Journal of Sports Sciences

ISSN: 0264-0414 (Print) 1466-447X (Online) Journal homepage: http://www.tandfonline.com/loi/rjsp20

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To cite this article: Sarita Bacciotti, Adam Baxter-Jones, Adroaldo Gaya & José Maia (2018) Body physique and proportionality of Brazilian female artistic gymnasts, Journal of Sports Sciences, 36:7, 749-756, DOI: 10.1080/02640414.2017.1340655

To link to this article: https://doi.org/10.1080/02640414.2017.1340655

Published online: 16 Jun 2017.

JOURNAL OF SPORTS SCIENCES, 2018
VOL. 36, NO. 7, 749–756
https://doi.org/10.1080/02640414.2017.1340655

Body physique and proportionality of Brazilian female artistic gymnasts

Sarita Bacciotti[a,b,c], Adam Baxter-Jones[d], Adroaldo Gaya[e] and José Maia[a]

[a]CIFI[2]D, Faculty of Sport, University of Porto, Porto, Portugal; [b]CAPES Foundation, Ministry of Education of Brazil, Brasília, Brazil; [c]Physical Education Department, Catholic University Dom Bosco, Campo Grande, Brazil; [d]College of Kinesiology, University of Saskatchewan, Saskatoon, Canada; [e]Department of Physical Education, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

ABSTRACT
This study aimed to identify physique characteristics (anthropometry, somatotype, body proportionality) of Brazilian female artistic gymnasts, and to compare them across competitive levels (sub-elite versus non-elite) within competitive age-categories. Two hundred forty-nine female gymnasts (68 sub-elite; 181 non-elite) from 26 Brazilian gymnastics clubs, aged 9–20 years and split into four age-categories, were sampled. Gymnasts were assessed for 16 anthropometric traits (height, weight, lengths, widths, girths, and skinfolds); somatotype was determined according to Heath-Carter method, body fat was estimated by bioimpedance, and proportionality was computed based on the z-phantom strategy. Non-elite and sub-elite gymnasts had similar values in anthropometric characteristics, however non-elite had higher fat folds in all age-categories ($P < 0.01$). In general, mesomorphy was the salient somatotype component in all age-categories, and an increase in endomorphy, followed by a decrease in ectomorphy across age was observed. Regarding proportionality, profile similarity was found between sub-elite and non-elite within age-categories. In conclusion results suggest the presence of a typical gymnast's physical prototype across age and competitive level, which can be useful to coaches during their selection processes in clubs and regional/national teams.

ARTICLE HISTORY
Accepted 26 May 2017

KEYWORDS
Somatotype; body proportionality; gymnasts; female; anthropometry

Introduction

Female artistic gymnastics is a highly challenging and demanding sport calling for a complex set of favourable traits for obtaining competitive success. Further, it has been shown that successful young gymnasts are part of a highly selected group in terms of motor skills and coordination, body size and shape (Baxter-Jones, Thompson, & Malina, 2002).

It has been emphasized that the prerequisites for the success of athletes in a variety of sports depends largely on their physical characteristics, namely somatic dimensions, somatotype and body composition (Claessens, Lefevre, Beunen, & Malina, 1999). Anthropometric measurements have traditionally been used in the identification of young talented female gymnasts (Bradshaw & Le Rossignol, 2004). Furthermore, when compared with reference standards high-level female gymnasts are characterized by being, on average, shorter in stature, lighter, having broader shoulders, relatively narrow hips, an ecto-mesomorphic somatotype, low body fat, high amount of lean body mass, and a pubertal maturation later than observed in their chronological aged peers (Beunen, Claessens, & Van Esser, 1981; Claessens et al., 1999; Malina et al., 2013).

Gymnasts' anthropometric traits have been linked to performance scores in all apparatuses (Claessens et al., 1999). For example, Claessens et al. (1999) showed that 32%-to-45% of the total variance in performance scores were explained by anthropometric traits and/or derived variables, although endomorphy and chronological age were the most important predictors. Moreover, gymnasts´ technical skills, which are somehow dependent on their anthropometric characteristics, significantly influence the relationship between the scores on each apparatus and the final standing. In uneven bars and balance beam scores were consistently good predictors of final standing, suggesting that they have a marked influence on overall performance, regardless of the competitors' standard (Massidda & Calò, 2012).

It has been suggested that in order to be a successful female athlete, including artistic gymnastics, athletes should display, or try to develop, a specific somatotype, similar to those who are already successful (Carter, 1981; Carter & Brallier, 1988). It has been found that elite gymnasts mostly exhibit a predominance of ecto-mesomorph type of physique (Amigó, Faciabén, Evrard, Ballarini, & Marginet, 2009; Claessens et al., 1990; Massidda, Toselli, Brasili, & Calò, 2013; Thorland, Johnson, Fagot, Tharp, & Hammer, 1981). This has also been shown in Brazilian elite gymnasts (Araujo & Moutinho, 1978; Ferreira João & Fernandes Filho, 2015). It has also been suggested that success is linked to the significant positive relationship of mesomorphy to physical performance (Bale, 1981). Body proportionality has also been shown to be related to success; mostly using Ross and Wilson (1974) z-phantom strategy (Keogh, Hume, Pearson, & Mellow, 2007; Kerr et al., 2007; Sterkowicz-Przybycień, Sterkowicz, & Zarów, 2011). Similarities in gymnasts' proportionality data have also been found in terms of body mass, skeletal width, girths, skinfolds and somatotype (Carter & Brallier, 1988).

The identification and forecasting of successful gymnasts in the international arena remain important challenges for all

CONTACT Sarita Bacciotti saritabacciotti@hotmail.com

coaches. Reliable information about differences between elite versus non-elite gymnasts´ profiles are of great help to coaches in order to reduce their selection errors, and gymnasts multivariate anthropometric profiles explain, in part, their success in competition (Claessens et al., 1999). Although previous studies have compared elite female gymnasts with athletes from other sports and reference norms (Bale, 1981; Beunen et al., 1981; Carter, 1981; Claessens et al., 1990; Román, del Campo, Solana, & Martín, 2012; Thorland et al., 1981), few have investigated physical differences among gymnasts in different stages of their long-term formation (Massidda et al., 2013) or their competitive level, i.e., elite versus non-elite (Bester & Coetzee, 2010; Vandorpe et al., 2011). Therefore, the present study aims to: (1) identify physique characteristics (anthropometry, somatotype, body proportionality) of Brazilian female artistic gymnasts; and (2) compare these characteristics across competitive levels within age-categories.

Material and methods

Sample

The study sample comprises 249 female gymnasts (sub-elite, n = 68; non-elite, n = 181) aged between 9 and 20 years of age. They were recruited from 26 Brazilian gymnastics clubs located in five different states. These clubs represent ~60% of all clubs in these states; individual participation rate in clubs was ~90%. All clubs are part of the three most important Brazilian states where gymnastics is widespread in terms of practice and participation in national events. Club selection was based on their participation and classification in the 2014 Official Brazilian Championships. All gymnasts included in the study (Table 1) were indicated by their coaches to be part of the core team in each club. Gymnasts were separated into four age categories according to the Brazilian Gymnasts Federation competition rules (CBG, 2015): 9-to-10 years (n = 98); 11-to-12 years (n = 72); 13-to-15 years (n = 64), and above 16 years (n = 15). Following the Olympic cycle, and considering the time of data collection, gymnasts were classified as follows: sub-elite; all those who participated in official international championships namely South American or Pan American, and/or those who participated in the Brazilian championships and obtained a classification between the 1st and 10th place of the general individual classification of their competitive category; non-elite; all those whose classification was below 10th place in the overall individual classification in the Brazilian championship in their respective category, and/or participated in lesser-known championships namely regional games, state championships and national tournaments.

All gymnasts were fully assessed by the same research team from May to October 2015. The study protocol was approved by the Brazilian ethics committee of Dom Bosco Catholic University (CAAE 42967215.9.0000.5162), as well as by the technical director of all Gymnastics clubs. Written informed consent was obtained from parents or legal guardians of gymnasts, as well as assent from all gymnasts.

Anthropometry

All anthropometric measurements were collected according to the ISAK standardized protocols (Ross & Ward, 1986). Height and sitting height were measured to the nearest 0.1 cm using a portable stadiometer (Personal Caprice Sanny Stadiometer, SP-BR) with the head positioned in the Frankfurt plane. Body mass (Kg) was measured with a portable bio-impedance scale (Tanita SC 240 Body Composition Analyser scale, IL, USA) with a 0.1 kg precision. Because of its ease, and lesser time needed to assess gymnasts, fat mass was estimated based on regression equations provided by the manufacturer of the bio-impedance Tanita SC 240 scale (unavailable to researchers). All widths (biacromial, biiliocristal, humerus and femur) were measured to the nearest 0.1 cm with a sliding caliper (Sanny, SP-BR). Contracted and relaxed arm and calf girths were assessed, using a Sanny measuring tape, to the nearest 0.1 cm. Triceps, subscapular, supraspinale and calf skinfold were measured with a John Bull British Indicators (England) skinfold calliper (0.2 mm precision). Upper limb length was measured with a Segmometer (SEG4, Rosscraft, CA). Leg length was estimated based on the difference between standing height and sitting height. Measurements were performed at the beginning of each training session by the same trained anthropometrists.

Somatotype

Body physique was estimated according to the Heath-Carter anthropometric method (Carter & Heath, 1990) using 10 measurements: weight, height, skinfolds (triceps, subscapular, supraspinale and medial calf), biepicondylar humerus and femur widths, contracted arm and calf girths. The somatotype is defined as the quantification of the present shape and composition of the human body, and is represented by three components: (1) endomorphy expresses relative fatness, (2) mesomorphy expresses the relative musculo-skeletal

Table 1. Training information (mean ± standard deviation) by age and competitive level.

Age groups (n = 249)	Competitive level	n	Training onset	P-value Cohen´s d	Training years	p-value Cohen´s d	Training hours (per week)	P-value Cohen´s d
9–10 years	Non-elite	84	5.8 ± 1.5	0.067	3.9 ± 1.9	0.019	20.7 ± 7.0	0.013
(n = 98)	Sub-elite	14	5.1 ± 1.3	0.51	5.1 ± 1.6	−0.65	24.4 ± 4.4	−0.55
11–12 years	Non-elite	45	6.5 ± 2.1	0.071	5.1 ± 2.2	0.099	19.4 ± 8.9	<0.001
(n = 72)	Sub-elite	27	5.8 ± 1.3	0.41	5.9 ± 1.8	−0.39	28.2 ± 3.1	−1.21
13–15 years	Non-elite	41	6.4 ± 2.0	0.379	7.4 ± 2.3	0.346	21.7 ± 8.8	<0.001
(n = 64)	Sub-elite	23	6.0 ± 1.4	0.22	7.9 ± 1.6	−0.24	30.1 ± 4.2	−1.12
above 16 years	Non-elite	11	8.1 ± 2.4	0.069	9.2 ± 2.8	0.381	24.0 ± 8.3	0.243
(n = 15)	Sub-elite	4	5.5 ± 1.9	1.13	11.8 ± 4.7	−0.74	27.8 ± 3.5	−0.50

robustness, and (3) ectomorphy expresses the relative linearity or slenderness of a physique [(Carter, 2002) for details concerning formulae to compute each component].

Body proportionality

Body proportionality analyses were conducted using the Phantom stratagem proposed by Ross and Wilson (1974) and further revised by Ross and Ward (1982). The Phantom stratagem is based on the concept of a theoretical reference human and is a conceptual, bilaterally symmetrical model derived from reference male and female data. Each variable was adjusted to the Phantom size using the following formula,

$$zscore = (1/s)v[(170.18/h)^d - P],$$

where z is a proportionality value, v is the size of any given variable, 170.18 is the Phantom stature constant, h is subject's obtained stature, d is a dimensional exponent, P is the Phantom value for variable v, and s is the Phantom standard deviation value for variable based on an hypothetical universal human population. As is well-known, z-values have 0 mean, and so a z-value of 0.0 indicates that variable v is proportionally the same as the Phantom; a z-value greater than 0.0 means that the subject is proportionally greater than the Phantom for variable v; otherwise a z-value of less than 0.0 shows that the subject is proportionally smaller than the Phantom for that variable (Ross & Ward, 1982).

Supplementary information

Based on a specific questionnaire, gymnasts answered questions regarding their onset of training, training years as well as the number of training hours per week. Further, these answers were confirmed by their parents and coaches.

Data quality control

Data quality control was performed in two steps. Firstly, a pilot study was conducted with 4 gymnasts who were re-tested a week later to confirm the quality of measurements taken. This step was supervised by a criterion anthropometrist. Secondly, during the field data acquisition each gymnast was measured twice and a third measurement was taken if the difference between the previous two measurements was outside the permissible range for each measurement and its replica (Carter, 1982; Ross & Marfell-Jones, 1991): 0.5 kg for weight, 3.0 mm for height, 2.0 mm for sitting height, biceps relaxed and biceps contracted girths; for biacromial and, biiliocristal widths, 1.0–2.0 mm were considered, and for humerus and femur widths as well as biceps and calf girths a 1.0 mm was used; for skinfolds a 1.0 mm was considered for triceps and calf, 1.6 mm for subscapular, and 1.5 mm for supraspinale. The technical error of measurement (TEM) was 0.1 kg for body mass and fat mass; 0.2 cm for height, sitting height, upper limb length, biacromial and biiliocristal widths; 0.1 cm for humerus and femur widths, contracted arm and calf girths; 0.3 cm for relaxed arm girth; 0.4 mm for triceps and subscapular skinfolds; 0.5 mm for supraspinale skinfold, and 0.2 mm for medial calf skinfold.

Statistical analysis

Exploratory and descriptive statistics were performed in SPSS 20.0. Somatotype components and somatoplots were calculated in the MER Goulding Software Development (1.2.6 version). The z-phantom scores were obtained from Excel and were plotted in Graph Pad Prism 6.0. Mean differences between sub-elite versus non-elite gymnasts in each age group were calculated in STATA 14 using a t-test with a Satterthwaite's approximation for degrees of freedom since in most cases variances were not equal between the groups. A 0.01 significant level was considered given the systematic testing. Cohen´s d effect sizes (d) were also calculated: d values up to 0.2 represent small effect, 0.5 moderate effect and greater than 0.8 a large effect (Cohen, 1988; Hopkins, Marshall, Batterham, & Hanin, 2009).

Results

Training information by age and competitive level are shown in Table 1. Training onset, i.e., the age at which each child started Gymnastics training, did not differ between sub-elite and non-elite gymnasts regardless of age group, and varies from 5.8 ± 1.5 to 8.1 ± 2.4 years in non-elite gymnasts and from 5.1 ± 1.3 to 6.0 ± 1.4 years in sub-elite gymnasts. Training years was significantly different only between sub-elite and non-elite gymnasts in the first age group (9–10 years), favoring the sub-elite.

Anthropometric measurements and somatotype components descriptive statistics for all gymnasts according to their age group and competitive level are shown in Table 2. In the youngest age group (9–10 years old), non-elite gymnasts were younger than sub-elite gymnasts ($P = 0.003$, $d = -0.76$), had smaller acromial ($P = 0.027$, $d = -0.62$) and humerus ($P = 0.014$, $d = -0.73$) widths, contracted ($P = 0.007$, $d = -0.84$) and relaxed arm ($P = 0.009$, $d = -0.73$) girths as well as higher mean skinfold values (triceps and calf; $P = 0.004$, $d = 0.67$, $P = 0.005$, $d = 0.60$ respectively); they also had higher endomorphy ($P = 0.016$, $d = 0.48$), but smaller mesomorphy ($P = 0.021$, $d = -0.69$). In the second age group (11–12 years old), non-elite gymnasts were taller ($P = 0.040$, $d = 0.50$) had higher biiliocristal ($P = 0.019$, $d = 0.56$) widths, skinfolds (triceps, subscapular, supraspinale and calf; $P < 0.001$, $d = 1.14$, $P = 0.001$, $d = 0.74$, $P < 0.001$, $d = 1.03$, $P < 0.001$, $d = 0.88$ respectively) and endomorphy ($P < 0.001$, $d = 1.17$); but had smaller mesomorphy ($P = 0.020$, $d = -0.56$). In the third age group, non-elite gymnasts (13–15 years old) were significantly heavier ($P = 0.018$, $d = 0.56$), fatter ($P = 0.031$, $d = 0.52$) and taller ($P = 0.025$, $d = 0.54$), and had also higher sitting heights ($P = 0.023$, $d = 0.51$), biiliocristal ($P = 0.001$, $d = 0.84$) widths, fat folds (triceps, subscapular, supraspinale and calf; $P = 0.001$, $d = 0.87$, $P = 0.002$, $d = 0.77$, $P = 0.001$, $d = 0.82$, $P = 0.002$, $d = 0.74$ respectively) and endomorphy ($P = 0.001$, $d = 0.85$). In the fourth age group (≥ 16 years old) non-elite gymnasts had higher triceps ($P = 0.005$, $d = 1.27$) and medial calf ($P = 0.017$, $d = 0.99$) fat skinfolds than sub-elite gymnasts´.

Somatoplot distributions by age groups and competitive level are shown in Figure 1. In the first group both non-elite and sub-elite gymnasts were classified as ectomorphic mesomorph (2.8-

Table 2. Anthropometric measurements and somatotype components by age and competitive level.

	9–10 years n = 98			11–12 years n = 72			13–15 years n = 64			≥ 16 years n = 15		
Competitive Level	Non-elite n = 84	Sub-elite n = 14	P-value Cohen ´s d	Non-elite n = 45	Sub-elite n = 27	P-value Cohen ´s d	Non-elite n = 41	Sub-elite n = 23	P-value Cohen ´s d	Non-elite n = 11	Sub-elite n = 4	P-value Cohen ´s d
Age (years)	9.5 ± 0.5	9.9 ± 0.4	0.003 −0.76	11.5 ± 0.5	11.5 ± 0.5	0.952 −0.01	13.8 ± 0.7	13.6 ± 0.7	0.293 0.27	17.0 ± 0.8	17.5 ± 1.9	0.643 −0.44
Weight (kg)	29.0 ± 3.9	30.8 ± 4.2	0.150 −0.46	37.6 ± 7.4	35.2 ± 7.0	0.174 0.33	47.4 ± 7.7	43.5 ± 4.9	0.018 0.56	53.8 ± 5.1	52.4 ± 4.1	0.605 0.28
Fat Mass (kg)	4.8 ± 1.4	5.5 ± 1.5	0.131 −0.48	7.1 ± 3.9	6.5 ± 3.2	0.502 0.16	10.8 ± 3.5	9.2 ± 2.5	0.031 0.52	11.7 ± 4.3	11.5 ± 2.7	0.895 0.06
Height (cm)	134.7 ± 6.2	135.8 ± 5.9	0.542 −0.17	146.1 ± 7.2	142.6 ± 6.6	0.040 0.50	154.2 ± 7.0	150.8 ± 4.8	0.025 0.54	159.3 ± 4.3	159.2 ± 5.0	0.959 0.03
Sitting Height (cm)	70.8 ± 3.2	71.7 ± 2.6	0.264 −0.29	76.1 ± 3.4	74.6 ± 3.1	0.054 0.47	80.5 ± 4.1	78.7 ± 2.1	0.023 0.51	84.1 ± 3.2	85.7 ± 0.8	0.157 −0.56
Upper Limb Length (cm)	58.8 ± 3.3	59.0 ± 3.2	0.773 −0.08	63.7 ± 3.6	62.9 ± 3.9	0.389 0.22	68.4 ± 3.3	67.7 ± 2.4	0.315 0.24	68.8 ± 2.9	69.6 ± 2.9	0.670 −0.26
Acromial width (cm)	30.5 ± 1.5	31.5 ± 1.3	0.027 −0.62	33.1 ± 1.8	33.0 ± 2.3	0.834 0.06	36.2 ± 2.1	35.7 ± 1.7	0.301 0.25	38.2 ± 2.0	37.2 ± 1.2	0.260 0.54
Biiliocristal width (cm)	20.6 ± 1.1	20.9 ± 1.2	0.368 −0.28	22.8 ± 1.8	21.8 ± 1.5	0.019 0.56	24.6 ± 1.9	23.2 ± 1.4	0.001 0.84	25.8 ± 1.4	25.5 ± 0.8	0.557 0.27
Humerus width (cm)	5.4 ± 0.3	5.6 ± 0.3	0.014 −0.73	5.7 ± 0.3	5.7 ± 0.4	0.869 −0.04	6.0 ± 0.3	6.0 ± 0.4	0.678 −0.12	6.0 ± 0.3	6.0 ± 0.4	0.866 0.13
Femur width (cm)	7.7 ± 0.3	7.9 ± 0.4	0.278 −0.38	8.2 ± 0.4	8.1 ± 0.5	0.387 0.22	8.5 ± 0.4	8.3 ± 0.4	0.148 0.36	8.6 ± 0.4	8.3 ± 0.2	0.062 0.91
Contract. arm girth (cm)	21.2 ± 1.5	22.4 ± 1.4	0.007 −0.84	23.4 ± 2.1	23.5 ± 2.4	0.746 −0.08	26.1 ± 2.0	25.5 ± 2.1	0.245 0.31	27.7 ± 2.0	28.0 ± 1.5	0.740 −0.17
Relaxed arm girth (cm)	19.3 ± 1.5	20.4 ± 1.2	0.009 −0.73	21.4 ± 2.0	21.2 ± 2.3	0.806 0.06	24.0 ± 2.0	23.7 ± 2.2	0.121 0.42	25.5 ± 1.8	25.4 ± 1.4	0.937 0.04
Medial calf girth (cm)	26.6 ± 2.0	27.2 ± 1.6	0.201 −0.33	29.3 ± 2.6	28.6 ± 2.1	0.194 0.30	31.8 ± 2.7	31.2 ± 1.6	0.317 0.23	33.3 ± 2.3	32.4 ± 0.8	0.264 0.45
Triceps skf (mm)	7.8 ± 1.9	6.6 ± 1.2	0.004 0.67	9.2 ± 2.8	6.4 ± 1.5	<0.001 1.14	9.6 ± 3.2	7.1 ± 2.3	0.001 0.87	12.6 ± 4.8	7.3 ± 1.3	0.005 1.27
Subscapular skf (mm)	5.8 ± 1.4	5.6 ± 0.8	0.347 0.19	7.4 ± 2.1	6.0 ± 1.3	0.001 0.74	9.1 ± 2.6	7.3 ± 2.0	0.002 0.77	10.1 ± 3.1	8.9 ± 1.7	0.367 0.42
Supraspinale skf (mm)	8.5 ± 3.8	7.4 ± 1.8	0.081 0.32	12.0 ± 5.3	7.4 ± 2.5	<0.001 1.03	15.2 ± 6.1	10.6 ± 4.5	0.001 0.82	16.9 ± 6.0	14.1 ± 3.5	0.281 0.52
Medial calf skf (mm)	7.7 ± 2.1	6.5 ± 1.2	0.005 0.60	9.4 ± 3.1	6.9 ± 2.3	<0.001 0.88	9.4 ± 3.4	7.2 ± 1.8	0.002 0.74	12.1 ± 4.1	8.5 ± 0.6	0.017 0.99
Endomorphy	2.8 ± 0.8	2.5 ± 0.4	0.016 0.48	3.3 ± 1.0	2.3 ± 0.6	<0.001 1.17	3.8 ± 1.2	2.8 ± 0.9	0.001 0.85	4.2 ± 1.3	3.3 ± 0.5	0.088 0.75
Mesomorphy	4.1 ± 0.8	4.6 ± 0.7	0.021 −0.69	3.9 ± 0.8	4.3 ± 0.6	0.020 −0.56	4.2 ± 0.7	4.4 ± 0.8	0.206 −0.34	4.1 ± 1.0	4.0 ± 0.6	0.806 0.12
Ectomorphy	3.6 ± 0.9	3.2 ± 0.9	0.150 0.41	3.5 ± 1.0	3.4 ± 0.8	0.612 0.12	2.8 ± 1.0	2.9 ± 0.9	0.616 −0.13	2.4 ± 1.1	2.6 ± 0.9	0.720 0.20

4.1-3.6, 2.5-4.6-3.2 respectively). In the second group non-elite were central somatotype (3.3-3.9-3.5) while sub-elite gymnasts have an ectomorphic mesomorph somatotype (2.3-4.3-3.4). In the third group non-elite are endomorphic mesomorph (3.8-4.2-2.8) while sub-elite are balanced mesomorph (2.8-4.4-2.9). Finally, in the oldest group non-elite gymnasts exhibited a mesomorph-endomorph physique (4.2-4.1-2.4), while sub-elite have endomorphic mesomorph (3.3-4.0-2.6).

Figure 2 displays somatic proportionality profiles of all gymnasts by their competitive level within each age group. With the exception of just two significant differences ($p < 0.01$) in humerus and biiliocristal widths in age groups 2 and 3,

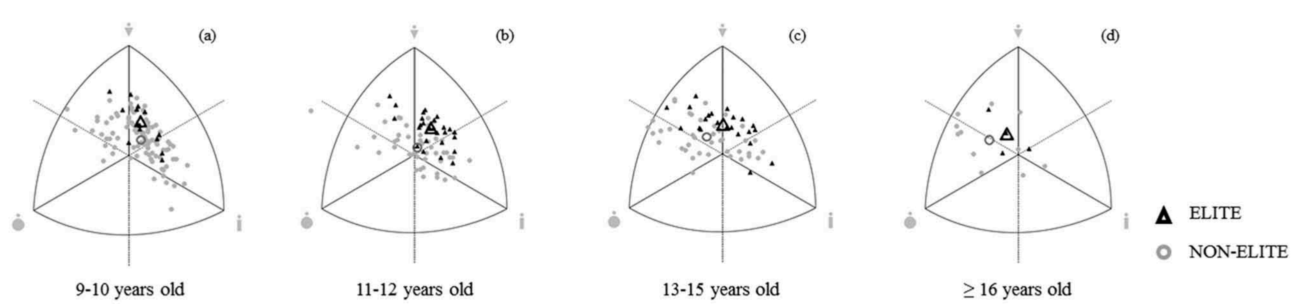

Figure 1. Somatoplot distributions of body type by age (a, b, c, d) and competitive level.

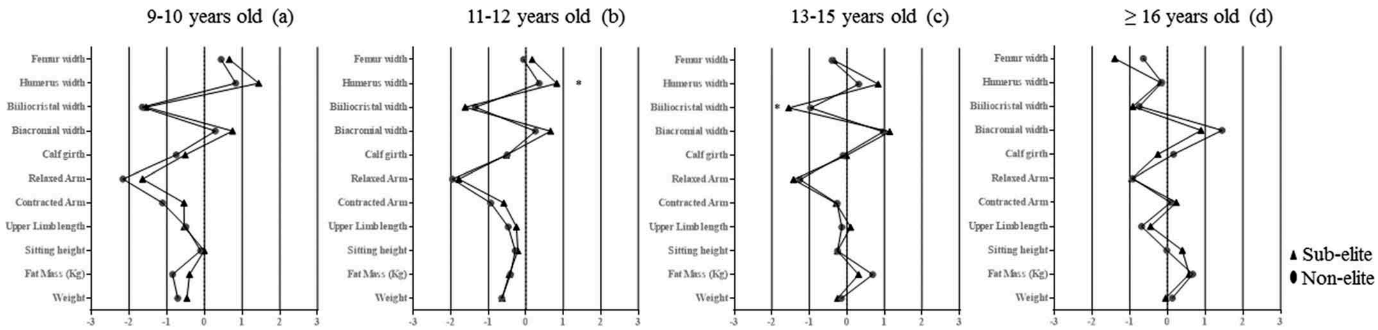

Figure 2. Gymnasts' proportionality profiles by age (a, b, c, d) and competitive level.

respectively, the major trend is for profile similarity across gymnasts irrespective of their competitive levels.

Discussion

This study not only described anthropometric traits, somatotype, and body proportionality of Brazilian female artistic gymnasts, but also compared them, sub-elite *versus* non-elite, within each competitive age group. We found that sub-elite gymnasts were smaller and lighter than non-elite ones (groups 2 and 3). Differences were also found in skinfolds in all groups. Further, it is possible that differences in other anthropometric measurements (no more than 1.2 cm) in the first group could be attributed to their chronological age, since the sub-elite gymnasts (9.9 ± 0.4years) were somewhat chronologically older than non-elite (9.5 ± 0.5years). In contrast in the other age groups and competitive levels values were very similar. Anthropometric characteristics are known to be related to maturity status. In our sample (data not shown) we found that a high frequency of non-elite gymnasts reached menarche prior to sub-elite gymnasts in each age category. This was expected since it has consistently been shown that elite gymnasts are late maturers (Baxter-Jones et al., 2002; Malina et al., 2013) and that the pre-pubertal physique confers a performance advantage in this sport (Baxter-Jones, Helms, Maffulli, Baines-Preece, & Preece, 1995).

In comparison with our findings, Claessens et al. (1990) extensive anthropometric data on the 1987 World Championship participants was divided into three performance levels, HP = Highest Performer, MP = Middle Performer, and LP = Lowest Performer. Their analysis only showed significant differences between levels in sitting height, thigh girth and skinfolds. A similar tendency was found by Pool, Binkhorst, and Vos (1969) using data from European Championship held in Rotterdam in 1967, but organized by the 10th, 20th, 30th, and 40th best classification (total score). Bester and Coetzee (2010) found similar results on their wide-ranging anthropometric data (61 measurements) between successful and less successful gymnasts in the vault apparatus, given that differences were found solely in four girths (contracted and relaxed arm, wrist and ankle) and in mesomorphy. This general trend in gymnasts' similarity in their growth data, irrespective of their competitive level, is apparently not affected by their different training loads as previously suggested (Bailey & Mirwald, 1988; Claessens et al., 1990). It is also possible that these similarities, a kind of general aesthetic cannon, reflect initial selection screening. Also, the lowest mean skinfolds of elite gymnasts may be the net result of their training demands and nutritional regulation aimed to increase lean body mass and decrease body fat (Bailey & Mirwald, 1988; Malina, Bar-Or, & Bouchard, 2004). For example, Parizkova (1974) compared three groups of young athletes with different amounts of training in terms of hours/week and showed that the most active group was heavier, had higher lean body mass, and lower fat mass than the less active group. Further, Claessens et al. (1990) compared world level female gymnasts and revealed that those with the highest ranking scores had significantly lower fat mass than the lowest classified. Finally, (Table 1) differences in training hours per week between our non-elite and sub-elite gymnasts as well as their training onset and trainings years do not seem to affect their anthropometric results. Yet, training onset and training years are related to deliberate practice and the necessity to have a minimum time of experience to achieve success (Ericsson, Krampe, & Tesch-Römer, 1993). Early specialization is common in artistic gymnastics (Callender, 2010). Considering that 18 years of age was the average age of gymnasts participating in fourteen Olympic Games from 1956 to 2008 (Sands, Slater, McNeal, Murray, & Stone, 2012) and that it is necessary, on average, to have 8 to 10 years for the training of a gymnast in order to obtain national and international titles (Bajin, 1987), the process of selection of suitable girls for gymnastics happens usually between 5 and 7 years old (Nunomura, Carrara, & Carbinatto, 2009).

There is a substantial evidence that somatotype and success in sport and physical performance are positively related (Carter & Heath, 1990). This suggests that in order to be a successful female athlete, including artistic gymnasts, they should display, or try to develop, a specific somatotype, mostly similar to those who are already successful (Carter, 1981; Carter & Brallier, 1988). Further, it has been suggested that success is linked to a significant positive relationship of mesomorphy to physical performance (Bale, 1981). Overall the present Brazilian gymnasts displayed a predominance for mesomorphy. Yet, with increasing age they also tended to change their predominance from ectomorphy to endomorphy. These results are in accordance with available data concerning changes in somatotype during adolescence – girls tend to decrease their mesomorphy component followed by increases in endomorphy (Carter & Heath, 1990; Malina et al., 2004). Furthermore, as described by Carter and Heath (1990) in their review study involving athletes from both sexes and different sports, mean somatotype of young gymnasts tend to be ecto-mesomorphic or central, near 2-4-3, and older gymnasts their somatotype is more likely to be endo-meso-morphic or central, near to 3-4-3. Similarly to our findings, previous studies have shown that mesomorphy clearly differentiates elite gymnasts of different competitive levels. For example, Bester and Coetzee (2010) found higher mesomophy values in successful gymnasts when compared to their less successful peers, and no differences in ectomorphy and endomorphy components were observed. Likewise, Claessens et al. (1990) reported that the HP gymnasts had higher values in mesomorphy when compared with MP and LP performers. On the contrary, both HP and MP showed lower endomorphy than the LP group, and no significant differences were found regarding to ectomorphy.

Gymnasts' body proportionality profiles were rather similar between competitive levels, and only showed significant differences in humerus and biiliocristal width (age group 2 and 3 respectively). Carter and Brallier (1988) reported that there seems to exist a trend for gymnasts to be remarkably similar in their proportional mass, skeletal widths, girths, skinfolds and somatotype. It has also been reported that gymnasts tend to have relatively broad shoulders in relation to their hips (Malina et al., 1984). Further, female gymnasts seem to be quite consistent in their proportional size, skinfolds and somatotype (Carter & Brallier, 1988), with low skinfolds and narrow hips, small size and low weight being dominating factors (Beunen et al., 1981; Claessens et al., 1999). Although we were not able to localize a study comparing body proportionality profiles between gymnasts from different competitive levels our results confirm the major proportionality profiles often seen in artistic gymnasts.

It has been suggested that in early talent detection and development processes this profiling could assist coaches in their decisions (Bradshaw & Le Rossignol, 2004; Claessens et al., 1999; Prescott, 1999). However, current development talent programs, namely the Talent Opportunity Program (USA-Gymnastics, 2014), excluded this information (i.e. weight, height, width, girth, length, skinfold) in practical evaluations, arguing that this data was mostly used for scientific purposes. Given that anthropometric measures are used in clubs to help in their initial selection, our results would suggest that body characteristics should be continually measured to assess development and potential performance success., especially as gymnasts that continue in the sport are probably those whose proportionality profiles closely matches successful gymnasts. In the absence of a clear differentiation between elite and non-elite gymnasts' body profiles, current practice is to look at motor performance and skills, as well as technical evaluation, to assess and selected progression in gymnasts. This represents a change in perspective from body proportionality profiles, to motor abilities and technical skills profiles (Pion, Lenoir, Vandorpe, & Segers, 2015; Vandorpe et al., 2011, 2012).

In summary, this study provided relevant information that in all likelihood will be useful to coaches not only when making selection decisions, but also in their varied ways to assess and control gymnasts´ response to training and competition. Furthermore we provided an update of anthropometric data on non-elite and sub-elite gymnasts that adds to those given in the 80–90´s (Claessens et al., 1999, 1991).

Notwithstanding the relevance of our findings, this study has, at least, three limitations. Firstly, the non-balanced sample size by competitive level and age groups is to be acknowledged. However this was expected given the selection pressure gymnasts face within their clubs as well as within the state or country levels. Further, available data with country specific samples investigating elite /sub-elite gymnasts also have small sample sizes (Baleani et al., 2008; Bester & Coetzee, 2010; Massidda et al., 2013). Secondly, it was not possible to assess gymnasts from the Brazilian national team because of their competitive constraints. Yet, sub-elite gymnasts considered in the present study have a multifaceted curriculum in their participation in several national and/or international championships. As such, they represent Brazilian sub-elite gymnasts fairly well. The third limitation is the absence of information about biological maturity. Given ethical issues as well as financial and time constraints, we were not able to obtain x-rays to estimate gymnasts´ skeletal maturity, nor were we allowed to obtain information regarding their sexual characteristics. Yet, in data not shown, a high frequency of non-elite gymnasts reached menarche prior to sub-elite gymnasts in each age category. There are, however, some strengths that should be highlighted, namely (1) the varied sample size per age category and competitive level, (2) their potential representation of elite Brazilian gymnasts, (3) the use of standardized measurement protocols and high quality data. Additionally, data from this study fills a gap in research with Brazilian gymnasts because of its broad inspection at different age and competitive categories.

Conclusions

Although similar in their basic anthropometric characteristics, non-elite Brazilian gymnasts differed from sub-elite in having greater skinfolds. Mesomorphy was the most important somatotype component in all age categories. Yet, older non-elite gymnasts favoured endomorphy, i.e., relative fatness. Gymnasts' overall body proportionality profiles were similar across competitive levels in all age groups. In summary, aesthetic constraints posed by competitions seem to favour a canon of physique from the beginning of a gymnast's career that apparently does not change with age untill the most demanding challenges at the international level.

Further, we anticipate that these results may be useful to coaches during their selection processes in clubs and regional/ national teams.

Acknowledgments

The author would like to acknowledge CAPES to granting Doctoral Scholarship. We would like to thank the study participants along with their parents, coaches and clubs for their involvement in the study.

Disclosure statement

No potential conflict of interest was reported by the authors.

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