Original article

Anthropometric profile of gymnast from childhood to maturity sport: report of 2 cases

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Summary

Introduction: The aim of the present study was to establish longitudinal anthropometric profile of two gymnasts from infantile category to senior category, and determining the effects of both growth and maturation as well as of high intensity training.
Material and methods: We have carried out a retrospective longitudinal study of two caucasian males that competed at international level in artistic gymnastics. The protocol included 32 variables: weight, height, sitting height, arm span, nine breadths, eleven girths and eight skinfolds. The procedures followed the International Society for the Advancement of Kinanthropometry guidelines. Their general anthropometric characteristics, body composition (percentage of body fat according to the equation of Withers) and proportionality (z-score applying Ross and Wilson Phantom-strategy) of anthropometric variables were determined from nine medical check-ups from age 14 years to 22 years.
Results: Adult height is not affected by training intensity, with the athletes remaining in their percentile growth curve throughout the study. The gains of body mass in the gymnasts were 22.9 and 15.7 kg, with increase in lean tissue mass in relation to height (kg/m^2), between the first and the last control, of 28% and 19%, respectively. The evolution of the skinfold profile reflects a change in the subcutaneous fat patterning with loss in lower limbs and increase in subscapular zone of trunk. The great adaptation of the musculoskeletal structure occurred primarily in the upper body (shoulders, chest and arms) and was more pronounced up to ages 17 to 18, although each athlete differed somewhat in their own biological rhythms.
Conclusions: At the end of the infantile category, the gymnast had the anthropometric profile which characterized the early gymnastic specialization and this continues to be accentuated up to the senior category.

Key words:
Gymnasts. Growth. Body composition. Proportionality.

Perfil antropométrico del gimnasta desde la infancia hasta la madurez deportiva: reporte de 2 casos

Resumen

Introducción: El objetivo del trabajo fue establecer la evolución del perfil antropométrico del gimnasta desde la categoría infantil hasta la senior, determinando tanto los efectos del crecimiento y maduración como los del entrenamiento de alta intensidad.
Material y métodos: Se realizó un estudio longitudinal retrospectivo a dos varones practicantes de gimnasia artística que competían a nivel internacional. El protocolo incluyo: peso, talla, talla sentado, envergadura, nueve diámetros óseos, once perímetros corporales y ocho pliegues cutáneos. La técnica antropométrica siguió las directrices de la Sociedad Internacional para el Avance de la Cineantropometría. Se determinaron sus características antropométricas generales, la composición corporal (porcentaje de grasa estimado por la ecuación de Withers) y la proporcionalidad (puntuación-z mediante el método del Phantom de Ross y Wilson) de las variables estudiadas en los nueve controles realizados desde los 14 años hasta los 22 años.
Resultados: La estatura adulta no se afectó por el entrenamiento intensivo, permaneciendo en su canal percentilar. La ganancia de peso de los gimnastas fue de 22,9 kg y 15,7 kg respectivamente; con un incremento del componente magro en relación a la talla (kg/m^2), entre el primer y el último control, del 28 % y 19% respectivamente. La evolución del perfil de pliegues refleja un cambio en la distribución de la grasa subcutánea con pérdida en la extremidad inferior y ganancia en la zona escapular del tronco. Se constata la gran adaptación del sistema músculo-esquelético fundamentalmente a nivel del tren superior (hombros, tórax y brazos) y de forma más marcada hasta los 17- 18 años, aunque cada deportista de los estudiados tiene su propio ritmo biológico que marca pequeñas diferencias en el patrón evolutivo.
Conclusiones: Al final de la categoría infantil el gimnasta tiene el perfil antropométrico que le caracteriza debido a su especialización temprana el cual se va acentuando hasta la categoría senior.

Palabras clave:
Gimnasia. Crecimiento. Composición corporal. Proporcionalidad.

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Introduction

Some sports require an early specialisation and intense training during the growth and maturity period. This means that the selection and talent spotting for these sports starts during childhood, and on the other hand the doubt arises as to whether or not this intense physical activity will have a negative effect on the overall development of the child[1-5]. One of the sports with these characteristics is artistic gymnastics, which has been associated with short stature and a delay in the onset of puberty due to training[6-10]. Following a meta-analysis, Malina *et al.*[11] concluded that there is no effect on the adult height or length of body segments. Nor did they find alterations in pubertal development, apart from a delay in menstruation in adolescent women, though they indicate that more longitudinal analysis is required to correctly assess the potential effects of training.

Artistic gymnastics is one of the most demanding sports due to its high requirements in flexibility, balance, coordination, strength, power, resistance, artistic talent and high technical capacity, requiring an average of ten years of training to achieve the optimum sporting results[12-13].

Morphological features constitute one of the predictive variables in talent selection. The profile of a gymnast has been described as short stature, with shorter lower-limb length, minimal subcutaneous fatty tissue, greater muscle-skeletal development in the upper part of the body, long arms, narrow pelvis and highly mesomorphic[6,7,13-20].

The aim of this study is to establish the evolution of the anthropometric profile throughout the sporting career of two elite gymnasts from the category of infants to senior, considering both the development and growth of the puberal stage as well as the high intensity training, and contrasting it with references from the general population and with those specific to this sport.

Material and method

A descriptive, longitudinal and retrospective study was carried out on the anthropometric profiles of 2 Caucasian males (GYMN 1 and GYMN 2), that practised artistic gymnastics for a consecutive 9-year period, from the age of 14 years (infant category) to the age of 22 years (senior category). The athletes participated in the infant, juvenile, junior and senior categories, and took part in national and international championships.

The first control was performed in their final year in the infant category, training 3 to 6 hours a day, 5 to 6 days a week; with a sporting history of 7 to 9 years. Later the follow-up was annual, with training sessions of 6 hours a day, 6 days a week.

The material used: scales (Seca), precision 0.1 kg; stadiometer (Holtain), precision 1 mm; anthropometers (GPM), precision 1 mm; pachymeter (Holtain), precision 1 mm; plycometer (Holtain), precision 0.2 mm; anthropometric tape (Rosscraft), precision 1 mm. The same technique, accredited with Level III by the ISAK (International Society for the Advancement of Kinanthropometry) was used to perform the measurements, following the recommendations of this Scientific Organisation[21], apart from in the perimeters of the shoulders and mid-thigh[22]. The perimeter of the shoulders was measured to the level of the maximum prominence of the deltoid muscles and below each acromion; the perimeter of the mid-thigh, at the same level where the skinfold of the anterior thigh is taken, at the middle point between the inguinal fold and the upper edge of the kneecap.

The anthropometric protocol included: weight; height; size; height sitting; bi-acromial, bi-iliocrestal, bitrochanteric diameters, transverse thorax, front to back thorax, humerus bi-epicondyle, bistyloid of the wrist; femoral condyle; bi-malleolar of the ankle; body perimeters of the neck, shoulders, thorax, waist (minimum abdominal perimeter), hips, relaxed arm, forearm, upper thigh (at 1 cm from the gluteal fold), mid-thigh, leg and ankle; and skinfolds, iliac crest, supraspinal, abdominal, subscapular, biceps, triceps, anterior thigh and medial leg. The skinfolds were taken on the right side, giving the average value of three measurements, previously ruling out any clearly erroneous measurements, to overcome the technical error of measuring.

The study of the body composition was performed using the skinfold profile, the outcome of eight skinfolds; body mass index (BMI, kg/m^2); fat percentage (% Fat), first estimating the body density by Withers *et al.* (DC = 1.0988 – 0.0004* (triceps + subscapular + biceps + supraspinal + abdominal + anterior thigh + medial leg, in mm) and later using the Siri equation, 1961 (% fat = ((4.95 / DC Withers) - 4.5)*100)[23]; and lean muscle ratio (IMM, kg/m2), lean component (body weight minus fat weight) in relation to the size chart. Cross-sectional muscle areas (CSA) were also calculated, cm^2, at the level of the arm, thigh and leg, according to Heymsfield, 1982[24].

To calculate the percentiles regarding the general population, recommendations from Spanish Growth Studies by Carrascosa *et al.*[25] were used. The assessment of the level of maturity of the gymnasts was estimated retrospectively, via the study of the evolution of the height: speed of growth (cm/year), percentage reached at each control regarding the final adult height, and age at which it is reached, comparing this data to the references described by Ferrández *et al.*[26], in which they characterise puberal maturers in five groups (very early, early, intermediate, late or very late).

For the analysis of proportionality, the rates were calculated: relative size (size/height), and relative sitting height (height sitting/height). And following the Ross and Wilson proportionality method, 1974[27], the diameter and perimeter variables were typified, calculating the Phantom z-scoring.

The athletes signed an informed consent form for the use of their data for research purposes, as long as confidentiality was upheld and the work was carried out under the ethical regulations of the Helsinki Declaration.

Results

The general anthropometric and body composition characteristics are displayed in Table 1. The increase in body weight from the first to the last control was 22.9 and 15.7 kg, and the increase in height was 14.2

Table 1. General anthropometric and body composition variables.

Gymnast 1									
Age (years)	14	15	16	17	18	19	20	21	22
Weight (kg)	45	48.3	54.8	58.1	61.5	63.6	64.7	63.6	67.9
Height (cm)	155	159.1	164.3	166.8	167.6	168.0	168.1	168.4	169.2
BMI (kg/m^2)	18.7	19.1	20.3	20.9	21.9	22.5	22.9	22.4	23.7
Size (cm)	164.2	169.9	176.4	180.1	180.1	180	180.2	180.1	180.4
Height Sitting (cm)	78.3	80.3	84.9	86.8	87.4	88.4	88.2	88.5	88.2
Size/height	1.06	1.07	1.07	1.08	1.08	1.07	1.07	1.07	1.07
Height sitting/height (cm)	50.5	50.5	51.7	52	52.2	52.6	52.5	52.6	52.1
Sum 8 SF (mm)	46.3	40.9	42.4	43.5	46.3	45,7	44.5	40.8	40.2
% Fat	6.7	6.3	6.6	6.8	7.2	7	6.8	6.3	6.2
LMM (kg/m^2)	17.42	17.88	18.96	19,47	20.32	20.95	21.33	21.01	22.25
Gymnast 2									
Age (years)	14	15	16	17	18	19	20	21	22
Weight (kg)	54.2	62.7	66	68.5	70.8	68.7	70.3	71.5	69.9
Height (cm)	163.4	168.5	169.9	170.0	170.3	170.6	170.7	170.6	170.7
BMI (kg/m^2)	20.3	22.1	22.9	23.7	24.4	23.6	24.1	24.6	24
Size (cm)	170.5	177.9	180.3	180.9	181.1	181.1	181.3	181.2	181.4
Height Sitting (cm)	82.8	86.3	88.1	88.2	89.2	88.7	89.1	88.3	88.6
Size/height	1.04	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Height sitting/height (cm)	50.7	51.2	51.8	51.9	52.4	52	52.2	51.8	51.9
Sum 8 SF (mm)	49.8	45.9	41.9	47.3	45.2	42.5	47.4	44.4	44.9
% Fat	7.8	7.2	6.5	7.3	7	6.6	7.3	6.9	6.9
LMM (kg/m^2)	18.72	20.50	21.37	21.96	22.71	22.04	22.37	22.88	22.34

SUM 8 SF: sum of the 8 skinfolds (iliac crest, supraspinal, abdominal, subscapular, biceps, anterior thigh and medial leg). % Fat compared to the total body weight estimated using the Withers *et al.* equation[23] LMM: lean muscle mass: lean weight (body weight - fat weight) divided by the height in kg/m^2.

and 7.3 cm respectively in each gymnast. The body weight of GYMN 1 remained within the percentiles 15-20, the height in percentile 10 and the BMI in percentile 20. The weight of GYMN 2 sat between percentiles 30-50, the height at the beginning is close to percentile 50 and drops to 15 at 18 years; the BMI oscillates between percentile 20-25. Table 2 displays the growth speed (cm/year) of the height recorded in the successive controls and the percentage that represents the height reached regarding the final adult size. The growth speed (cm/year) in GYMN 1 is between percentiles 60-70 and in GYMN 2, between percentiles 20-40. The arm perimeter of GYMN 1 has an accentuated increase, from percentile 60 at 14 years (25.4 cm) to percentile 95 at 18 years (32.1 cm). Whilst the arm perimeter of GYMN 2 increased from percentile 90 (28.1 cm) to 99.9 (35.7 cm). The tricipital skinfold of GYMN 1 oscillated between percentiles 10-20 (6.6 - 6.4 mm) and for GYMN 2 between percentiles 10-15 (5.2 - 4.7 mm) in relation to the Spanish reference population of 14 and 18 years.

In both gymnasts at 22 years, the body weight and body mass index were within the intermediate range, whilst their adult height was positioned in percentile 10 and percentile 15 respectively.

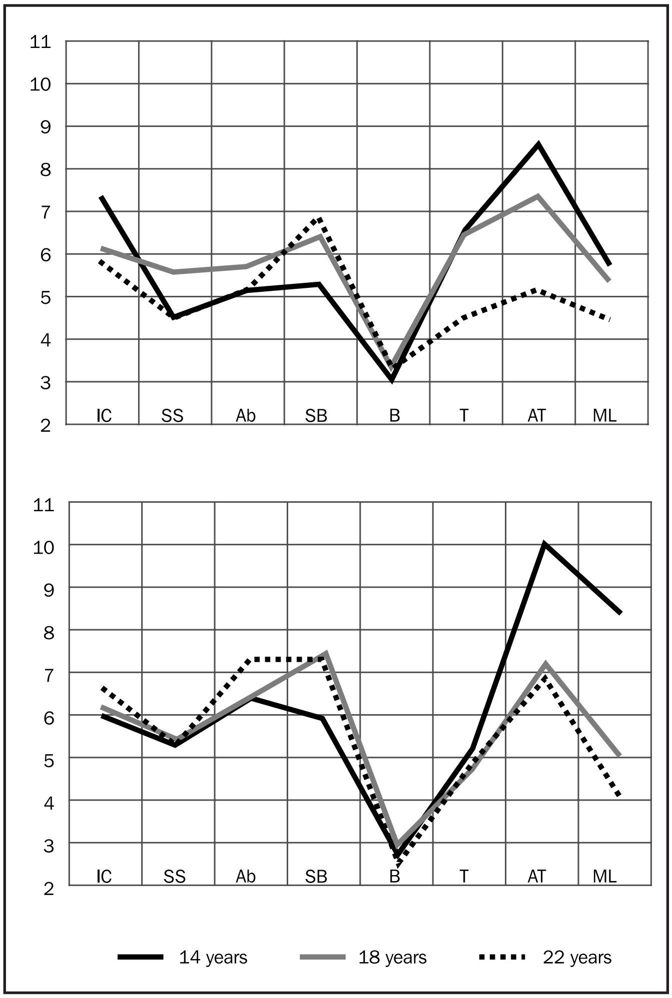
The size exceeded the height in all the controls and the difference increased with age until 17 years, at which point it remained stable. The sitting height increased in GYMN 1 until 19 years, and in GYMN 2, until 18 years. With regards to the sitting height percentiles in both gymnasts, they were low, at around percentile 5, progressively increasing to sit in an average range, percentile 60 and 25 at 19 years.

Table 2. Developmental study of the height of gymnasts.

Control	Growth speed (cm/year)		% Adult height reached	
	GYMN 1	GYMN 2	GYMN 1	GYMN 2
14 years			91.61	95.72
15 years	6.83	4.64	94.03	98.71
16 years	4.73	1.27	97.10	99.53
17 years	1.92	0.10	98.58	99.59
18 years	0.73	0.30	99.05	99.77
19 years	0.44	0.30	99.29	99.94
20 years	0.10	0.11	99.35	100.00
21 years	0.30	-0.09	99.53	99.94
22 years	0.80	0.11	Final height	Final height

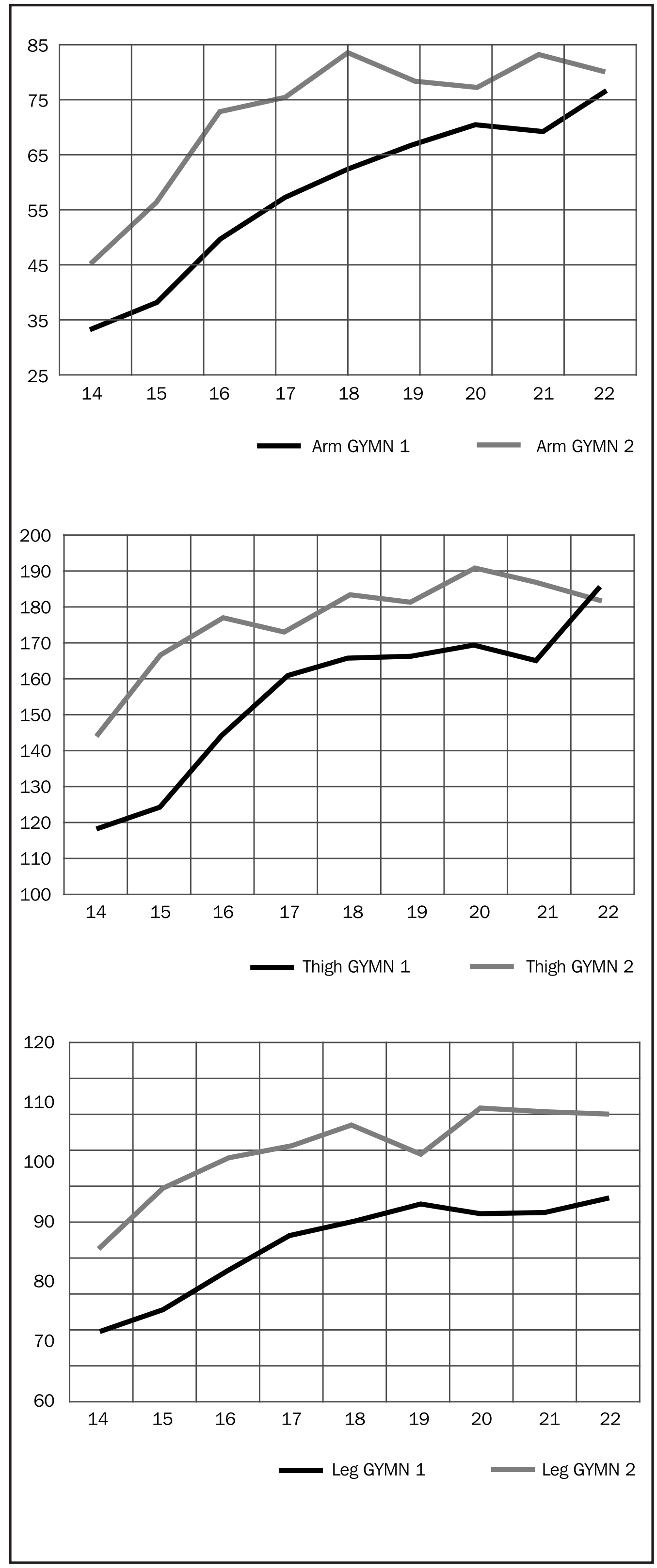
GYMN 1: gymnast 1; GYMN 2: gymnast 2. It is considered that adult height is reached when the change does not exceed 0.5 cm between two consecutive controls 6-12 months[26].

Figure 1. Evolution of the skinfold profile. Gymnast 1 and 2.



Values at the 14, 18 and 22 years controls. Upper part Gymnast 1 and lower part Gymnast 2. IC: iliac crest; SS: supraspinal; Ab: abdominal; SB: subscapular; B: biceps; T: triceps; AT: anterior thigh; ML: medial leg. (mm.).

Figure 2. Areas of the arm, thigh and leg (CSA, cm²).



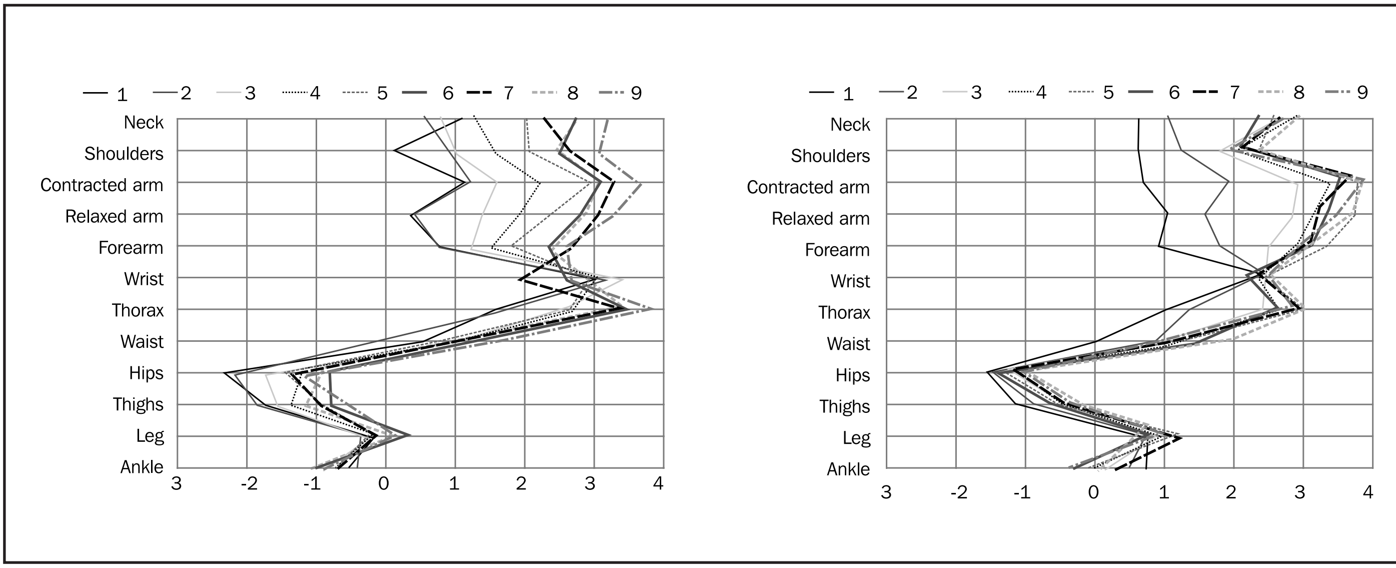
FALTA TRADUIR

The evolution of the skinfold profile is displayed in Figure 1. In both gymnasts there is a reduction in the skinfolds of the lower limbs, anterior thigh and medial leg; and an increase of the subscapular skinfold. This trend is maintained throughout the 9 years. In GYMN 1 there is also a reduction in the triceps and the iliac crest. In GYMN 2 there is a slight increase in the abdomen. The most stable skinfolds are the biceps and the supraspinal. The total sum of the 8 skinfolds reduced minimally in GYMN 1 from 18 years; whilst they remained stable in GYMN 2.

From the first to the last control, the fat percentage reduced in GYMN 1 by half a point and by around one point in GYMN 2. Whilst the lean muscle component increase was of 4.83 kg/m^2 (27.7%) and of 3.62 kg/m^2 (19.3%), GYMN 1 and GYMN 2 respectively.

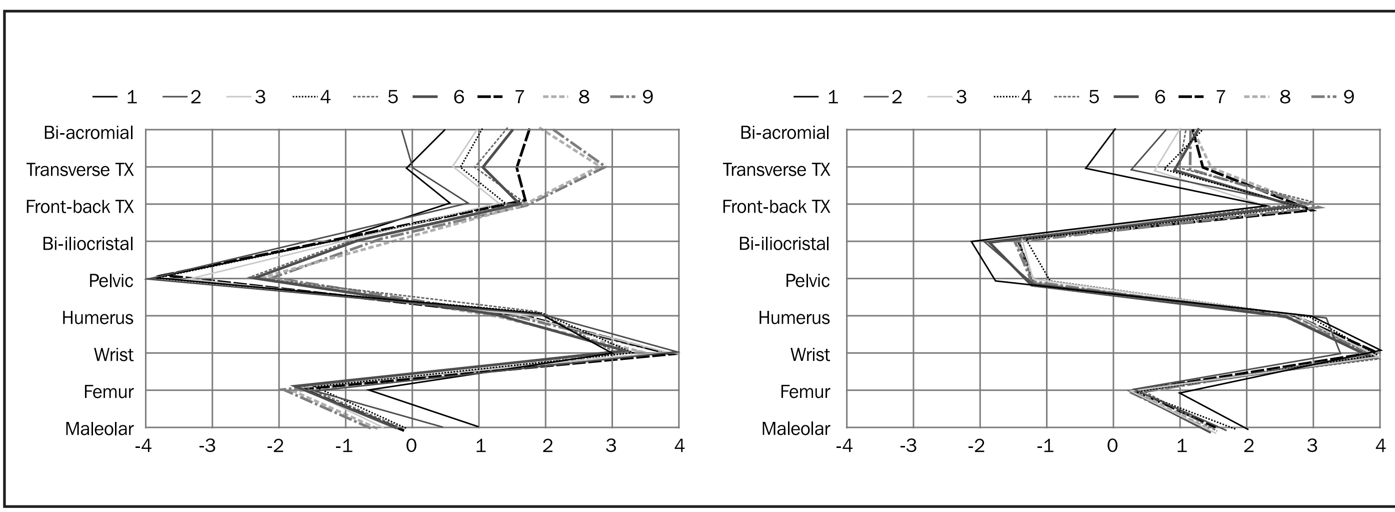
The cross-sectional muscle area (CSA) is displayed in Figure 2. That of the arm increased considerably in both gymnasts: in the gymnast that started with lower values, the increase is continuous until the age

Figure 3. Proportionality: z-score of the body perimeters in the 9 controls.



Typified diameters using the Ross and Wilson method[26], gymnast 1 in the left part and gymnast 2 in the right part.

Figure 4. Proportionality: z-score of the bone diameters in the 9 controls.



Typified diameters using the Ross and Wilson method[27], gymnast 1 in the left part and gymnast 2 in the right part.

of 22, whilst it stabilises in the other gymnast, with both reaching similar values. The same occurs at the level of the thigh, in GYMN 2 it stabilises at 18 years, whilst in GYMN 1 there is a very marked increase from 15 to 17 years, and the development continues at a less accentuated rate until the age of 21, to match that of the other gymnast at the final control at 22 years. At the level of the leg the increase is more accentuated at the beginning, with the differences between both gymnasts remaining.

The relative size and sitting height rates are displayed in Table 1. The first rate indicates a greater length of the upper limbs in relation to the height in all the controls, stabilising at 15 years. The second rate increases in the first controls, changing from having a value in the short trunk range to having a value in the average trunk range, due to a proportionally greater growth in the trunk in relation to the growth of the height.

Figures 3 and 4 display the proportionality profiles. The highest values of the perimeters correspond to the upper extremity, the upper part of the trunk and neck; whilst the lowest values are those of the hip and upper thigh. In GYMN 1 there is a more progressive increase, whilst in GYMN 2 the increase is more accentuated in the first controls. Comparing the profiles of both gymnasts in the final control, we can see that GYMN 1 has proportionally more development in the neck, shoulders and thorax, whilst GYMN 2 has more in the forearm, leg and ankle. Throughout the 9 years the z-score increases in all the perimeters, apart from the ankle, which reduces, and the wrist, which remains the same. In the z-score of the diameters, particularly outstanding is the greatest value of the bi-styloid diameter of the wrist; followed by the cross-sectional diameter of the thorax, bi-acromial, anterior to posterior thorax and humeral in GYMN 1; and anterior to posterior thorax, humeraland malleolar in GYMN 2. The greatest changes in GYMN 1 occurred in the cross-sectional thorax, followed by the trochanteric;and bi-acromial whilst in GYMN 2 the changes are less marked, with notable increases in the thorax and the bi-acromial.

Discussion

A longitudinal follow-up has been performed on two high-level gymnasts from their final year in the infant category at 14 years, to the senior category at 22 years, an age at which both physical and technical maturity is considered to be achieved. In the (2014-2015)[28] world ranking, the average age of the 10 best gymnasts was considered to be 22.4 years. We could consider therefore that this is the age at which the greatest achievements will be obtained in this sport.

The "tempus madurativo" is an individual feature with variability in the starting age of puberty of around 4 to 5 years[29]. It is considered that adult height is reached when the change does not exceed 0.5 cm between two consecutive controls 6-12 months[26]. The first control, carried out at 14 years, corresponds to the deceleration phase of the second peak of growth speed. The two gymnasts, despite having the same chronological age, are not at the same maturity phase, according to the growth speed model and the percentage of adult height reached. GYMN 1 has a later maturity, with a significant increase (growth speed > 0.5 cm/year)[26] until 18 years, continuing to progress until the final control; whilst GYMN 2 only had significant increases until the age of 16 years and by 18 years his height was stable; and if we assess his height in the corresponding profiles for this maturity group[26], he is positioned in percentile 10 from 14 to 18 years, Therefore both gymnasts had a height in percentile 10 at the start and both finished with an adult height at 22 years at around percentile 10, i.e. they kept to their genetic growth channel, and were not affected by intensive training. The average height of international gymnasts varies between 161 and 173 cm[17], positioning percentile 50 at 167 cm, whilst for the general population this value would be at around percentile 3-10. This low height is bio-mechanically favourable to gymnasts, with centre of gravity close to the rotation axes. The current Olympic champion (2012 Olympic Games) and five-time world champion is 160 cm high. With this low height comes a lower body weight, also due to a low fat component. The weight of the gymnast varies between 57 and 70 kg, positioning the percentile 50 at 63.2 kg[17], which, in comparison to the general population, would be percentile 15. The height and weight of our gymnasts in the controls have been within the range according to the age and the sport, apart from GYMN 2 in the first two years of follow-up, in which both his body weight and height were slightly above; due, as previously commented, to his earlier maturity. The sitting height/height relation is also within the average range for this sport[17,18,30].

The skinfolds are within the cited ranges for male gymnasts[17,18]. On the other hand, regarding the general Spanish population of the same age, the triceps and subscapular skinfolds are within percentiles 10-20 and 20-25 respectively throughout the nine controls.

The fat distribution model changes with growth and maturity, in males, fat is lost from the extremities and accumulates at the level of the trunk. As we can see this trend continues throughout the entire follow-up period, both puberal and post-puberal, with slight differences between both gymnasts, partly due to the different initial values.

The body composition indexes in relation to the height highlight that the increase in total weight is mainly at the expense of the lean muscle component, with GYMN 1 showing a progressive increase throughout the 9 years, whilst GYMN 2, who started with higher values, stabilises from 18 years, with both reaching similar values. In relation to the general Spanish public, the fat percentage is positioned in the first period controls (14-18 years) in percentile 10 for both gymnasts. I.e. just as we saw in the skinfolds, it is within the lower range but does not reach extremely low values. In the second period, in comparison to the Spanish sporting population[20], GYMN 1 moves from percentile 25 at 18 years to percentile 10 at 22 yeas, whilst GYMN 2 remains in percentile 20.

The cross-sectional muscle areas that determine muscle strength increase with growth, then stabilise and later diminish in the ageing of the general population. It can be seen that GYMN 2, who starts with higher values, follows this pattern, stabilising at 18 years, whilst in GYMN 1 the increase continues past 18 years, mainly at the level of the arms and in lesser measure in the thigh measurement, with both gymnasts ending with similar values, apart from at the level of the leg, where the differences are maintained. The greatest development and increase is of the arm, as if we compare this to the general population, the perimeter of the arm of GYMN 1 moves from percentile 60 at 14 years to percentile 97 at 18 years; whilst GYMN 2 is already at percentile 90 at 14 years, and moves up to over percentile 99 at 18 years. This major muscle development in the arms is accompanied by longer lever lengths than expected for their height, as they are relatively high in size (1.06 and 1.07), which favours a greater increase in applicable strength.

The proportionality profile helps us to assess the evolution during growth and maturity and reveals a slightly different development between the gymnasts. In both, and from the first control at 14 years, both the perimeter and the bone diameter of the wrist already have a very high z-score, revealing one of the characteristics common to this sport, the same as the z-score of the humeral bi-epicondylar diameter. Both joints - the elbow and the wrist - receive high impacts and must frequently bear the weight of the gymnast. The proportionality profile also indicates a greater development of the scapular belt (estimated via the bi-acromial diameter and the perimeter of the shoulders) and the ribcage (represented by the diameters and chest perimeter), in contrast with the lesser development of the pelvic band (estimated by the bi-iliocristal and pelvic diameters). Compared to GYMN 2, GYMN 1 has a more developed bi-acromial diameter and ribcage width, especially between 16-17 years and between 20-21 years. GYMN 2 already started with higher values in his bone development, which increased in a less marked way also at the level of the thorax, with greater anterior-posterior depth than GYMN 1.

One study limitation was not having any other criteria in addition to the anthropometric measurements to establish the state of maturity, such as the bone age and/or sexual maturity; even though as we have commented, the evolution of the height growth was useful when establishing a posteriori the type of maturity group. The gymnast that had an earlier maturity stabilised his anthropometric profile at around 20 years, whilst the other gymnast continued to develop. At 22 years the only initial difference that remains between both athletes is a greater development at the level of the leg of GYMN 2; whilst GYMN 1 exceeds him at the level of the neck, shoulders and thorax. This data proves that until at least 22 years, improvements can be made to the body composition of the gymnast. The minor differences between the gymnasts could be reflected in their performance levels in different competition trials.

Conclusions

We have seen that there is a major adaptation to the musculoskeletal system with training, though the greatest increases occur up to 17-18 years, with the response to the mechanical demands imposed by gymnastics located at the level of the upper body. The final year of the infants category is when the athletes already have an established anthropometric profile, reflected in their early specialisation which is accentuated with years of training until they reach the senior category, with the possibility of slight variations, which in part depend on the initial level of maturity and on the individual biological rhythm of the athlete.

This adaptation, which translates as an important increase in the lean muscle component, along with the energy requirements entailed in training for 36 hours a week, suggests the need for a special control by the sports doctor to ensure that the nutritional intake is appropriate.

The anthropometric technique is a useful tool for the follow-up of adolescent athletes, and an individual and regular assessment should be carried out; it is important to start the study early so as to include the peak of growth speed and to associate it to other biological criteria to establish the degree of maturity.

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