MORPHOLOGICAL CHARACTERISTICS OF YOUNG FEMALE ARTISTIC GYMNASTS FROM THE CZECH REPUBLIC

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Original article

Abstract

The aim of the study is to analyse the somatic parameters of artistic gymnasts in the pupil competition category and to compare them with the values of the general population in the corresponding age group. The study included 16 female gymnasts in the pupil category and 652 girls in the same age group, which formed the control group. Body height was measured using a stadiometer InBody BSM 370, body mass and body composition by BIA analyser InBody 770 (Biospace, South Korea). The monitored values of each gymnast we compared with the mean values of the control group at the corresponding age separately, using the normalisation index (Ni). The results of the study show that the gymnasts in the youngest competition category already differ in basic anthropometric parameters from the general population. Since the age of nine, the gymnasts have a lower body height (except for one person) and lower body weight than the girls in the general population. The body height and body mass values are below average or highly below average in nine gymnasts (56.3%). The high volume of specific physical activity of the gymnasts, included in their training, affects their body composition parameters. The gymnasts have lower body fat (%) and visceral fat (cm2), their values are below average to highly below average, and higher skeletal muscle mass (%), with values above average or highly above average.

Keywords: *artistic gymnastics, youth, female, morphology.*

INTRODUCTION

In artistic gymnastics, achieving the highest performance level requires a significant development of motor abilities, skills and an overall high-level development of physical fitness. That is also related to the precondition of optimal development of somatic parameters that represent a significant determinant of each sport performance (Schnabel, Haare, & Krug, 2008). Gymnastics requires explosive sprinting, jumping, pushing and pulling skills, together with balance and artistry on four apparatus for women (beam, uneven bars, floor, vault) (Bradshaw & Hume, 2012). These gymnastic elements lay demands on the strength of the corresponding muscle groups and on the coordination of the muscle activity in space and time.

The intensity of the gymnastic elements requires a long-lasting preparation of gymnasts that starts at an early age, at the end of the period of the first infancy (Infans I), as confirmed by the experience of gymnastic clubs where girls start training at the age of 4. Bradshaw and Hume (2012) stated that women's artistic gymnastics attracts a large number of children with participation often beginning at five years of age. According to the rules of competition of the Czech Gymnastic Federation, the youngest age group are pupils. This category is defined as ages from 7 to 12 and it thus includes the beginning of the second infancy (Infans II). Previous studies have shown that gymnastics training has numerous health benefits such as bone mineral accrual advantage and reduced risk of osteoporosis (Zanker, Osborne, Cooke, Oldroyd, & Truscott, 2004), enhanced fine postural control (Vuillermea et al., 2001), and increased core strength (Scerpella Davenport, Morganti, Kanaley, & Johnson, 2003). However, the combination of the young age of the gymnasts, and the high volume of physical training that increases throughout the competitive levels, could increase the potential of injuries (Daly, Bass, & Finch 2001).

The intensity of the gymnastic elements together with the specific long-term preparation has to have an effect on the morphological parameters of both male and female gymnasts. This is also confirmed by the incorporation of such parameters into the structure of the performance in gymnastics (Bale & Goodway, 1990). These authors stated that elite female gymnasts are generally short, light, and have excellent strength, power, flexibility and agility. Moreover, it has been suggested that successful young gymnasts are part of a highly select group in terms of specialized motor skills, body size and shape (Baxter-Jones, Thompson, & Malina, 2002). Thus, a question arises: whether or not gymnasts in the youngest competition age group differ morphologically from general population. The results of several studies confirm that the somatic parameters of athletes in various sports do not only differ between the individual disciplines, but also from the values of the general population (Dostálová, Přidalová, & Kudrna, 2005; Gil, Gil, Ruiz, Irazusta, & Irazusta, 2007; Özçakar, Cetin, Kunduracýo, & Ülkar, 2003; Sánchez-Muñoz, Sanz, & Zabala, 2007). Moreover, these differences increase with age and time spent in specific training process (Kutáč, 2012; Norton & Olds, 2001). These parameters are usually consisted from body height, body mass, body mass index, % body fat, skeletal muscle mass and/or skinfold thicknesses measures to determine an anthropometric profile of athletes.

Therefore, the aim of the study is to analyse the somatic parameters of artistic gymnasts in the pupil competition category and to compare them with the values of the general population in the corresponding age group. The current research may provide information about the talent selection in artistic gymnastics, and whether specific gymnastic training affects the morphology of young female gymnasts when compared with the normal population of the same age; and to determine an anthropometric profile of talented young female gymnasts.

METHODS

The study included 16 female gymnasts (8-12 years) in the pupil category and 652 girls in the same age group, which formed the control group (CG). All gymnasts had more than five years of experience with systematic training and competitive gymnastics. Their training volumes were 5 ± 0.8 training days per week and 3.7 ± 0.5 training hours per day. Informed consent and parental consent were obtained from each gymnast and their parents, respectively, in accordance with the guidelines of the Institute's Ethics and Research Committee. The girls in the control group were healthy individuals without any medical problems that did not do any regular organised physical activity. The precise numbers in the individual age categories and groups are presented in Table 1. The classification into the corresponding age category was executed according to WHO. An individual is included in the age group after exceeding the chronological age within the range of a year (e.g. 11 years old = 11.00–11.99 years old) (Vignerová, Lhotská, Bláha, & Roth, 1996).

Table 1
Frequency of participants in age categories.

Age (years)	Gymnasts (n)	Control group (n)
8	2	149
9	3	152
10	4	148
11	5	105
12	2	98

n – frequency

The basic parameters of body height (BH) and body mass (BM) were measured in all participants and these were used to calculate the body mass index (BMI). Out of the body composition parameters, the following were measured: body fat (BF), total body water (TBW), fat free mass (FFM), skeletal muscle mass (SMM) and visceral fat (VFA). Body height was measured using a stadiometer InBody BSM 370 (Biospace, South Korea), body mass and body composition by BIA analyser InBody 770 (Biospace, South Korea) (Figure 1). The InBody 770 analyser is a tetrapolar multi-frequency bioimpedance analyser using a frequency of 1 000 kHz; this instrument was simultaneously used as a scale. BMI calculation:

$$BMI = \frac{BM\ (kg)}{BH^2\ (m)} \qquad (1)$$

Figure 1. Measurement technology.

With regard to the range of the age distribution of the group of gymnasts, it is not possible to assess the gymnasts as one group and therefore we determined the mean age. Their frequency in the individual age groups, however, does not allow for the use of the method of descriptive statistics. Therefore, we compared the monitored values of each gymnast with the mean values of the control group at the corresponding age separately, using the normalisation index (Ni). Ni calculation:

$$Ni = \frac{X - M}{SD} \qquad (2)$$

Legend: X – gymnast's value, M – mean control group, SD – standard deviation control group.

The Ni value in the range of ±0.75 SD shows an average development of the indicator, in the range from ±0.76 to 1.5 SD a below average (above average) development of the indicator and the value above ±1.5 SD means a highly below average (above average) development.

RESULTS

The results present the comparison of the mean values of the basic anthropometric parameters of our control group with the values of the 6th Nation-wide Anthropological Survey of Children and Adolescents (Bláha & Vignerová, 2006) (Table 2), the found values of the morphological parameters of the monitored gymnasts (Table 3), and comparison of their values with the values of the control group (Table 4).

Table 2
Comparison of basic anthropological parameters of the control group with 6th Nation-wide Anthropological Survey of Children and Adolescents.

Years		BH (cm)	BM (kg)	BMI (kg/m^2)
8	M±SD (6th NAS)	132.8±6.1	29.5±5.6	16.6±2.4
	Ni CG	-0.01 SD	-0.05 SD	-0.05 SD
9	M±SD (6th NAS)	138.4±6.4	32.7±6.7	17.0±2.6
	Ni CG	-0.16 SD	-0.13 SD	- 0.07 SD
10	M±SD (6th NAS)	144.6±7.1	37.3±7.9	17.7±2.8
	Ni CG	-0.10 SD	-0.02 SD	0.03 SD
11	M±SD (6th NAS)	151.0±7.6	41.8±9.1	18.2±3.0
	Ni CG	-0.16 SD	-0.07 SD	-0.01 SD
12	M±SD (6th NAS)	157.6±7.3	47.1±9.1	18.9±3.0
	Ni CG	0.25 SD	0.27 SD	0.14 SD

Legend: M – mean, SD – standard deviation, 6th.NAS - national anthropological research, BH – body height, BM – body mass, BMI – body mass index

Our control group can be considered to be a generally healthy Czech population in basic anthropometric parameters. The values we measured can be labelled as average in all monitored age categories. The comparison of their Ni values with the values of 6th NAS did not exceed the level of ±0.75 SD.

The BH values range from above average (Ni > 0.75 SD) in one eight-year-old gymnast to highly below average (Ni < -1.5 SD) in one eleven-year-old gymnast. The BM values also correspond with the BH values, ranging from average values to below average values. The eleven-year-old gymnast with a highly below-average value is an exception (Ni = -1.55 SD). The BMI values calculated from the BH and BM values are average with regard to the control group values, the Ni values range from -0.61 SD to +0.59 SD. The exception includes two eleven-year-olds and one twelve-year-old gymnast. Their values show a below-average to highly below-average BM with regard to their BH (Ni BMI = -0.85 to -1.61 SD). Organism hydration of most gymnasts was average. Their TBW values corresponded with the average values found in the control groups (Ni = ± 0.75 SD). The TBW value was lower only in three gymnasts (Ni = - 0.77 to -1.09 SD) and higher in three gymnasts (Ni = 0.86 to 1.67 SD).

The BF ratio in kilograms was lower in all gymnasts than in the control group. The value was below average in fourteen gymnasts (Ni ranging from -0.84 to -1.28 SD) and highly below average in two gymnasts (Ni < -1.5 SD). When comparing the percentage BF ratio of the gymnasts with the control group, the difference in the BF ratio is more significant. The value is highly below average in twelve gymnasts (Ni < -1.5 SD) and below average in four gymnasts (Ni ranging from -0.93 to -1.46 SD). In addition to body fat (BF), we also measured visceral fat (VFA), which is in the abdominal cavity. The values of this parameter were also lower in gymnasts than in the control group. All the determined values were below average (Ni ranging from -0.90 to -1.49 SD).

A higher ratio of FFM and SMM was only found in three gymnasts. The FFM value was even below average in three gymnasts (Ni ranging from -0.76 to -1.11 SD) and two gymnasts had below-average SMM value in kilograms (Ni = -1.06 SD). The increased SMM ratio in gymnasts was reflected in the comparison of the percentage ratio of SMM to BM. The value was highly above average in fourteen gymnasts (Ni > 1.5 SD) and above average in two gymnasts (Ni > 0.75 SD).

Table 3
Values of the morphological parameters of the gymnasts and the control group.

Groups	BH (cm)	BM (kg)	BMI (kg/m^2)	TBW (l)	BF (kg)	BF (%)	FFM (kg)	SMM (kg)	SMM (%)	VFA (cm^2)
CG8										
M±SD	132.7±5.8	29.2±6.4	16.5±2.9	16.8±2.2	6.4±4.1	20.3±8.8	22.8±6.0	11.5±1.8	39.9±4.0	39.5±22.1
$G8_1$	139.0	29.3	15.2	20.5	1.4	4.8	27.9	14.6	49.83	12.6
$G8_2$	134.5	27.8	15.4	18.9	2.1	7.5	25.7	13.4	48.2	10.0
CG9										
M±SD	137.3±5.8	31.8±6.4	16.8±2.8	18.2±2.2	7.0±4.3	20.7±8.1	24.8±3.0	12.6±1.8	40.3±4.1	39.7±24.3
$G9_1$	127.0	25.3	15.7	17.6	1.5	5.7	23.8	12.5	49.4	7.0
$G9_2$	131.0	26.8	15.6	18.6	1.6	6.0	25.2	13.1	48.9	12.6
$G9_3$	133.0	27.6	15.6	18.9	1.8	6.7	25.8	13.4	48.6	10.0
CG10										
M±SD	143.9±7.1	37.1±8.5	17.8±3.2	20,7±3.0	9.0±5.6	22.6±8.8	28.2±4.0	14.6±2.4	40.1±4.4	46.9±29.0
$G10_1$	143.0	34.0	16.6	23.2	2.4	7.1	31.6	16.9	49.7	7.8
$G10_2$	135.0	30.3	16.5	20.3	2.8	9.1	27.5	14.4	47.5	10.8
$G10_3$	143.0	32.8	16.0	21.7	3.2	9.7	29.6	15.6	47.6	11.6
$G10_4$	138.0	31.2	16.4	19.8	4.3	13.7	26.9	13.8	44.2	20.7
CG11										
M±SD	149.8±7.4	41.1±9.4	18.2±3.0	23.19±3.7	9.6±5.7	22.1±7.9	31.5±5.1	16.5±3.0	40.7±4.1	48.9±29.2
$G11_1$	140.5	32.4	16.4	20.2	4.8	14.8	27.6	14.3	44.1	19.1
$G11_2$	136.5	31.6	17.0	21.2	2.8	9.0	28.8	15.2	48.1	9.0
$G11_3$	150.0	36.7	16.3	24.7	3.1	8.6	33.6	18.2	49.6	5.4
$G11_4$	135.0	28.5	15.6	19.0	2.6	9.0	25.9	13.5	47.4	8.6
$G11_5$	141.5	26.6	13.3	19.0	0.8	3.0	25.8	13.5	50.8	13.8
CG12										
M±SD	159.4±8.1	49.6±11.5	19.3±3.3	28.4±4.8	10.8±6.1	20.5±7.2	38.8±6.5	20.8±3.9	42.5±3.6	47.4±28.0
$G12_1$	148.5	38.6	17.5	26.9	2.2	5.7	36.4	19.7	51.0	10.3
$G12_2$	160.0	40.7	15.9	29.0	1.2	3.0	39.5	21.6	53.1	9.2

Legend: CG – control group, G8 – 8 gymnasts years old, G9 – 9 gymnasts years old, G10 – gymnasts 10 years old, G11 - 11 gymnasts years old, G12 - gymnasts 12 years old, BH – body height, BM – body mass, BMI – body mass index, TBW – total body water, BF – body fat, FFM – fat free mass, SMM – skeletal muscle mass, VFA – visceral fat.

Table 4
Values of normalisation indexes (Ni) of the morphological parameters of the gymnasts.

Gymnasts	BH (cm)	BM (kg)	BMI (kg/m2)	TBW (l)	BF (kg)	BF (%)	FFM (kg)	SMM (kg)	SMMp (%)	VFA (cm2)
G81	1.09 SD*	0.01 SD	-0.45 SD	1.67 SD**	-1.23 SD*	-1.77 SD**	1.67 SD**	1.72 SD**	2.47 SD**	-1.21 SD*
G82	0.31 SD	-0.22 SD	-0.38 SD	0.96 SD*	-1.05 SD*	-1.46 SD*	0.95 SD*	1.06 SD*	2.06 SD**	-1.33 SD*
G91	-1.77 SD**	-1.01 SD*	-0.39 SD	-0.27 SD	-1.28 SD*	-1.85 SD**	-0.33 SD	-0.08 SD	2.25 SD**	-1.35 SD*
G92	-1.09 SD*	-0.78 SD*	-0.42 SD	0.17 SD	-1.25 SD*	-1.81 SD**	0.13 SD	0.25 SD	2.12 SD**	-1.12 SD*
G93	-0.74 SD	-0.65 SD	-0.42 SD	0.31 SD	-1.21 SD*	-1.73 SD**	0.33 SD	0.42 SD	2.04 SD**	-1.22 SD*
G101	-0.12 SD	-0.37 SD	-0.38 SD	0.86 SD*	-1.18 SD*	-1.76 SD**	0.85 SD*	0.96 SD*	2.21 SD**	-1.35 SD*
G102	-1.18 SD*	-0.81 SD*	-0.41 SD	-0.13 SD	-1.11 SD*	-1.53 SD**	-0.17 SD	-0.09 SD	1.71 SD**	-1.24 SD*
G103	-0.12 SD	-0.51 SD	-0.57 SD	0.35 SD	-1.04 SD*	-1.46 SD*	0.36 SD	0.41 SD	1.72 SD**	-1.22 SD*
G104	-0.83 SD*	-0.70 SD	-0.44 SD	-0.30 SD	-0.84 SD*	-1.01 SD*	-0.31 SD	-0.35 SD	0.95 SD*	-0.90 SD*
G111	-1.26 SD*	-0.93 SD*	-0.59 SD	-0.77 SD*	-0.85 SD*	-0.93 SD*	-0.76 SD*	-0.74 SD	0.83 SD*	-1.02 SD*
G112	-1.80 SD**	-1.02 SD*	-0.39 SD	-0.51 SD	-1.20 SD*	-1.66 SD**	-0.53 SD	-0.44 SD	1.80 SD**	-1.37 SD*
G113	0.03 SD	-0.47 SD	-0.62 SD	0.43 SD	-1.14 SD*	-1.71 SD**	0.41 SD	0.56 SD	2.17 SD**	-1.49 SD*
G114	-2.00 SD**	-1.35 SD*	-0.85 SD*	-1.09 SD*	-1.23 SD*	-1.66 SD**	-1.09 SD*	-1.00 SD*	1.62 SD**	-1.38 SD*
G115	-1.12 SD*	-1.55 SD**	-1.61 SD**	-1.09 SD*	-1.55 SD**	-2.41 SD**	-1.11 SD*	-1.00 SD*	2.45 SD**	-1.20 SD*
G121	-1.35 SD*	-0.96 SD*	-0.56 SD	-0.31 SD	-1.41 SD*	-2.05 SD**	-0.37 SD	-0.29 SD	2.33 SD**	-1.32 SD*
G122	0.07 SD	-0.78 SD*	-1.05 SD*	0.13 SD	-1.58 SD**	-2.42 SD**	0.10 SD	0.19 SD	2.89 SD**	-1.36 SD*

Legend: G8 – 8 gymnasts years old, G9 – 9 gymnasts years old, G10 – gymnasts 10 years old, G11 - 11 gymnasts years old, G12 - gymnasts 12 years old, BH – body height, BM – body mass, BMI – body mass index, TBW – total body water, BF – body fat, FFM – fat free mass, SMM – skeletal muscle mass, VFA – visceral fat, * Ni = ±0.76 to 1.5 SD, ** Ni = above ±1.5 SD.

DISCUSSION

The BH of gymnasts aged 9 and above is lower than the mean values of the control group, except for one twelve-year-old gymnast. Even though the differences are not of the same significance for all the gymnasts, they confirm the results of other authors who state in their studies that child and adolescent gymnasts are at the level of P10 – <P50 in the percentile growth chart of reference data for the corresponding age group (Malina, 1994; Malina, 1998), which represented a lower to low BH. Also, the peak height velocity (PHV) of the gymnasts was found at a later age. PHV of gymnasts is stated at the age of 13.2±0.7 and of other physically active girls at the age from 11.8±0.9 to 12.3±0.8, of not physically active girls at the age of 11.4-12.2 (Malina, 1999; Malina & Geithner, 2011; Malina, Rogol, Cumming, Coelho e Silva, & Figueiredo, 2015). Although it is possible that small BH and late maturation are due to self-selection for gymnastics (Lindholm Hagenfeldt, & Ringertz, 1994; Peltenburg, Erich, Zonderland, Bernink, Van Den Brande, & Huisveld, 1984; Malina, 1999), it is also possible that growth is retarded as a result of inadequate nutrition for level of activity, particularly during the sensitive phase of pubertal maturation in female gymnasts (Weimann, 2002). With regard to the age of the gymnasts we monitored, it is obvious that they were not in the PHV period yet. However, in spite of that we cannot assume that they would have a future BH comparable with other athletes or general population. Malina, Bouchard and Bar-Or (2004) state that the mean annual increases of gymnasts in the PHV period were 5.6 to 5.8±0.5 cm, which is less than in other athletes or non-active population. The lower BH values also correspond to the low BM values. Like BH, BM is also between P10 - < P50 in the percentile growth chart (Malina, 1994; Malina, 1998). Also, elite adult gymnasts have a lower BM than other athletes (Claessens, Benedict, & Specker, 1991; McArdle, Katch, & Katch, 2007). It has been assumed that the trend toward smaller height and lighter weights in elite female gymnasts may in part be attributed to talent selection based on biomechanical advantages of a pre-pubertal physique that include increased relative strength/weight ratio, greater stability, and decrease moments of inertia (Sands, Borms & Caine, 2003). These parameters have the potential for more complex vaults, increase swing skills on uneven bars, increase stability on the balance beam and also increase take off abilities during floor exercises (Sands, Borms & Caine, 2003).

The gymnasts we monitored can be called proportional individuals as their BMI values were average with regard to the values of the control group, with the exception of three gymnasts. These gymnasts had a significantly lower BM to their BH. The lower BM of the monitored gymnasts is reflected in the lower weight of other tissue (FFM, SMM), which leads to smaller differences in these parameters, expressed in kilograms, between the gymnasts and the control group. The values of the FFM and SMM ratio (kg) in some gymnasts were even lower than in the control group, in spite of the fact that the gymnasts are individuals with regular physical activity. However, the comparison of the percentage ratio of the individual tissues in the total BM clearly shows a significantly lower BF ratio and higher SMM ratio. Findings from the current study are in accordance with previous studies by Cassell, Benedict and Specker (1996) and Soric, Misigoj-Durakovic, & Pedisic (2008). These authors stated that young female gymnasts have lower % BF when compared to chronologically age–matched non gymnast groups. However, caution in interpretation is necessary since their biological age is also lower (Bacciotti, Baxter-Jones, Gaya, & Maia, 2017). From a performance perspective, low percent body fat is clearly beneficial in gymnastics where the body is propelled against gravity, and thus any non-power producing tissue may result in inefficiencies (Sands, Borms & Caine, 2003). Also, the VFA values representing the area that this fat takes up in the abdominal cavity are significantly lower than in the control group. These lowered values can be a health benefit, especially at an older age. The increased VFA quantity may be a risk factor of many illnesses. Graphically, the Ni values of the monitored gymnasts in the stated parameters are shown in the Figure 2. All Ni values in SMM exceeded the level of 0.75 SD, all the Ni values in VFA and BF were lower than -0.75 SD. The low BF determined in the monitored gymnasts also corresponds with the results of other authors who deal with young athletes. The authors state lower BF ratio in young female gymnasts, not only when compared with reference data, but also when compared with other athletes in various sport disciplines (Malina, Bouchard, & Bar-Or, 2004; Malina & Geithner, 2011).

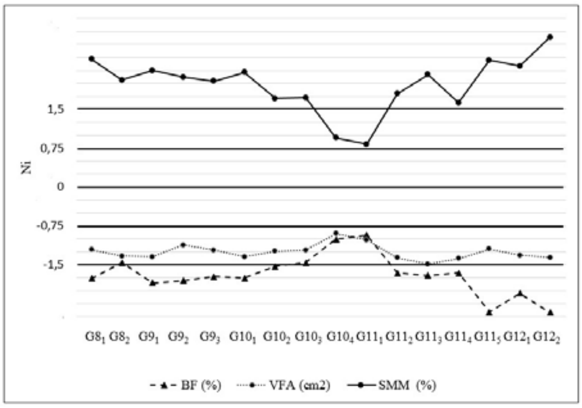

Figure 2. Position of gymnasts according to normal population.

Conclusions from this study must be considered with the sample size in mind and age variability within current sample size of young gymnasts. However, the current study has benefited from the use of gymnasts that are members of talent-selection program in the Czech Republic. In future long-term prospective studies that include morphology components would be useful to clarify specific changes in morphology caused by specific gymnastics training.

CONCLUSIONS

The results of the study show that the gymnasts in the youngest competition category already differ in basic anthropometric parameters from the general population. Since the age of nine, the gymnasts have a lower body height (except for one gymnast) and lower body weight than the girls in the general population. The BH and BM values is below average or highly below average in nine gymnasts (56.3%). The high volume of specific physical activity of the gymnasts, included in their training, affects their body composition parameters. The gymnasts have lower BF (%) and VFA (cm^2), their values are below average to highly below average, and higher SMM (%), with values above average or highly above average.

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