contributing factor to the individual success in sports like rhythmic gymnastics (RG). According to previous studies in RG, these gymnasts are characterized by low fat mass and long extremities [2,3]. Those morphological constitution are related to the gymnasts initial selection [4] and are a guidance of young female gymnasts talent because of their anthropometric characteristics [1,5]. It is also known that psychological, skill-based factors and morphological constitution have a significant impact in attaining good performances in gymnastic [1,5]. However, the development of disorders eating to achieve a thin body appearance [6] increase risk of injury due to a decreased endurance, strength, reaction time, speed and ability to concentrate [7]. Special medical concerns should be considered when caring for young female athletes [6,7]. These young athletes can develop abnormal eating patterns, which can be associated with menstrual dysfunction (amenorrhea or oligomenorrhea) and subsequent decreased bone mineral density, or osteoporosis. A female athlete triad concerns when tree conditions (disordered eating, menstrual cycle dysfunction and bone weakness) occur in athletic female [6,7]. Menstrual dysfunction is divided on primary amenorrhea that is defined among other factors as the absence of menarche by age 16 years [6], secondary amenorrhea that is defined as the absence of at least three to six consecutive menstrual cycles in a female who has begun menstruating, and oligomenorrhea that refers to intervals longer than every 35 days between menstrual periods [7,8]. Aesthetic sports such as gymnastic, dance, and figure skating may put athletes at higher risk to develop these dysfunctions [7]. The normal menstrual cycle can be a somewhat fragile system altered by low body weight, inadequate nutrition, excessive training, illness, and psychosocial factors [6]. Early intervention after recognition of risk factors for menstrual dysfunction is the key to limiting untoward effects [6]. So, amenorrhea should not be considered a normal response to exercise [7], but incidence of simple delayed menarche must be also considered [9]. It is unclear whether any observed delay in growth or maturation is due simply to selection of genetically late maturing individuals because of their body appearance [10]. This type of shape is indirectly encouraged by the International Gymnastics Federation Code of Points (FIG CP) demands, where factors such as elegance, fluidity and amplitude of movement are related to the ability to perform the technical skills [11,12]. The FIG CP is used as the technical handbook by the RG coach, what means that although the FIG CP does not include specific penalties related to the gymnasts' body shape and composition, it requires that all gymnasts participating in a group exercise should be of similar body shape within the group [12]. Therefore, coaches try to have lean body gymnasts to have a unity and harmony between the five gymnasts technical performance. However, very few studies have focused on the physical characteristics and BC of Elite level RG gymnasts (competing in the main international competitions: European Championships, World Championships, Olympic Games or in World Cups) [2,13—16] and the most part of them have no specific reference to group gymnasts.

The aim of this study was to analyse the anthropometric characteristics, BC, training experience and onset of

menarche of elite RG gymnasts who competed in the group exercises at the 2009 and 2010 World Cups according to their chronological age.

2. Methods

2.1. Subjects

Data were collected during the Portimão Rhythmic Gymnastics World Cup (2009 and 2010). This study was approved by the Scientific Committee of the International Gymnastic Federation, and authorized by the coaches and heads of national delegations. Eighty-four group gymnasts from 14 countries competing at the World Cup were invited and gave consent to participate in the study. The sample was divided into two groups based on the chronological age. The cut point was set at 18 years old to be useful for menarcheal status report [17]. Age reflects a beneficial effect of experience yet, fatness tend to accumulate with age during adolescence in females [1]. The young group was defined for gymnasts less than 18 years old (16.5 ± 0.9 years) and the adult group for those of more than 18 years old (20.5 ± 1.7 years).

2.2. Methodology

Anthropometric measurement were taken according to Ross and Marfell-Jones protocol [18] including their anthropometric tolerances. The gymnasts were measured before training session in Portimão World Cup, because measurements should not be taken after exercise due to sweating and increased blood flow to the subcutaneous tissue, both causing larger skinfolds [19]. Body mass was measured using an electronic digital scale (model 770, Seca, Munich, Germany) and height using a Holtain stadiometer. We registered the mean value of two consecutive measurements. The gymnasts stand in the anatomic position [18]. Skinfolds thickness were measured with a Holtain Skinfold Caliper (Holtain Ltd., Dyfed, UK) range 0 mm to 48 mm, graded with 0.2 mm and a pressure of 10 g mm^2. All measurements were taken on right side of the gymnasts, a minimum of two trials were taken for each skinfold and registered the mean value of two measurements. Gymnasts were measured by only one person. Each skinfold was measured according to marks made in advance on the anterior thigh, triceps, suprailiac and calf by one experienced skinfold tester following Ross and Marfell-Jones protocol [18].

Circumferences were measured with the tape at right angles to the long axis of bone or body. The tape is passed around the part and held so that the stub end and the scale calibrations are in juxtaposition. The aim was to obtain the perimeter distance of the part with the tape in contact with, but not pressing, the fleshy contour. A minimum of two trials were taken, the mean is selected as the value for subsequent analysis. Thigh, relaxed arm, hip and calf circumferences were measured in this way.

Anthropometric and BC variables were calculated using the following equations:

a) To determine the body mass index (BMI) (kg/m^2) we used the following equation:

$$BMI = BM/(H)^2$$

BM: body mass (kg); H: height (m).

b) For Body density (BD) (g/m^3), we used the specific equation of Jackson et al. [20]:

$$BD\left(g/m^3\right) = 1.0994921 - 0.0009929 \times \left(\sum Sf1\right) + 0.0000023 \times \left(\sum Sf1\right)^2 - 0.0001392 \times (age)$$

ΣSf1: sum of skin folds: triceps, thigh and suprailiac (mm); age: years of age.

c) From the equation of Slaughter et al. [21] (for gymnasts aged under 18 years) and Siri [22] (for gymnasts aged over 18 years), we calculated the relative fat mass (FM) (%):

$$FM\ (\%)\ \text{gymnasts} < 18\ \text{years old} = 0.610 \times \Sigma Sf2 + 5.1$$

$$FM\ (\%)\ \text{gymnasts} > 18\ \text{years old} = ((4.95/BD) - 4.50) \times 100$$

ΣSf2: sum of triceps and calf skin fold (mm); BD: body density (g/m^3) of Jackson et al. [20] above.

d) From the FM (%) calculated by the equations of Slaughter et al. [21] and Siri [22], we calculated the absolute FM (kg):

$$FM\ (kg) = (FM\ (\%) \times BM)/100$$

BM: body mass (kg).

e) From the equation of Poortmans et al. [23], we calculated the lean body mass (LBM) (kg):

$$LBM\ (kg) = H \times ((0.0064 \times ACA^2) + (0.0032 \times ACT^2) + (0.0015 \times ACC^2)) + (2.56 \times \text{gender}) + (0.136 \times \text{age})$$

ACA: adjusted circumference of arm (cm); ACT: adjusted circumference of thigh (cm); ACC: adjusted circumference of calf (cm); gender: 0 for women, 1 for men; age: years; H: height (meters), age: years of age.

f) From the LBM (kg) calculated using the Poortmans et al. equation [23], we calculated the relative LBM (%):

$$LBM\ (\%) = (LBM\ (kg) \times 100)/BM$$

BM: body mass (kg).

g) We calculate the waist/hip ratio (cm) as follows:

$$\text{waist/hip}\ (cm) = WC/HC$$

WC: waist circumference (cm); HC: hip circumference (cm).

We used the BMI values as additional information since it has very strong association with fat-free mass [24]. In most RG studies found in literature, relative body fat (% BF) and BMI were the most frequently used parameters [2,13–16,25]. Because BMI provides limited information on the adiposity of thin subjects [24], we decided to measure skinfold thickness that has the potential to substantially improve the prediction of adiposity of thin subjects [24]. We used a BF predictors equations that had a triceps skinfold thickness since provide a better additional information

to predict the body fatness [24] and had a high correlation with performance in gymnastic [1].

We also used a different relative BF equation (% BF) for young and adult gymnasts to control the age influence on data analysis. In previous RG studies [16,26,27] that used a % BF equations by skinfold thickness, Slaughter et al. [21] and Siri [22] equations were used in gymnasts with less and with more than 18 years old respectively. For the adult gymnasts body density was calculated using Jackson et al. equation [20].

A specific age equation (Poortmans et al. [23]) for female subjects was used to predict absolute LBM. We used the waist/hip ratio to classify the gymnasts' biotype [16].

Onset of puberty was determined, in 59 over the 84 gymnasts, by the age at menarche via questionnaire with two questions (Have you ever had a menstrual period? How old were you when you had your first menstruation?) adapted from Bond et al. [28], Ross and Marfell-Jones [18] and Baxter-Jones et al. [17]. We used the age that the gymnasts began RG training and the years of practice to determine the training experience and the training duration (hours/day) and volume (hours/week) were used to quantify the gymnasts training level.

2.3. Statistical analysis

Descriptive statistics were calculated using the mean values as a measure of central tendency and standard deviation as measure of dispersion. Data distribution normality was verified by the Kolmogorov-Smirnov test. A *t*-test was used to determine whether there were significant differences between age groups. To analyze the relationship between pubertal maturity, chronological age and training experience, a linear regression was used on full sample. Chronological age and RG years of practice before menarche entered as independent variables, and age at menarche entered as the dependent variable. Only the gymnasts that report a menarche age were included in this analysis. An α level less than 0.05 was used as a criterion for significance.

3. Results

Gymnasts' main data are shown in Table 1. There was a four-year interval between the young gymnasts mean age (< 18 years old) and the adult gymnasts (> 18 years old) with significant differences. The adult gymnasts had a significant higher body mass than the young gymnasts. No significant differences were found in height between the two groups analysed. Adult gymnasts' hip and thigh circumferences were significantly larger than young gymnasts.

BMI was significantly lower in young gymnasts than in the adult gymnasts. However, no significant differences were found in % BF and FM (kg) between the two groups analysed. We observed a significant difference in both absolute and relative LBM (kg, %) between the young and adult gymnasts with higher values in the adults group. Both groups had very close values of waist/hip ratio.

As we can see in Table 1, the gymnasts of our sample began the RG training at 6.1 and 6.8 years of age. The young gymnasts reported a younger age of initiation in RG than the adult gymnasts, but the adult group had more training years ($P < 0.05$).

The mean training load in young and adult gymnasts was 6.6 vs 7.0 hours/day, and 39.5 vs 41.4 hours/week respectively, and we did not find significant differences between groups.

Among the 59 gymnasts who answered the menstrual history questions, 88.1% were postmenarcheal and 11.9% were premenarcheal. The mean age at menarche was 14.8 in young gymnasts and 16.6 in adult gymnasts.

The regression analysis used to further research whether the chronological age was associated with the onset of menarche, had shown that age at menarche was significantly positively related to gymnasts chronological age ($\beta = 0.30$; $r^2 = 0.31$; $P < 0.001$) and to the RG years of practice before menarche ($\beta = 0.38$; $r^2 = 0.29$; $P < 0.001$). According to these results, as the chronological age and the years of practice before menarche increased, later was the menarche age.

4. Discussion

Anthropometric characteristics, BC variables, training experience and age at menarche data collected from RG studies are resumed in Table 2.

The chronological age of young gymnasts group in our study had a range of 2.7 years (15.27 and 17.99 years old) much lower than adult gymnasts group that had a range of 7 years (17.99 and 25.04 years old) that means that nowadays the high level groups RG gymnasts are older and more experienced [1].

The adult gymnasts in our sample had higher body mass than younger gymnasts. Both groups had higher body mass than that found in the majority of the RG studies presented in Table 2 [13,14,25—27]. However, the anthropometric data in adult gymnasts group are in accordance with other studies conducted on age-matched gymnast groups [2,11,16]. Only Pineau [25] and Berlutti et al. [16] studies had a similar body mass than our young gymnasts group. These studies were made with 1994 Germany international level gymnasts and during 1986 European championship (EC) data respectively. Adult gymnasts in RG, not only from our study but also from those in the literature [2,11,16], were taller compared to the reference height values (163.7 cm) reported by the World Health Organization (WHO) [29]. The adult gymnasts were between 75th and 90th percentile according to international growth curves [30,31]. The young gymnasts also reported high height values compared to the references (162.7 cm) [29] and were between 50th and 75th percentiles according to international growth curves [30,31]. The body mass was lower than the WHO reference data [29] for their age (56.4 kg for young group and 56.6 kg for adult group), the young and adult gymnasts were between 25th and 50th percentiles according to international growth curves [30,31]. Those anthropometric characteristics could be probably related to the gymnasts initial selection, because the anthropometric characteristics [4] are one of the most common selection criteria in aesthetic sports [1,5,10]. Berlutti et al. [16] studied the BC, biological maturity, dietary habits and anthropometric characteristics of the RG gymnasts who participated in 1986 EC (Florence) and in 2008 EC (Turin). As shown in Table 2, the

Table 1 Anthropometric characteristics, body composition variables, training data and age at menarche for the young gymnasts (< 18 years old) and the adult gymnasts (> 18 years old). Data are mean (SD).

	Young ($n = 39$)	Adult ($n = 45$)	
Variables	Mean (SD)	Mean (SD)	*t*-test
Chronological age (years)	16.5 (0.9)	20.5 (1.7)	< 0.001[a]
Body mass (kg)	51.6 (4.7)	54.3 (4.3)	0.007[a]
Height (cm)	167.2 (4.5)	169.0 (5.2)	ns
Hip circumference (cm)	86.3 (3.9)	89.6 (3.4)	0.001[a]
Thigh circumference (cm)	51.2 (2.7)	53.1 (2.6)	< 0.001[a]
BMI (kg/m^2)	18.5 (1.4)	19.0 (1.2)	0.043[a]
BF (%)	17.3 (2.8)	16.3 (2.9)	ns
FM (kg)	9.0 (1.9)	8.9 (1.9)	ns
LBM (kg)	25.0 (2.5)	27.5 (2.5)	< 0.001[a]
LBM (%)	48.4 (2.1)	50.6 (2.1)	< 0.001[a]
Waist/Hip Ratio	0.77 (0.03)	0.76 (0.04)	ns
Onset RG (years of age)	6.1 (1.2)	6.8 (1.7)	0.027[a]
Training Experience (years)	10.3 (1.6)	13.4 (2.5)	< 0.001[a]
Training duration (hours/day)	6.6 (1.2)	7.0 (1.1)	ns
Training Volume (hours/week)	39.5 (7.0)	41.4 (5.9)	ns
Menarche (age)	14.8 (1.1) $n = 19$	16.6 (1.2) $n = 33$	< 0.001[a]

BMI: body mass index; BF: body fat; FM: fat mass; LBM: lean body mass; *n*: subjects number; ns: not significant; RG: rhythmic gymnasts.
[a] $P < 0.05$.

2008 groups gymnasts of EC [16] had similar characteristics to our sample. The author showed that, in 1986 study sample, the gymnasts were smaller, with less body mass and younger that in the 2008 sample. The RG groups in the past were composed by younger and thinner gymnasts than today. Berlutti et al. [16] reported that the thin profile of RG gymnasts required in the past is no longer the case nowadays, and that a thin profile should no longer be considered the role model in this sport. We found significant differences between the young and the adult gymnasts only in the hip and thigh circumferences. Douda et al. [27] also noted lower values of hip circumferences in gymnasts younger than 18 years of age than Berlutti et al. [16] in adult gymnasts.

According to Amigo et al. [11], the most used BC parameters in sports are % BF and LBM. However, in most RG studies found in literature, % BF and BMI were the most frequently used parameters. In the most part of studies in RG, including the present study, BMI values for adult gymnasts are at the lower limit of what is considered the normal BMI range by WHO [32] (18.50 to 24.99 kg/m^2). Our sample of young gymnasts had significantly lower BMI than the adult gymnasts falling slightly below the minimum reference value, while the RG studies with gymnasts under 18 years of age reported lower values for BMI than ours [2,13–15,25]. According to Freedman et al. [24], a lower BMI levels may reflect low levels of either fat mass or fat-free mass. The young and adult gymnasts were between 10th and 25th percentile according to the international BMI-for-ages percentiles references [30,31]. The reference values for 50th percentile for our young group is 20.6 kg/m^2 and for adult group is 21.8 kg/m^2.

The two groups analysed in our study (young vs adult gymnasts) had similar % BF values and this is in accordance with some RG studies previously reported [2,16,25]. There are previous studies reporting lower % BF than found in our sample [13–15,26,27]. This difference may be explained by the younger and individual gymnasts in their sample, which may have influenced the results. We think that judges subjective aesthetic evaluation in groups competition is more focused on the group work design [33] than in individual competition that is more focused on the gymnast profile. According to the reference % BF values [34,35] gymnasts reported lower values in both young and adult group analyzed. The young gymnasts reported values between 5th and 10th percentile and the adult gymnasts group reported values between 2nd and 5th percentile. The % BF that Amigo et al. [11] recorded in Spanish gymnasts was much lower than what we, and the most authors, reported (Table 2). According to the authors [11], their data is significantly lower than the reference values of the Spanish population. On the other hand, when we compare gymnasts from different studies, some precautions must be taken because the different training requirements, seasonal variations, and diets [11].

The LBM (kg) values of our sample were lower than that reported by the Douda et al. [26] in elite RG gymnasts from Greece and Cyprus (Table 2). When we compare the adult with young gymnasts in our sample, we found a significant

Table 2 Anthropometric, body composition, training data and age at menarche (average ± standard deviation) previously reported in rhythmic gymnasts.

Variables/ Authors	Pineau (1994) [25]			Georgopoulos et al. (1999) [2]		Georgopoulos et al. (2001) [13]	Georgopoulos et al. (2002) [13]	Douda et al. (2002) [27]	Theodoropoulo et al. (2005) [15]	Douda et al. (2008) [26]	Amigo et al. (2009) [11]	Berlutti et al. (2010) [16]	
Sample (*n*)				255	16	104	129	9	423	15	151		139
Level of performance	Nat. (France)	Int. (Germany)	Int. (Italy)	EC 1997	EC 1997	EC and WC 1997–2000	WC 1999	Nat. (Greece)	WC and EC (1997–2004)	Int. (Greece and Cyprus)	Nat. Int. (Spain)	EC Groups 1986	EC Groups 2008
Age (years)	14.9 ± 9.4	16.0 ± 1.0	16.4 ± 0.5	14.7 ± 2.1 (11–23)	18.4 ± 2.1 (15–23)	16.0 ± 1.7 (12–23)	17.1 ± 1.4	(15–17)	15.9 ± 2.4	13.4 ± 1.6	18.2 ± 0.2	16.4 ± 2.1	18.8 ± 2.2
Body mass (kg)	40.8 ± 3.3	49.4 ± 2.2	46.6 ± 3.1	42.0 ± 7.4	52.4 ± 5.1	45.3 ± 6.6	47.3 ± 4.8	44.1 ± 3.6	Nr	35.6 ± 5.5	53.7 ± 3.3	49.5 ± 5.5	52.4 ± 4.5
Height (cm)	162.0 ± 4.5	164.7 ± 4.6	159.0 ± 2.2	160.4 ± 7.4	168.2 ± 5.2	163.6 ± 5.6	166.3 ± 4.6	160.4 ± 4.8	Nr	151.1 ± 9.5	170.8 ± 2.9	164.8	168.9 ± 5.6
BMI (kg/m^2)	15.5 ± 0.5	18.2 ± 0.6	18.4 ± 0.8	16.3 ± 1.8	18.5	16.8 ± 1.8	17.1 ± 2.1	Nr	16.9 ± 1.8	Nr	Nr	18.1 ± 1.5	18.3 ± 1.3
BF (%)	13.2 ± 0.4	16.8 ± 1.6	15.5 ± 1.8	16.1 ± 4.1	Nr	15.9 ± 4.9	13.1 ± 4.9	14.3 ± 2.8	15.5 ± 4.6	14.0 ± 2.2	11.3 ± 1.4	14.4 ± 3.8	17.6 ± 3
LBM (kg)	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	29.8 ± 1.8	Nr	Nr	Nr
LBM (%)	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	47.7 ± 1.7	Nr	Nr
Waist/Hip Ratio	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	0.75 ± 0.03
Onset RG (years of age)	Nr	Nr	Nr	6.8 ± 1.9	Nr	7.3 ± 2.3	7.7 ± 2.2	Nr	7.4 ± 2.3	Nr	Nr	7.8 ± 2.8	6.2 ± 1.9
Training duration (hours/day)	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	Nr	3.8 ± 1.6	6.0 ± 1.8
Training Volume (hours/week)	Nr	Nr	Nr	29.1 ± 15.4	Nr	32.5 ± 13.5	31.2 ± 9.6	Nr	27.1 ± 10.4	Nr	Nr	21.7	36
No. of competitions per year	Nr	Nr	Nr	6.6 ± 3.0	Nr	6.4 ± 2.7	7.6 ± 3.1	Nr	6.8 ± 3.0	Nr	Nr	Nr	Nr
Menarche (age)	Nr	Nr	Nr	14.3 ± 1.5	Nr	Nr	15.2 ± 1.4	Nr	14.6 ± 1.5	Nr	Nr	14.0 ± 1.3	15.9 ± 1.3

EC: European Championship; WC: World Championship; Nat.: National; Int.: International; BF (%): Body Fat; BMI: body mass index; LBM: Lean Body Mass; FFM: Fat-Free Mass; Nr: Not reported; RG: rhythmic gymnasts.

difference, the young gymnasts having the lowest values. The gymnasts chronological age of Douda et al. [26] study was lower than our young gymnasts (13.4 vs 16.5 years old respectively), and so we expected that the LBM values were lower in younger gymnasts with lower gymnastics involvement, and it did not happen. According to Amigo et al. [11], longitudinal gymnasts study reported that the LBM do not differ significantly with chronological age (15 to 18 years old), which support our initial expectation as the Douda et al. [26] chronological age sample were less than the minimum range of Amigo et al. [11] study. However, we expect that the LBM values reported in our young gymnasts group will remain the same until they reach the adult group (> 18 years old).

We also found a significant difference in relative LBM (%) between the young and adult gymnasts with higher values in the adults, probably due to their longer carrier in sports.

The gymnasts from our sample (both groups) had a waist/hip ratio less than 0.78 cm. Berlutti et al. [16] found similar values and classified them to the gynoid biotype.

Regarding to the training experience (Table 2) and according to Berlutti et al. [16], the gymnasts who competed in the 2008 EC began their RG career at 6.2 years of age, whereas the gymnasts competing in the 1986 European Championship started at 7.8 years of age, suggesting an actual tendency to an earlier onset in RG. Indeed, the young gymnasts group in our study reported a younger age of onset in RG than adult gymnasts ($P < 0.05$). All other studies (Table 2) reported an onset in RG between 6.8 years old [2] and 7.7 years old [13].

Concerning the training level, only Berlutti et al. [16] refer to the daily training of RG gymnasts. The gymnasts who participated in the EC of 2008 also trained on average 6 hours a day similarly to gymnasts from our sample. We can see in the same study [16] that the gymnasts who participated in the European Championship of 1986 trained 3.8 hours/day. This difference can also evidence a tendency to increase the training volume over the recent years in response to the new technical requirements [36]. Actually, our data recorded more hours of training per week than all RG studies done in previous years [2,13—16]. We can see in RG literature (Table 2) that there was an increase training volume that starts at the second half of first decade of this century.

In the Georgopoulos et al. [13] study, 28.7% of the gymnasts who participated in the 1999 Osaka World Championships had not reached menarche and they were older than 15 years of age. Theodoropoulou et al. [15] also reported that 16.8% of the RG gymnasts participating in the World Cups and European Championships from 1997 to 2004 were premenarcheal. In our study, seven of the 59 (11.9%) gymnasts who answered about the menarche age, were not menstruating. Three of these gymnasts were less than 16 years old (young group), and four of them were more (three belonged to young group and one to adult group). According to the American Academy of Pediatrics [7], primary amenorrhea is defined among other factor as the absence of menarche by age 16 years [6,8]. Although only 6.8% (all sample) of the present study had a disturbed delayed menarche that can be related to a primary amenorrhea. We recognized the limitation of this evaluation that should be monitored by biological maturation progress that has two components: timing and tempo [17]. According to Baxter-Jones et al. [17], the timing refers to the age at which specific maturational events occur (e.g. age when menarche is attained, age at the beginning of breast development, age at the appearance of pubic hair, or age at maximum growth during the adolescent growth spurt) and tempo refers to the rate at which maturation progresses (i.e. how quickly or slowly an individual passes from the initial stages of sexual maturation to the mature state). However, amenorrhea should not be considered a normal response to exercise [7] but incidence of simple delayed menarche must be also considered [9]. Special medical concerns should be considered when caring for young female athletes, a serious health consequence of disordered eating, amenorrhea and osteoporosis conjugation in athletic female (triad female athlete) [6,7] can occur. Coaches should make a point to be up to date regarding recognition and recommendations to medical entities [6]. It is important that no disturbed maturation cases are reported in Gymnastics but if there is a case, it should be medically reported for a proper treatment.

The athletes and dancers who begin training before menarche occurs (premenarcheal trained athletes) have later menarche and more incidence of menstrual dysfunction when compared with athletes and dancers who begin training after menarche occurs (postmenarcheal trained athletes) [7,8]. According to regression analyses, the greater the training experience at the time of menarche, the later the age at menarche, which confirms references in the literature. We also observed that the older the chronological age, the later the age at menarche, which confirms the previous analysis according to the chronological age group. In this way, we expected that the onset in RG training might be later in younger than in adult gymnasts and it did not happen. Somewhat contradictory data which should be analyzed in future studies. According to Frisch et al. [8], each year of training before menarche delayed menarche by 5 months. The training increased the incidence of oligomenorrhea and amenorrhea among both premenarche and postmenarche trained athletes [8]. In our sample, the mean age at menarche was 14.8 ± 1.1 years in young gymnasts and 16.6 ± 1.2 years in adult gymnasts group (Table 1). As shown in Table 2, Berlutti et al. [16] reported a mean age at menarche of 15.9 years. These values were higher than those reported in non-athletic females (12.2 years) and the delayed onset of puberty in these gymnasts can be explained by their lower body mass [16]. According to Claessens et al. [1], the performance scores in gymnastics are also associated with degree of fatness. Di Cagno et al. [37] conclude that the anthropometric and BC characteristics to reach high performance in jumping ability in RG could be described like taller gymnasts, with longer limbs and with high fat-free mass [37]. In this way, there are some aesthetic pressures to a lean body appearance in gymnastics but also performance assessment that related this lean profile with the sport performance in gymnastics. The gymnasts of the 1986 European Championship reported age at menarche of 14 years old, earlier than that observed in more recent studies [13,15] including ours. Some studies have reported significant differences between age at menarche of gymnasts, of their mothers and non-gymnast sisters suggesting the delayed menarche may not have a genetic origin [2,15]. In dancers longitudinal study [38], the mean age at menarche was 13.5 and 14

years old in two groups analysed according to their height progression. We think that one of the biggest differences between the RG older studies and the most recent RG studies is the weekly training volume (29 hours/week in 1997 European Championship [2] and 36 hours/week in 2008 European Championship [16] and 39 to 41 hours/week in the present study) that has increased over the years. We think that for a long-term sport carrier in gymnastics, it is important to study the initial years of practice in RG regarding the training volume, anthropometric characteristics and biological maturation progress (timing and tempo).

5. Conclusion

The elite group RG gymnasts had a similar height, % BF, FM, and waist/hip ratio profile no matter their chronological age and they had higher values than what is reported in previous RG studies. The younger elite RG had a lower BMI than adult gymnasts, but at the normal range. The absolute and relative LBM (kg, %) was higher in the adult gymnasts with longer gymnastics involvement.

The young gymnasts had earlier onset in RG than the adult gymnasts suggesting an earlier specific initiation in RG in recent years. We recorded more training volume in both groups (young and adult gymnasts) than all of previous RG studies. The young gymnasts had less years of RG practice, earlier onset in RG and earlier menarche. It was the increased years of training before menarche and the chronological age that explained the delayed menarche age in Elite RG gymnasts. This study provides updated information that reports some specific anthropometric characteristics in RG high level gymnasts. The results also pointed out the importance of initial years of practice in RG for a long-term sport carrier in gymnastics.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

Acknowledgments

The authors would like to thank the RG World Cup of Portimão 2009 and 2010 Organization, the gymnasts, coaches and heads of national delegations that made this study possible.

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