ORIGINAL ARTICLES

Height, weight, somatotype and body composition in elite Spanish gymnasts from childhood to adulthood

Alfredo Irurtia Amigó[a], Albert Busquets Faciabén[a], Michel Marina Evrard[a], Pedro A. Galilea Ballarini[b] and Marta Carrasco Marginet[c]

[a]Department of Sports Performance of the National Institute of Physical Education in Catalonia. Centre belonging to the University of Barcelona. Barcelona, Spain.

[b]Department of Physiology and Functional Assessment of the Science Unit of the High Performance Centre. Sant Cugat del Vallés. Barcelona, Spain.

[c]Service of Nutrition and Dietetics. High Performance Studies Centre. Esplugues de Llobregat. Barcelona. España.

ABSTRACT

Introduction and aims: The aim of the present study was to characterize the evolution of height and weight (from 7 to 25 years old) and somatotype and body composition (from 12 to 18 years old) in elite male gymnasts.

Method: For each of the variables, a mixed-longitudinal design was used to analyze: *a)* its evolution with age and *b)* its differences with respect to a reference population. Somatotype was analyzed with the Heath-Carter method, fat free mass with the Slaughter formula and muscle mass with the Poortman formula.

Results: Male gymnasts were significantly shorter and lighter than the reference population. The best gymnasts were even more so with respect to their fellow gymnasts, except for specialists in vault and floor where the lower limbs are especially important. The peak height velocity occured at the age of 14, at the same age as in the reference population. The somatotype was ecto-mesomorphic in 90% of the gymnasts. Fat mass percentage was significantly lower than in the reference population. Somatotype, fat free mass and muscle mass showed no significant increases with age.

Conclusions: Gymnasts showed a growth pattern considered as normal in the variables analyzed in the present study. The main differences between the gymnasts and the reference group were observed from the beginning of the follow-up. These findings suggest the effects of a selection process, both before and during the training process, before the elite level is reached.

KEY WORDS: Gymnasts. Growth. Height. Weight. Somatotype. Body composition. Mixed-longitudinal.

RESUMEN

Introducción y objetivos: El objeto del presente estudio fue caracterizar, a lo largo de la edad, el comportamiento de la talla y el peso (7-25 años), el somatotipo y la composición corporal (12-18 años), en gimnastas masculinos de élite.

Métodos: Basándose en un diseño mixto-longitudinal se analizó de cada una de las variables: *a)* evolución a lo largo de la edad, y *b)* diferencias en relación con una muestra de referencia. El somatotipo se analizó mediante el método Heath-Carter, la masa grasa mediante la fórmula de Slaughter y la masa muscular mediante la fórmula de Poortmans.

Resultados: Los gimnastas son significativamente más bajos y ligeros que la muestra de referencia. Además, los mejores gimnastas lo son aún más que el resto de compañeros de entrenamiento, salvo los especialistas en suelo y salto, donde el tren inferior es protagonista. El pico de crecimiento de la talla se produce a la edad de 14 años, a la misma edad que en la muestra de referencia. El 90% de los gimnastas se clasifica en un perfil ecto-mesomórfico. Poseen un porcentaje de masa grasa significativamente inferior al de la muestra de referencia. El somatotipo, la masa libre de grasa y el porcentaje de masa muscular no describen incrementos significativos a lo largo de la edad.

Conclusiones: Los gimnastas españoles muestran un patrón de crecimiento, en las variables de estudio analizadas (talla, peso, somatotipo y composición corporal), que responde a la normalidad. Las principales diferencias entre éstos y la muestra de referencia se producen desde las primeras edades analizadas. Todos estos factores sugieren la implicación de un proceso de selección, tanto previo como el que el propio proceso de entrenamiento realiza a lo largo de los años, antes de alcanzar la elite deportiva.

PALABRAS CLAVE: Gimnastas. Crecimiento. Talla. Peso. Somatotipo. Composición corporal. Mixto-longitudinal.

Article history: Received on: 11 July 2008 / Accepted on: 1 January 2009.

How to quote this article: Irurtia Amigó A, Busquets Faciabén A, Marina Evrard M, Galilea Ballarini PA, Carrasco Marginet M. Talla, peso, somatotipo y composición corporal en gimnastas de elite españoles desde la infancia hasta la edad adulta. Apunts Med Esport. 2009;161:18-28.

This study was carried out with the support of the General Secretariat for Sport and the Department of Universities, Research and Information Society of the Government of Catalonia (*Generalitat*).

Correspondence to: Alfredo Irurtia Amigó (alfredo.irurtia@inefc.net).

Introduction

Men's artistic gymnastics (MAG) is an Olympic discipline regulated by the International Gymnastics Federation (FIG), in which gymnasts perform short routines on 6 different apparatus: floor, pommel horse, still rings, vault, parallel bars and bar. In terms of hours of training, diversity and intensity it may be one of the most demanding sports for children, who are already experiencing significant changes in their growth, development and maturation.[1]

Unlike in women's artistic gymnastics, in men's artistic gymnastics there are few studies that use anthropometric techniques to assess certain somatic variables.[2-13]

Of the few studies involving male artistic gymnasts, there is only one that focuses on Spanish gymnastics which is a mixed-longitudinal, cross-sectional study which reflects the peak height and weight velocity of subjects aged 7 to 24.[11] Changes in other relevant somatic variables like body composition or somatotype, which are particularly important when selecting talented athletes,[14] have not been analysed in MAG.

Children specialising in gymnastics from an early age has sparked debate about the potential advantages and disadvantages of the sport. Some reviews have suggested that intensive gymnastic training may negatively affect growth,[15] while others believe that the sport should be practiced with caution and recommend further research in longitudinal and/or mixed-longitudinal studies.[16]

In short, there is a number of questions that still need to be answered: Do elite male gymnasts grow and develop in the same way as the control population? Do somatic variables like height, weight, somatotype and body composition remain stable or can significant changes be identified with age?

The aims of this study are as follows:

- To describe the body dimensions (height and weight), somatotype and body composition of Spanish gymnasts across a range of ages.
- To compare these results with the values obtained by the male subjects in the reference sample.

Method

Design

This is a retrospective, observational, descriptive study that includes two sample grouping strategies: cross-sectional and mixed-longitudinal. The variables that have been analysed are: height, weight, somatotype (ectomorphic, mesomorphic, endomorphic) and body composition (∑ 6 skinfolds, body fat mass [FM%], muscle mass [MM%] and fat free mass [FFM].)

Height and weight data was collected from two sources for the analysis of the population of Spanish male gymnasts *a)* an assessment carried out by the Department of Physiology in the High Performance Centre in Sant Cugat del Vallés from 1991-2003, and *b)* the doctoral thesis[17] "*Valoración, entrenamiento y evolución de la capacidad de salto en gimnasia artística de competición*" (Assessment, training and evolution of the vertical jumping capacity in competitive artistic gymnastics.) Only data from the Department of Physiology in the High Performance Centre was analysed for the somatotypes and body composition.

Inclusion criteria

a) Male gymnasts of Spanish nationality for the cross-sectional sample, who competed at a national or international level, and *b)* follow-up on the variables analysed for at least four years as well as the aforementioned criteria, with measurements carried out once a year.

Ethical aspects

The data collected from both sources included in our study was handled confidentially.

Comparative analysis

For the comparative analysis with the reference sample we extracted the data from two of the very few studies that have been carried out in Spain that were similar to this one: *a)* growth curves from a longitudinal study (n = 300) with a follow-up on subjects from the age of 6 to 18[18] were used to compare height and weight, and *b)* a mixed-longitudinal study (n = 1902) with a follow-up on subjects from the age of 7 to 16 was used to compare somatotype and body composition.[19]

Sample

102 kinanthropometric reports on male gymnasts aged between 7 and 25 were analysed. This highly specific sample (that included national, European, world and Olympic medal winners) which covered a wide age range, was classified in the following way (table I.)

Instruments and procedures

The rules and techniques for measuring recommended by the International Working Group of Kinanthropometry, outlined by Ross and Marfell-Jones[20] and adopted by the International Society for the Advancement of Kinanthropometry (ISAK) and the Spanish Group of Kinanthropometry (GREC) were followed for each assessment.

The following anthropometric instruments were used:

- Seca 220® telescopic stadiometer (measuring range: 85-200cm; precision: 1mm.)
- Seca 710® weighing scale, calibrated beforehand (capacity: 200kg; precision: 50g.)
- Antropometric tape (precision: 1mm.)
- Caliper (measuring range: 0-250mm; precision: 1mm.)
- Holtain® skinfold caliper (measuring range: 0-48mm; precision: 0.2mm; constant pressure of 10g/mm^2.)
- Anthropometer (precision: 1mm.)
- Additional equipment (wooden bench for measuring sitting height; a wax pencil for marking the individual, a spirit level to ensure the correct alignment of the anthropometer.)

The peak growth velocity for the variables height and weight was calculated separately, following the recommendations made by Mirwald[2]: annual increase was expressed in centimetres/year for height and in kilograms/year for weight. The peak growth velocity occurred when the greatest annual increase in height or weight was recorded. Furthermore, the difference between the values with age that characterised the sample of gymnasts (Z value) and those who achieved better results in competition (European, world and Olympic finalists: n = 6) was calculated.

The Heath-Carter[22,23] method was used to calculate the somatotype. The following was established:

- The mean somatotype.
- The three separate components of the somatotype (endomorphic, mesomorphic, ectomorphic.)
- The somatotype attitudinal mean (SAM.)

This final concept was used to calculate the distance between an individual somatotype and the mean somatotype for that age group, by means of a three dimensional analysis. The homogeneity of the group decreased as the values increased. 3 levels of homogeneity were established for this study, following the recommendations made by Carter[24]: elevated distance (SAM $\geq$ 1.0); moderate distance (SAM = 0.80-0.99), and reduced distance (SAM $\leq$ 0.79).

Somatocharts were used to show: *a)* the individual values from the sample of gymnasts, and *b)* the overlap of the mean somatotypes of each of the ages analysed (index I.) Index I represents a group or population as a circle whose centre is the mean somatotype, and whose radius is the somatotype dispersion index (SDI.) The SDI is the mean of the somatotype distance dispersion (SDD) of the group in relation to the mean somatotype. The SDD is a two dimensional analysis that establishes the distance between two somatotypes (S_1 and S_2.) The formula for calculating this is as follows[25]:

Equation 3: According to Ross and Wilson (1973.)

$$SDD = \sqrt{3\,(X_1-X_2)^2 + (Y_1-Y_2)^2}$$

Where (X_1,Y_1) and (X_2,Y_2) represent the coordinates of two individuals.

Finally, the formula for calculating index I[26]:

Equation 4: According to Ross (1976.)

$$\text{Index I} = \frac{\text{Area common to the 2 circles}}{\sum \text{Areas not common to the 2 circles}} \times 100$$

Table I Sample (n_1: number of measurements; n_2: number of subjects) and age range (years) for each of the variables. Cross-sectional and mixed-longitudinal design.

	Height (cm) Weight (kg)		Somatotype Body composition	
	n_1 (n_2)	Age range (years)	n_1 (n_2)	Age range (years)
Cross-sectional	219 (102)	7-25	79 (39)	12-18
Mixed-longitudinal	82 (17)	11-25	61 (12)	12-18

When index I = 100, the circles are concentric and have the same radius. When index I = 0 the circles have no common area.

Only body fat mass (%FM and ∑ 6 skinfolds: triceps, subscapular, iliac crest, abdominal, anterior thigh and medial calf), muscle mass (MM%) and FFM (kg) were used to calculate the body composition. Given the fact that there are no formulas for estimating the body composition of young male gymnasts, the recommendations made by Claessens[27] that were applied to young female gymnasts aged between 6 and 17 were followed. These authors suggest using Slaughter's[28] formula to estimate the body composition of gymnasts (FM% and FFM.) Finally, since the subjects were male, the following formula was to be applied:

Equation 1: According to Slaughter et al. (1988.)

$$\%MG = (0.735 \times \sum 2) + 1.0$$

Where ∑2 (mm) = triceps skinfold + medial calf skinfold

∑ 6 skinfolds (mm) was included as a direct measurement of the FM, in addition to the FM% estimate, before the error inherent in any estimate formula.[23]

With regard to the MM%, a new anthropometric formula was used, which has been validated using dual-photon X-ray absorptiometry (DXA) by Poortmans,[29] to estimate the total muscle mass during childhood and adolescence ($r^2 = 0.966$; $p < 0.001$), which was an adapted version of the formula developed by Lee.[30]

Equation 2: According to Poortmans et al. (2005)

$$MM\ (kg) = h \times [(0.0064 \times CAG^2) + (0.0032 \times CTG^2) + (0.0015 \times CCG^2)] + (2.56 \times sex) + (0.136 \times age)$$

Where: MM = muscle mass (kg); h = height (m); CAG = skinfold- corrected upper arm girth (cm); CTG = skinfold-corrected thigh girth (cm); CCG = skinfold-corrected calf girth (cm); sex = "0" for women and "1" for men age (years).

The anthropometric assessments needed to calculate the somatotype and body composition were carried out by 3 expert anthropometrists. As a general rule, the recommendations made by Ross and Marfell-Jones[20] were followed during the period in which the measurements were taken (1991-2003.) According to these recommendations, any technical variability in interevaluator and intraevaluator measurements below 5% for skinfolds and 2% for all other measurements is acceptable.

Statistical analysis

The normal distribution of the sample in each of the variables of the analysis was confirmed using the Kolmogorov-Smirnov test for normality. A t-test of unrelated samples was carried out to establish, in each age and variable: *a)* the differences between the cross-sectional and the mixed-longitudinal sample in the group of gymnasts, and *b)* the differences between the latter and the reference sample. Despite the difference in sample size between some ages, the Levene test confirmed the equality variances. The analysis of variance (ANOVA) and Tukey's post hoc test were used to establish any differences between each of the variables in the gymnasts of different ages. The statistical analysis was carried out using the statistical software package SPSS® version 12.0 for Windows (Chicago, USA.) The level of significance was set at $p \leq 0.05$.

Results

The descriptive statistics for chronological age, height and weight can be found in table II, while the somatotype statistics (endomorphic, mesomorphic, ectomorphic components, SAM) and the body composition (∑ 6 skinfolds, FM%, MM%, FFM) are shown in table III.

Since no significant differences were observed ($p > 0.05$) between the cross-sectional and mixed-longitudinal samples in sample of gymnasts, the results of the cross-sectional sample were considered age-related changes in the age ranges that were common to both samples.[17]

Height and weight

The mean height and weight values for gymnasts increase progressively from the age of 7.2 ± 0.3 until they begin to stabilise at the age of 19.1 ± 0.3 (height: 170.1 ± 5cm; weight: 64.2 ± 4.3kg.) Significant differences in height were found ($p \leq 0.05$) between the ages of 12.1 ± 0.4 and 15.1 ± 0.2, and in weight between the ages of 14.3 ± 0.5 and 16.1 ± 0.3 (fig. 1.)

Across all ages the mean height value for gymnasts was lower than that of the reference sample, with significant differences between the ages of 10.2 ± 0.4 and 12.1 ± 0.4 ($p \leq 0.05$), and 14.3 ± 0.5 and 18.1 ± 0.4 ($p \leq 0.001$.) The weight results followed a similar trend, except between the ages of 9.1 ± 0.4 and 12.1 ± 0.4 where significantly lower values were observed ($p \leq 0.05$) compared with those of the reference sample (fig. 1.)

Table II Height and weight of Spanish gymnasts with age. The grey shaded area highlights the cross-sectional data in the sample for the first four years (7-10 years old.)

Age (years)	X̄	7.2	8.1	9.1	10.2	11.0	12.1	13.2	14.3	15.1	16.1	17.1	18.1	19.1	20.2	21.0	22.1	23.3	24.1	25.0
	SD	0.32	0.45	0.37	0.42	0.38	0.41	0.52	0.5	0.23	0.27	0.41	0.38	0.29	0.36	0.28	0.49	0.39	0.42	0.41
Height (cm)	X̄	117.9	123.9	128.1	133.1	136.8	141.2	148.2	153.9	159.2	163.6	165.6	167.3	170.1	170.3	170.2	168.7	168.9	168.3	170.6
	SD	4.73	4.92	6.15	6.02	7.48	8.82	8.60	8.37	7.95	7.59	6.34	5.94	5.02	6.24	4.60	6.11	5.67	6.65	5.93
Weight (kg)	X̄	21.4	23.6	26.8	29.0	32.4	37.1	41.8	45.3	50.9	56.7	60.3	62.3	64.2	65.3	64.3	64.7	63.6	63.6	65.9
	SD	1.02	1.52	3.02	3.74	4.36	7.55	8.24	9.49	8.65	8.85	8.51	6.61	4.34	7.35	2.47	5.14	4.88	6.05	6.18
Sample (n = 219)		6	7	7	14	15	12	15	18	27	20	18	13	9	7	5	9	7	4	6

X̄: mean; SD: standard deviation; grey shaded area: cross-sectional data.

Table III Somatotype and body composition of Spanish gymnasts with age.

Estadística	Age (years)	Endo.	Meso.	Ecto.	SAM	Σ 6 skinfolds				FM (%)	MM (%)	FFM (kg)	Sample (n = 79)
						UL	TR	LL	Total				
X̄	12.1	1.8	5.6	2.8	0.6	12.4	12.9	15.3	40.6	9.3	47.7	34.2	6
SD	0.36	0.33	0.84	0.51	0.14	2.07	1.48	2.91	2.15	1.56	2.65	3.53	
X̄	13.2	1.3	5.5	3.6	0.7	11.4	11.1	13.6	36.1	7.9	46.8	36.8	9
SD	0.43	0.36	1.12	1.23	0.27	1.87	1.78	2.95	2.20	1.11	3.88	4.63	
X̄	14.2	1.5	5.6	2.9	0.9	10.8	11.0	13.1	34.9	7.5	47.3	41.3	13
SD	0.41	0.45	1.32	1.21	0.56	1.87	2.40	2.83	2.37	0.77	2.10	6.20	
X̄	15.0	1.5	5.9	2.6	1.1	11.1	10.3	12.8	34.2	7.5	47.8	46.7	13
SD	0.36	0.31	1.25	0.90	0.49	1.83	2.49	2.32	2.21	0.73	1.66	7.99	
X̄	16.1	1.6	6.2	2.6	0.9	11.8	11.0	12.6	35.4	7.8	48.8	51.8	14
SD	0.32	0.53	0.95	0.91	0.57	2.14	2.76	2.51	2.47	1.23	1.53	7.40	
X̄	17.3	1.5	6.1	2.5	1.1	10.8	10.6	12.4	33.8	7.4	49.5	54.2	14
SD	0.39	0.43	1.15	1.07	0.58	1.99	2.07	2.57	2.21	0.91	1.70	6.95	
X̄	18.1	1.7	6.3	2.4	1.0	11.2	10.4	11.6	33.2	7.3	49.5	56.2	10
SD	0.42	0.30	1.43	1.11	0.57	1.75	1.87	2.59	2.07	0.81	1.12	4.60	

SAM: somatotype attitudinal mean; Σ6 skinfolds: UL (upper limb: triceps, subscapular); TR (torso: iliac crest, abdominal); LL (lower limb: anterior thigh, medial calf); FM: body fat mass; MM: muscle mass; FFM: fat free mass; X̄: mean; SD: standard deviation

The growth curves of the reference sample[18] indicate that from the age of 7.2 ± 0.3 to 13.2 ± 0.5 the height of gymnasts is between percentiles 25-50. From the ages of 14.3 ± 0.5 to 18.1 ± 0.4 this variable is between percentiles 10-25. The weight of gymnasts was between percentiles 25-50 for the whole age range analysed (7.2 ± 0.3 to 18.1 ± 0.4.)

The Z test showed that best gymnasts were shorter and lighter than fellow gymnasts who obtained mean values, regardless of age. It is worth highlighting however, that the weight of the best floor and vault gymnast is higher than the mean weight of fellow gymnasts, regardless of age (fig. 2.)

Figure 1 Height and weight of Spanish gymnastics and the Spanish reference population with age. Significant differences between ages and between both samples at the same age (*: p ≤ 0.05; **: p ≤ 0.01; ***: p ≤ 0.001.) The grey shaded area highlights the cross-sectional data in the sample for the first four years of MAG (7-10 years old.)

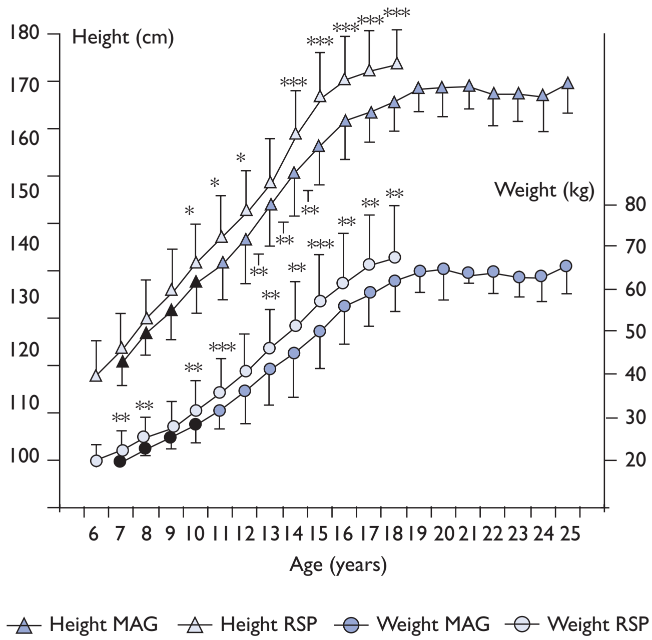
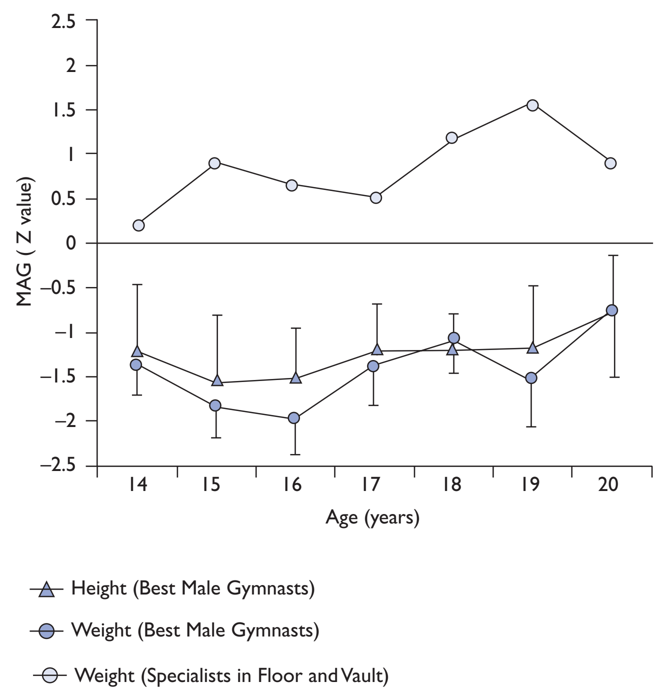


Figure 2 The characterising values (Z value) that corresponded to the mean height and weight value of the sample of Spanish gymnasts with age (14-20 years old.) Comparison with the values of the best gymnasts from the sample (Olympic and world medallists.)



The greatest annual height increase in gymnasts or the peak height velocity (PHV) occurred at age 14.3 ± 0.5 (7.4 ± 2.3cm/year), which coincided with the reference sample (9.0 ± 1.0cm/year.) The difference in PHV between both populations is significant ($p \leq 0.05$.) Before PHV, height increases in gymnasts are always lower than those experienced by the control population. In contrast, gymnasts experience significantly higher growth increases from the age of 16.1 ± 0.3 to 18.1 ± 0.4 than the reference population (fig. 3.)

Peak weight velocity (PWV) occurred in gymnasts aged 14.3 ± 0.5 (7.0 ± 2.2kg/year), which coincided with the reference sample (9.5kg/year.) A second peak was observed in the results of the sample of gymnasts aged 17.1 ± 0.4 (5.5 ± 1.8kg/year). Before the PWV, weight increases in gymnasts were always lower than those experienced by the control population. The opposite is true after PWV (15.1 ± 0.2 to 18.1 ± 0.4 years of age), when gymnasts experience greater increases in weight (fig. 3.)

Somatotype

The somatochart (fig. 4) shows that in 90% of cases, the individual somatotypes of the sample of gymnasts can be classified as ecto-mesomorphic, regardless of age. The remaining 10% have mesomorphic-ectomorphic body types (4%), meso-ectomorphic body types (3%) and balanced mesomorphic body types (3%.)

Despite the fact that the somatochart indicates that the mean somatotype of gymnasts at age 13.2 ± 0.4 tends to be ectomorphic (fig. 5), no significant differences were found between any of the ages in the study ($p > 0.05$.) If the endomorphic, mesomorphic and ectomorphic components are analysed separately, the lack of significant differences ($p \leq 0.05$) indicates that the gymnast's somatotype is very stable with time.

The differences between the distance of each individual somatotype and the mean value that corresponds to each age

Figure 3 Increase in the height (cm/year) and weight (kg/year) of male Spanish gymnasts (MAG) and the reference sample (RSP) with age. The grey shaded area highlights the cross-sectional data in the sample for the first four years of MAG (7-10 years old.)

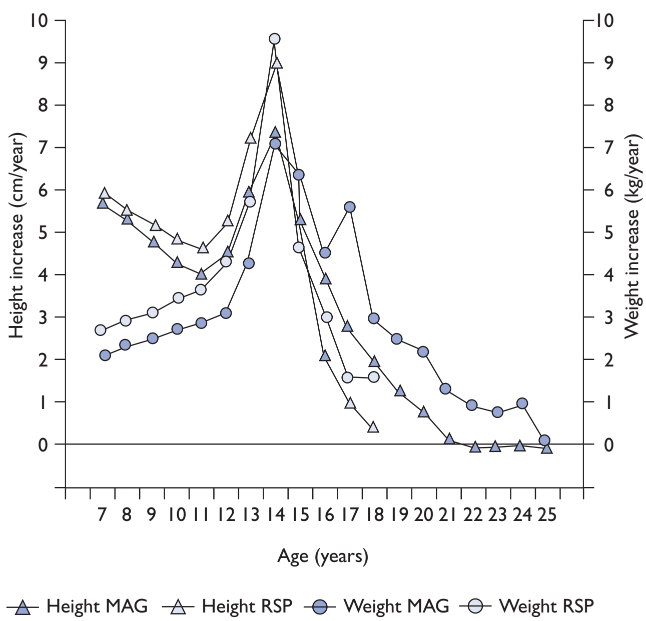


Figure 4 Distribution of the individual somatotypes of Spanish gymnasts by age in the somatochart (n = 79.)

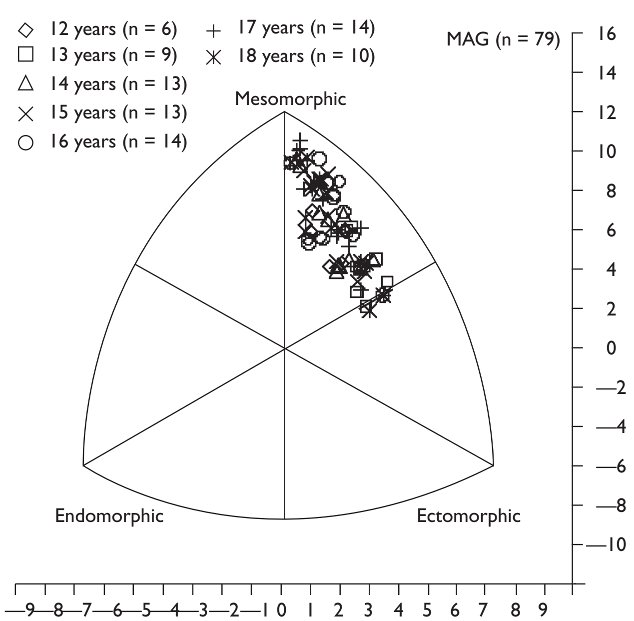
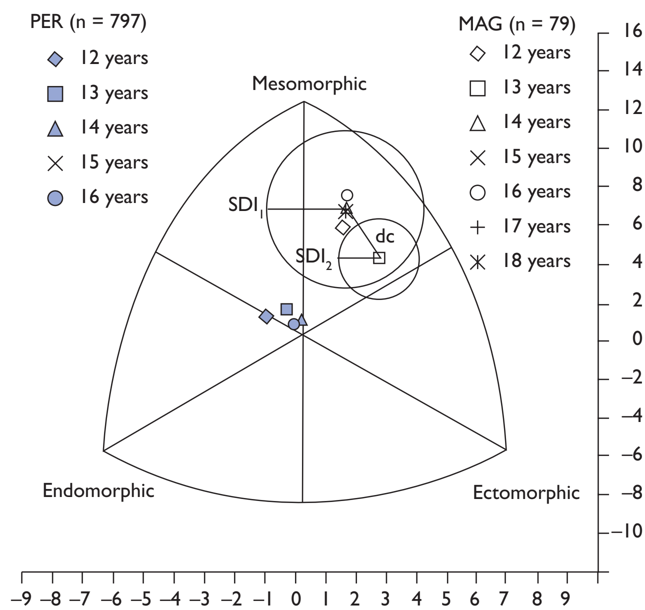


Figure 5 Distribution of the mean somatotype of Spanish gymnasts (MAG) and the reference sample (RSP) in the somatochart. Index I between the ages of 13 and 14 in MAG has been highlighted. The SDI of each mean somatotype corresponds to its respective radius (SDI_1 = 3.5; SDI_2 = 2.1.) The distance between the centres (dc) corresponds to the SDD between both somatotypes (dc = 3.3.) This is how index I = 15.1 was obtained.



(SAM) were not significant (p > 0.05.) 41% of cases were classified as elevated distance (SAM ≥ 1.0), 21.3% of cases as moderate distance (SAM = 0.80-0.99), and 37.7% of cases as reduced distance (SAM ≤ 0.79.)

The index I calculation of the difference between consecutive years indicated a high level of dispersion among the younger gymnasts of the sample (12.1 ± 0.4 years old and 13.2 ± 0.4 years old, index I = 10.1; 13.2 ± 0.4 years old and 14.2 ± 0.4 years old, index I = 15.1.) The mean was established as 88.6 ± 9.2. The lowest values were recorded between the ages of 13.2 ± 0.4 and 16.1 ± 0.3 (index I = 9.8.)

An endo-mesomorphic body type was prevalent across all ages, except for subjects aged 12 ± 0.5, who had meso-endomorphic body types (fig. 5.) When both samples were compared across all ages, there were significant differences in the mesomorphic and endomorphic components (p ≤ 0.001), and gymnasts had more mesomorphic and less endomorphic body types than the other subjects.

Body composition

The FM% of the sample of gymnasts in relation to the reference sample was significantly lower ($p \leq 0.001$) across all the ages studied (12-16 years old.)

With regard to changes in the FM% over time, a gradual reduction in the FM% was observed in gymnasts, although the differences were never significant ($p > 0.05$.)

There were no significant changes ($p > 0.05$) in either FFM or MM% in gymnasts of different ages. When comparing the FFM weight of the gymnasts and the reference sample, the former always obtained lower values. This was significant ($p \leq 0.01$) from the age of 13 to 15.

Discussion

Height and weight

Different studies on the anthropometric variables in MAG have focused on a particular moment in a gymnast's career, generally when they have reached elite level.[12,13] This study not only covers a considerably wider age range (7-25 years old) but also analyses the aforementioned variables of gymnasts at each age.

Despite the limitations of a cross-sectional sample that includes younger children (7-10 years old), the data shows that Spanish gymnasts are shorter and lighter than the reference sample throughout the whole range of ages studied. The data presented in this study confirms that the best gymnasts are even shorter and lighter than fellow gymnasts. This data confirms the trend observed over the last 25 years that gymnasts are increasingly younger, shorter and lighter compared to the general population.[31]

The literature available offers several explanations for this: from the likely influence of genes that explains the strict initial selection process carried out by trainers, to the highly demanding, ongoing training schedule.[10,32] At present, there is no doubt that reduced height and weight are an advantage for gymnasts who perform the highly demanding techniques associated with this discipline.[8,31]

The exception to this trend is found in the physical characteristics of gymnasts that specialise in floor and vault gymnastics, since MAG is a discipline in which gymnasts perform short routines on 6 different apparatus, each one requiring different skills and techniques.[31] The Spanish gymnasts who perform best on these apparatus weighed more than their fellow gymnasts across all ages, possibly because of a higher muscle mass in the legs.

The significant height differences in gymnasts aged between 12.1 ± 0.4 and 15.1 ± 0.2 were considered normal.[33] The greatest increase in height, both in the sample of gymnasts and the reference sample, was experienced by subjects aged 14. However, the size of the increase was always lower among gymnasts (fig. 3.) From the age of 14 onwards, the growth rate of gymnasts is higher than that of the reference sample. However, Baxter-Jones[16] recommends that this phenomenon should be interpreted with caution given that growth potential, to a large extent, depends on factors that have not been monitored in this study, like genes, hormones, nutrition and amount and intensity of training.

With regard to weight, two peaks emerged: the first at age 14.3 ± 0.5, shows a growth profile that is similar to the standard pattern mentioned in other studies.[33] The second occurred at age 17.1 ± 0.4 and could be attributed to muscular development caused by the training process, although this cannot be confirmed given that the body composition data does not indicate any significant differences.

Somatotype

The assessment and monitoring of the 3 somatotype components is particularly interesting in athletes. Gymnasts have a mesomorphic and ecto-mesomorphic somatotype which supports a possible link between the mesomorphic component and sports performance.[8] Furthermore, differences in the somatotype may be observed depending on the apparatus a gymnast specialises in and the level at which they practice the sport.[6]

Changes in the somatotypes of Spanish gymnasts followed a normal pattern in relation to male subjects. Few changes were observed in the somatotype components from childhood to adolescence: the endomorphic component tends to decrease and the mesomorphic and ectomorphic components increase. Once the gymnast reaches the end of adolescence, the mesomorphic content continues to increase until it reaches its maximum value (18 years old) and the ectomorphic component gradually decreases until the gymnast reaches adulthood. However, the endomorphic component is very variable.[34]

The somatotype of Spanish gymnasts remains stable over time and is always ecto-mesomorphic. The slight tendency towards an ectomorphic body type at the age of 13 may be due to the effects of growth during this period,[34] or to the limitations of this study because it is not a pure longitudinal study and it included a limited sample for some of the ages analysed.

Index I supports the results previously obtained and describes a greater overlap of the somatotypes that correspond with adolescence (14.3 ± 0.5 to 18.1 ± 0.4 years old) and a greater distance in the earlier age range. This data coincides with studies involving Olympic athletes, which indicated that there was a specific somatotype pattern for each discipline in sport at elite level and that this pattern becomes more limited as the level of international elite sportsmen increased.[35]

As in the case of height and weight, differences in somatotype between the gymnasts and the reference sample are evident early on and remain evident until adulthood. This suggests that genetics and early selection, combined later on with a demanding training schedule, could boost the development of the somatotype necessary to be successful in artistic gymnastics.[6] It is also worth highlighting that despite the fact that it is difficult to modify the somatotype through a specific type of training during childhood and adolescence, this is possible in the case of a discipline like artistic gymnastics because the arm and torso muscles increase significantly.[36]

Body composition

The indicators that are most frequently used by trainers are the body fat mass and muscle mass. Regular training leads to a reduction in fat mass and an increase in muscle mass, which is generally associated with an increase in body weight.[36]

In MAG the fat mass, expressed in this study as a percentage and ∑ 6 skinfolds, is lower than that of the reference sample and the muscle mass percentage is higher.[5] The fat mass percentages of the gymnasts in this study are very low which once again confirms the findings and data published by other authors.[5,37]

Despite the lack of significant differences, a gradual decrease in the fat mass percentage and ∑ 6 skinfolds was observed with age (12.1 ± 0.4 to 18.1 ± 0.4 years old.) This change varies slightly in relation to the normal profile of development, in which the fat mass percentage in males decreases until the age of 16 and then gradually increases from this age onwards.[38] With regard to the ∑ 6 skinfolds and their distribution throughout the body, once again, gymnasts have a distinct growth pattern. In the control population the ∑ 6 skinfold value was stable throughout childhood and varied from adolescence onwards with a gradual accumulation of body fat mass on the torso and decreased body fat on the limbs.[36] The comparison with other studies in MAG was difficult, mainly because there was no data or because the ∑ did not include the same skinfolds.[5,10]

Muscle mass values were stable over time which coincided with the stable somatotype (table III.) There are no studies on gymnasts that analyse changes in muscle mass in children. There were several fat free mass values in the reference sample that were higher than those from the sample of gymnasts, which is considered normal given the total weight and body dimensions of the subjects from the reference sample.

Conclusions

The growth pattern of the variables of Spanish gymnasts in this study (height, weight, somatotype and body composition), were normal. However, certain characteristics should be highlighted:

- From an early age, gymnasts are always shorter and lighter than the reference population, except for those who specialised in vault and floor where the lower limbs are especially important.
- The peak height velocity of gymnasts, despite being slower than that of the reference subjects before PHV, increases in later years.
- The somatotype and body composition of the gymnasts is stable across the whole age range analysed. Once again, the differences between the reference sample and the gymnasts are evident early on.

All these factors suggest a selection process both before and during the ongoing training. Finally, the fact that certain factors were not analysed in this study make it impossible to make further evaluations. More research about the growth processes, maturation and development of young gymnasts wanting to compete at elite level should be carried out.

References

1. Leglise M. Age and competitive gymnastics. FIG World of Gymnastics. 1992;3:23
2. Carter J, Sleet DA, Martin GN. Somatotypes of male gymnasts. J Sports Med Phys Fitness. 1971;11:162-71.
3. LeVeau B, Ward T, Nelson RC. Body dimensions of Japanese and American gymnasts. Med Sci Sports Exerc. 1974;6:146-50.
4. Caldarone G, Leglise M, Giampietro M, Berlutti G. Anthropometric measurements, body composition, biological maturation and growth predictions in young male gymnasts of high agnostic level. J Sports Med Phys Fitness. 1986;26:406-15.
5. Faria IE, Faria EW. Relationship of the anthropometric and physical characteristics of male junior gymnasts to performance. J Sports Med Phys Fitness. 1989;29:369-78.
6. Claessens AL, Veer FM, Stijnen V, Lefevre J, Maes H, Steens G, et al. Anthropometric characteristics of outstanding male and female gymnasts. J Sports Sci. 1991;9:53-74.
7. Gualdi-Russo E, Gruppioni G, Gueresi P, Belcastro MG, Marchesini V. Skinfolds and body composition of sports participants. J Sports Med Phys Fitness. 1992;32:303-13.
8. Gualdi-Russo E, Graziani I. Anthropometric somatotype of Italian sport participants. J Sports Med Phys Fitness. 1993;33:282-91.
9. Daly RM, Rich PA, Klein R, Bass SL. Short stature in competitive prepubertal and early pubertal male gymnasts: the result of selection bias or intense training? J Pediatr. 2000;137:510-6.
10. Damsgaard R, Bencke J, Matthiesen G, Petersen JH, Muller J. Body proportions, body composition and pubertal development of children in competitive sports. Scand J Med Sci Sports. 2001; 11:54-60.
11. Marina M, Rodríguez FA. Age-related changes in dynamic strength as indicated by vertical jumping capacity in gymnasts. En: Mester J, King G, Strüder H, Tsolakidis E, Osterburg A, editors. Perspectives and profiles of 6th ECSS Congress. Cologne, Germany: German Society of Sport Science; 2001.
12. Gurd B, Klentrou P. Physical and pubertal development in young male gymnasts. J Appl Physiol. 2003;95:1011-5.
13. Georgopoulos NA, Theodoropoulou A, Leglise M, Vagenakis AG, Markou KB. Growth and skeletal maturation in male and female artistic gymnasts. J Clin Endocrinol Metab. 2004;89:4377-82.
14. Reilly T, Williams AM, Nevill A, Franks A. A multidisciplinary approach to talent identification in soccer. J Sports Sci. 2000; 18:695-702.
15. Caine D, Bass SL, Daly R. Does elite competition inhibit growth and delay maturation in some gymnasts? Quite possibly. Pediatric Exercise Science. 2003;15:360-72.
16. Baxter-Jones AD, Maffulli N, Mirwald RL. Does elite competition inhibit growth and delay maturation in some gymnasts? Probably not. Pediatric Exercise Science. 2003;15:373-82.
17. Marina M. Valoración, entrenamiento y evolución de la capacidad de salto en gimnasia artística de competición. Tesis doctoral. Barcelona: Universidad de Barcelona; 2003.
18. Sobradillo B, Aguirre A, Aresti U, Bilbao A, Fernández Ramos C, Lizárraga A, et al. Curvas y tablas de crecimiento: estudios longitudinal y transversal. Bilbao: Instituto de Investigación sobre Crecimiento y Desarrollo. Fundación Faustino Orbegozo Eizaguirre; 2004.
19. Muniesa A, Casajús JA, Terreros JL. Valoración antropométrica y funcional de niños deportistas aragoneses. Zaragoza: Diputación General de Aragón. Servicio de Publicaciones; 2004.
20. Ross WD, Marfell-Jones MJ. Kinanthropometry. En: MacDougall JD, Wenger HA, Green HJ, editors. Physiological testing of elite athlete. London: Human Kinetics; 1991. p. 223-308.
21. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP. An assessment of maturity from anthropometric measurements. Med Sci Sports Exerc. 2002;34:689-94.
22. Heath BH, Carter JEL. A modified somatotype method. Am J Phys Anthr. 1967;27:57-74.
23. Carter J. The Heath-Carter somatotype method. San Diego: San Diego University; 1975.
24. Carter J, Mirwald RL, Heath-Roll BH, Bailey DA. Somatotypes of 7- to 16-year-old boys in Saskatchewan, Canada. Am J Human Biol. 1997;9:257-72.
25. Ross WD, Wilson NC. A somatotype dispersion distance. Res Quart. 1973;44:372-4.
26. Ross WD. Metaphorical models in the study of human shape and proportionality. En: Broekhoeff J, editor. Physical education, sports and the sciences. Oregon: Microcard Publications; 1976. p. 284-304.
27. Claessens AL, Delbroek W, Lefevre J. The use of different prediction equations for the assessment of body composition in young female gymnasts. Is there a best equations? En: Jürimae T, Hills AP, editors. Body composition assessment in children and adolescents. Basel (Suiza): Karger; 2001. p. 139-54.
28. Slaughter MH, Lohman TG, Boileau RA, Horswill CA, Stillman RJ, Van Loan M, et al. Skinfold equations for estimation of body fatness in children and youth. Hum Biol. 1988;60:709-23.
29. Poortmans JR, Boisseau N, Moraine JJ, Moreno-Reyes R, Goldman S. Estimation of total-body skeletal muscle mass in children and adolescents. Med Sci Sports Exerc. 2005;37:316-22.
30. Lee RC, Wang Z, Heo M, Ross R, Janssen I, Heymsfield SB. Total-body skeletal muscle mass: development and cross-validation of anthropometric prediction models. Am J Clin Nutr. 2000;72:796-803.
31. Jemni M, Friemel F, Sands W, Mikesky A. Evolution of the physiological profile of gymnasts over the past 40 years. A review of the literature. Can J Appl Physiol. 2001;26:442-56.

32. Bass S, Bradney M, Pearce G, Hendrich E, Inge K, Stuckey S, et al. Short stature and delayed puberty in gymnasts: influence of selection bias on leg length and the duration of training on trunk length. J Pediatr. 2000:136:149-55.
33. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity, and weight velocity: British children, 1965. Part I. Arch Dis Child. 1966;41:454-71.
34. Malina RM, Bouchard C, Bar-Or O. Development of physique. En: Malina RM, Bouchard C, Bar-Or O, editors. Growth, maturation, and physical activity. Champaign, Illinois: Human Kinetics; 2004. p. 83-100.
35. Carter J. Somatotypes of olympic athletes from 1948 to 1976. En: Carter J editor. Physical structure of Olympic athletes. Basel: Karger; 1984. p. 80-119.
36. Malina RM. Growth and maturation: normal variation and effect of training. En: Gisolfi CV, Lamb RD, editors. Perspectives in exercise science and sports medicine. Indianapolis: Benchmark; 1989. p. 223-72.
37. Caldarone G, Giampetro M, Berlutie G, Leglise M, Giastella G, Mularoni M. Caractéristiques morphologiques et biotype des gymnastes. En: Petito B, Salmela JH, Hoshizaki TB, editors. World identification systems for gymnastics talent. Montreal: Sport Psyche Editions; 1987. p. 62-7.
38. Malina RM, Bouchard C, Bar-Or O. Body composition. En: Malina RM, Bouchard C, Bar-Or O, editors. Growth, maturation, and physical activity. Champaign, Illinois: Human Kinetics; 2004. p. 101-19.