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Evaluation of somatotype in artistic gymnastics competitors: a meta-analytical approach

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Running Title: **Somatotype in artistic gymnastics**

Abstract

INTRODUCTION: Studies on the anthropometric characteristics of athletes have a long history, but there are no published reviews on the somatotype of artistic gymnasts. Practitioners and professional coaches can gain guidance from improved understanding of the ideal body constitution and the impact of high-intensity training since preadolescence on body build. The present review is designed to provide this information.

EVIDENCE ACQUISITION: Academic Search Complete, SPORTDiscus, Medline, Google Scholar, and ResearchGate were searched in January 2017. All studies on the body composition of male artistic gymnasts were included. We identified 19 studies assessing somatotype in male gymnasts.

EVIDENCE SYNTHESIS: We found high heterogeneity of somatotype components between younger gymnasts (≤ 18 years) and older gymnasts (> 18 years) (1.6±0.3 -5.4±0.8 - 3.0±0.6 vs. 1.8±0.4 -5.9±0.6 -2.2±0.4). Four different somatotypes resulted from the literature analysis, and ectomorphic mesomorph was the prevalent somatotype in both younger and older athletes. The main result showed a significant difference in ectomorphy (lower in older gymnasts than in younger gymnasts).

CONCLUSIONS: Proper interpretation of the literature data may inform future research and enable professional coaches to longitudinally monitor gymnasts' somatotype components during growth and in talent identification. More research is needed to better understand the most suitable somatotype variations related to the different apparatuses used in artistic gymnastics.

Key words: Body constitution - kinanthropometry - male gymnasts - sport sciences.

Introduction

One of the key elements in talent identification is the anthropological assessment since it is used in monitoring, analysis, and evaluation of the efficiency of training and athlete selection. Some important anthropological characteristics and indices can respond to training load (body weight, muscle mass, body fat, and bone density), while others are genetically determined (height and bone breadth), even if the environment can influence them (e.g., short height due to malnutrition). The combination of characteristics might largely affect the level of achievement in sports. [1]

According to sports classification, gymnastics is an anaerobic sport (Levine et al. 2015). The shortest event is vault (5.16±0.41 s), whereas the longest is floor exercises (60.90±3.44 s).[2] Different types of exercises are practiced during training and competition in men's artistic gymnastics: 1. pommel horse (exercises performed only in support); 2. horizontal bar, parallel bars (exercises performed in hanging or support); 3. floor exercises, vault (strong interaction with support).[3] Several changes in the last 20-30 years were introduced in men's artistic gymnastics.[4] The apparatuses have undergone and are still undergoing extensive modifications, such as: spring-loaded ring suspension frames made for bow and recoil; sprung-top and much wider vaulting tables; thicker landing mats; parallel bars with thinner and hollow fiberglass rails; vaulting boards with adjustable spring; increasing elasticity in all apparatus. These modifications have strongly influenced different skills. The code of points changed dramatically with the introduction of a new points system for artistic gymnastics in 2006 (International Federation of Gymnastics, F.I.G.). Unlike the old code of points, scores are no longer limited to 10 points and there are two different evaluations: an execution score and a difficulty score. At the same time, standard of gymnastic apparatuses was also improved. [5] A feedback between competition demands and training technology should affect changes in sports activities and, in consequence, in body characteristics of gymnasts. Previous publications have examined gymnasts up to 1986[6] and 1993[7], while not always mentioning the age of gymnasts.[6-7] Few papers have examined adult athletes in more recent years.[8] Studies of junior and adult athletes conducted by the same research teams are very scarce.[9] Artistic gymnastics is one of the oldest sports. Olympic medal winners[10] and contemporary athletes (older and younger) should be examined and compared in terms of body build to provide insights into effective methods to identify somatically talented athletes in this sport. Therefore, this study updates the knowledge with more recent studies aiming to determine the somatotype of older and younger artistic gymnasts in light of available references by means of a meta-analysis. A secondary aim was to understand if body characteristics of the athletes changed during the analyzed period.

Evidence acquisition

A literature search using the key words “Somatotype AND Gymnastics AND Male” was performed in publications from 1993–2016 of the following databases: Academic Search Complete, SPORTDiscus with full text, Medline, Google Scholar and ResearchGate. The electronic search was supplemented by hand searching the references lists for the selected articles. The inclusion criteria were (a) data on the age of study participants; (b) competitive level; (c) sample size with data on means and SD concerning the somatotype components; and (d) male sex. The exclusion criteria were (a) failure to provide information about the age of study participants; (b) a lack of standard deviations for somatotype components; and (c) female participants. Given the reduced number of studies found on the topic, we also considered non-English literature. The data collected were classified according to age (younger: 18 years or younger; older: over 18 years). The combined means and SDs for age, body height, and body weight were calculated according to Kirkendall *et al* [11] while taking sample sizes into account.   Comparisons were performed using t-test. In addition, distribution of somatotypes in older and younger gymnasts, as well in periods before and after 1993, was analyzed in 25 samples (19 articles). The Fisher exact test was-employed to compare frequency distributions.

Dedicated software was used to identify somatotypes,[12] and the Fisher exact test was performed to compare frequency distributions. Somatotype components were compared by meta-analysis using Medical Bundle software (Statistica v.12). After finding the significance of heterogeneity Q between individual samples, the I^2 index (independent of trial size) was computed. I^2 ranges from 0% to 100% and is interpreted as low (≤ 25%), moderate (25-50%), or high (≥ 75%). Further analysis was done using the random effects option. Confidence intervals for individual samples, age groups, and overall confidence intervals were also computed. The significance of intergroup differences (older vs. younger) was calculated for each component of the somatotype using a Z-test ($p<0.05$).

Evidence synthesis

The results of the literature search are illustrated in a flow chart in Fig. 1.[13] After the initial search in the international databases, 1491 documents related to gymnasts and other sports were found. Further analysis led to the exclusion of 32 papers that did not meet the inclusion criteria. During the screening stage, 19 eligible studies that reported 25 individual samples of 431 older male and 107 younger male gymnasts were identified for quantitative analysis. From the results presented by Amigò *et al.*,[14] we included younger gymnasts aged 12.1, 14.2, 16.1 and 18.1 years.

Figure 1 near here

Based on observational cross-sectional studies, we found that the sample sizes ranged from 6 to 165 subjects in older groups and from 6 to 17 in younger groups. The mean age of older participants in individual samples ranged from 19.8 to 27.2 years, whereas the mean age of younger participants ranged from 12.1 to 18.1 years. In younger athletes with age ranging from 8 to 15 years, the authors did not present standard deviations.[14] The combined SD for age was not computed.

Athletes Characteristics

The combined sample size of the 25 coded individual samples was 538 subjects. The 431 senior athletes (age = 22.2 years; stature =167.8 ± 6.3 cm; weight = 64.2 ± 6.7 kg) were naturally older, taller (t=34.01, df=536, p<0.001), and heavier (t=26.7, df=536, p<0.001) than younger athletes (age = 13.4 years; stature = 142.0 ± 9.4 cm; weight = 43.4 ± 9.0 kg).

Differentiation of somatotypes in gymnasts

Four different somatotypes were identified in gymnasts (Table I). Ectomorphic mesomorphs coexisted most often with other somatotypes. No significant differences were found between older and younger athletes (Fisher exact test p=0.229). In older participants, balanced mesomorphs occurred as often as ectomorphic mesomorphs, in contrast to the observations in younger athletes. These differences were statistically significant (Fisher exact test p=0.027). Endomorphic mesomorphs occurred occasionally in older athletes, whereas mesomorph-ectomorphs occurred only in the younger group without any statistical significance.

Table I near here

The somatotype distribution before and after 1993 is presented in Table II.

Table II near here

No difference in ectomorphic mesomorph (p=0.241) was found between gymnasts before and after 1993. For balanced mesomorph, different frequency (p=0. 021) resulted between periods. Balanced mesomorph was prevalent after 1993.

The location of individual samples is illustrated in somatocharts for older (Fig. 2)[8,9,15-27] and younger gymnasts (Fig. 3).[9,14,28-31] The mean somatotype for the older group was $\overline{S}$ = 1.8 ± 0.4-5.9 ± 0.6-2.2 ± 0.4 (balanced mesomorph), whereas that for younger athletes was $\overline{S}$ = 1.6 ± 0.3-5.4 ± 0.8-3.0 ± 0.6 (ectomorphic mesomorph). The SANOVA results show a significant difference between the components of older and younger gymnasts ($F=7.00_{(1,23)}$, p=0.014).

Figures 2 and 3 near here

ANOVA does not show any significant difference between gymnasts before and after 1993 for endomorphy (F(1,23)=0.28, p=0.392; “before 1993”: 1.71±0.40 vs “after 1993”:1.79±0.36), and mesomorphy (F(1,23)= 0.40, p=0.460; “before 1993”: 5.64±0.70 vs “after 1993”:5.82±0.71). For ectomorphy, the difference was close to significance level (F(1,23)= 3.00, p=0.093; “before 1993”: 2.65±0.71 vs “after 1993”: 2.22 ± 0.46). Similarly, somatochart (Fig.4) displays a different somatotype distribution: gymnasts somatotype was ectomorphic mesomorph before 1993 and balanced mesomorph after 1993.

Figure 4 near here

Meta-Analysis of Somatotype Components in Subgroups of Older and Younger Gymnasts

Definite heterogeneity was a characteristic of older samples in individual components of the somatotype: endomorphy (Q=195.590, df=15, p<0.001; I^2=92.33%, Cl= 89.12-94.59%), mesomorphy (Q= 188.403, p<0.001; I^2=92.04%, Cl=88.66-94.41%), and ectomorphy (Q=111.086, p<0.001; I^2=86.37%, Cl=79.40-90.99%). Similarly, high heterogeneity was found in the younger subgroups for endomorphy (Q=39.039; df=8, p<0.001; I^2=79.51%, Cl=

61.68-89.04%), mesomorphy (Q=94.98, p<0.001; I^2=91.58, Cl= 86.26-94.84%), and ectomorphy (Q=59.41, p<0.001; I^2=86.3, Cl=74.44-95.30%). Therefore, comparisons were based on the mean difference, random effects, and T^2 in separate subgroup analyses.

Older and younger athletes showed no statistical significant difference for endomorphy (Z=1.014, p=0.311, mean=1.76, Cl=1.62-1.89 vs. 1.65, Cl=1.61-1.81) (Fig.5). In the older group, these confidence limits did not contain positive outliers (mean=2.60, Cl=2.19-3.01; [14] mean=2.73, Cl =2.40-3.06) [8] and negative outliers (mean=1.10, Cl=0.96-1.24) .[20] In the younger group, the most outlying results were presented by Araujo and Montinho (mean=2.20, Cl=1.96-2.40)[29] (Fig.5). [8,9,14-31]

For mesomorphy (Z=1.600, p=0.107), we found differences that were close to the significance level between older athletes (mean=5.87, Cl=5.62-6.12) and younger athletes (mean=5.39, Cl= 4.88-5.90) (Fig. 5). The most positive outlying results for mesomorphy of adults (mean=7.06, Cl=6.57-7.55) were presented by João and Filho,[27] whereas negative outliers (mean=4.43; Cl=4.14-4.72) were documented by Čuk *et al.*[25] Among younger subgroups, the most pronounced positive results were those of Italian (mean=6.30, Cl=5.87-6.73)[9] and Spanish gymnasts (mean=6.30, Cl=5.42-7.18),[14] and the most pronounced negative results were those of Brazilian gymnasts (mean=4.20, Cl=3.73-4.47)[29] (Fig.6).[8,9,14-31]

With respect to ectomorphy, a significant difference was found between the means of older (mean=2.13, Cl=1.94-2.33) and younger (mean=3.02, Cl=2.59-3.62) gymnastics athletes (Z=-3.722, p<0.001) (Fig.7). [8,9,14-31] The highest outliers were observed for two individual samples of older athletes (mean=1.50, Cl=1.25-1.75;[15] mean=1.60, Cl=1.35-1.85) [27] and younger athletes (mean=3.90, Cl=3.53-4.27;[28] mean=4.00, Cl=3.41-4.59)[29].

Figures 5-7 near here

Discussion

The principal focus of our interest was somatotype in male competitors of the Artistic Gymnastics according to age. Body height and body mass have been documented in studies of somatotypes in various sports groups. The results support the hypothesis that gymnasts are generally shorter and lighter than athletes from other sports.[2,8,24,26] The mean age of athletes from individual samples ranged from 12.1[14] to 27.2[6,26]. The mean age of Olympic medal winners from the Olympic Games in London (2012)[10] was 23.3 years and was similar to the mean age in the older subgroup in our review (22.2 years). Interesting differences occurred between medal winners in individual events. The greatest age difference (7.7 years) was found between the results in the rings and vault events (27.0 and 19.3 years, respectively). Outstanding athletes in the last decade started training at the age of 6.2 years.[10]

The body build of older athletes was more diverse than that of younger gymnasts, but the most prevalent somatotype in both subgroups was ectomorphic mesomorph. An exception of endomorphic mesomorph was observed in older gymnasts before 1993.[15] This situation, however, concerned touring gymnastic demonstration team (no competitors at their readiness moment). A de-training effect was probably responsible for their highest endomorphy. Almost the same frequency was found in the older group for balanced mesomorph, but this somatotype was not found in younger athletes. Therefore, age and weekly training volume, which tends to increase with age in athletes,[32] represent factors that moderate the body build of male artistic gymnasts. Also, contemporary changes in rules and mastering of apparatuses for training and competition occurred during the examined update period from 1993.[5]

The routine requirements, becoming more demanding and increasingly difficult, can explain the adaptation in body build of gymnasts selected for competitions. In addition to training effects, the athlete's anthropometric characteristics play an important role in defining the potential for success in a given sport.[33-34] For these reasons, our findings from studies on gymnast's somatotype may also support decision making for this sport and for adequate training programs used by professional coaches.

One problem is specialization in gymnastic apparatuses used in all-around events. Athletes perform routines during events using the floor, pommel horse, rings, vault, parallel bars, and high bar. Thus, it is difficult to match various special skills demonstrated on different apparatuses with the quality of dismount. This is likely to affect the scores in all-around events and thus the level of achievement in artistic gymnastics in the Olympic Games.[35] We found no studies concerning the relationships of somatotypes with apparatuses preferred by gymnasts, who should be examined in these terms despite athletes being difficult to access for research.

A characteristically high level of mesomorphy was observed in the younger subgroup,[28-29,31] and the level of individual samples coincided with values characteristic for adult athletes .[25] Another six individual younger samples[14] showed Cl values similar to those recorded in adult athletes. This phenomenon can be regarded as feedback in the biological paradigm of mutual relationships between somatotype and the effects of sport-specific training. This approach to solving the problem has also been presented in studies focusing on the relationships between the type of sport and body build of athletes with respect to their competitive level [8,34-35] and compared to a control group of non-athletes.[8,37]

In this review, no meta-analysis was conducted among different competitions level due to a lack of uniformity of the available studies concerning this criterion: limited information on achievements within each competition (medallist, non-medallists) is included, again making comparisons difficult.

The prognoses of the development of gymnasts should consider anthropological methods to predict adult body height,[33, 38] since gymnasts tend to be shorter than athletes from other sports. From this point of view, the peak height velocity (PHV) needs consideration.

Investigations on the PHV year in gymnasts are very rare. According to a longitudinal study, Polish elite gymnasts reached PHV (7.8±1.1cm/per year) at 15.1±0.8 years.[40] Moreover, as regards the changes in somatotype after PHV, it appeared that the gymnasts mesomorphy reached 6.2 and 6.3 at the age 16 and 18, respectively.[14] A more comprehensive approach to this problem can also be found in sports science in light of the relationships between heredity, lifestyles, environmental, personal attributes and physical activity, physical fitness, health, and wellness.[38] One of the studies in our update review from 1993 to present and meta-analysis discussed the somatotypes of male gymnasts across various age categories: juniors differed in their somatotypes and individual somatotype components from seniors.[9] Nevertheless, contemporary juniors are judged under the same code of points as the seniors of the F.I.G..

The results of individual samples have demonstrated that younger athletes (aged 12 to 18 years) are characterized by the same somatotype (ectomorphic mesomorph). The mesomorphy component becomes more pronounced from the youngest to the oldest individual samples, but its position with respect to endomorphy and ectomorphy is similar between groups.[14] The same somatotype was also present in an independent study of junior athletes,[9,30] and its determination could be useful for the identification of talented candidates for artistic gymnastics. The mentioned group revealed a strong relationship between the starting age and the age of retiring from artistic gymnastics, as well as their dependence on the event.[10] We suppose that this group of Olympians is characterized by a specific body build that gives them an advantage over their opponents. However, further research is needed.

Conclusions

This review is the first to consider several empirical studies focusing on somatotype components among male gymnasts. Since artistic gymnastics represents an Olympic sport, it is important to base current and future interventions on somatotype evidence in this discipline. Although a limited numbers of articles were available, our findings demonstrated significant differences between the somatotypes of older and younger gymnasts. The differences were found mainly in the values of ectomorphy (older < younger) and mesomorphy (older > younger), but no difference was observed in the endomorphy somatotype component. Ectomorphy, which is based on the height-to-weight ratio, turned out to be significantly lower in older athletes than in younger athletes. While striving to increase mesomorphy, professional coaches should take into account the structural aptitudes of candidates, the breadth of the epiphyses of the humerus and the femur, and the individual responses of muscles of the upper and lower limbs to training load. Endomorphy pointed to higher fat percentage, which did not differ between older and younger athletes. However, its level should be controlled since it can have negative effects on relative strength, which is essential in artistic gymnastics, since numerous movements are based on hangs and supports and it is necessary to use the comprehensive effect of the athlete's own body.

This review contributed to the existing body of knowledge in the area of artistic gymnastics by providing further objective instruments for evaluation, also highlighting that current research has overlooked apparatuses used in artistic gymnastics. To provide a better picture in this field, we recommend that researchers consider the most appropriate somatotype specific to the requirements of a given apparatus.

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Disclosure statement

No potential conflict of interest was reported by the authors.

References

1. Barbieri D, Zaccagni L, Cogo A, Gualdi-Russo E. Body composition and somatotype of experienced mountain climbers. High Alt Med Biol. 2012; 13: 46-50.

2. Jemni M, Friemel F, Lechevalier J-M, Origas M. Heart rate and blood lactate concentration analysis during a high-level men's gymnastics competition. J Strength Cond Res. 2000; 14:389-394.

3. Arkaev LI, Suchilin NG. Gymnastics. How to Create Champions: The Theory and Methodology of Training Top-Class Gymnasts. Aachen, Germany: Meyer & Meyer Fachverlag und Buchhandel GmbH, 2009.

4. Russell K. The Evolution of Gymnastics. In Caine DJ, Russell K, Lim L (Eds) Handbook of sports medicine and science: gymnastics. Oxford:United Kingdom; 2013. Pp. 1-14.

5. Apparatus Norms English Version 2006. http://www.fig gymnastics.com/publicdir/rules/files/en_Apparatus%20Norms.pdf, (accessed Janauary 15, 2018).

6. Carter JEL, Heath BH. Somatotyping - Development and applications. Cambridge, England: Cambridge University Press, 1990.

7. Raschka C. Sportanthropologie: Leitfaden der modernen, vergleichenden sportanthropologie, sportanthropometrie und trainingsrelevanten konstitutionbiologie [Sports anthropology: guide to modern comparative sport anthropology, sport anthropometry, and training-relevant constitutional biology]. Köln, Germany: Sportverlag Strauss, 2006.

8. Gualdi-Russo E, Graziani I. Anthropometric somatotype of Italian sport participants. J Sports Med Phys Fitness 1993; 33: 281-291.

9. Massida M, Toselli S, Brasili P, Calò CM. Somatotype of elite Italian gymnasts. Coll Antropol 2013; 37: 853-857.

10. Andreev P. Age analysis of the Olympic medal holders-men in artistic gymnastics for the period 1960-2012. Activities in Physical Education and Sport 2015; 5: 138-143.

11. Kirkendall DR, Gruber JJ, Johnson RE. Measurement and evaluation for physical educators. ed. 2 Champaign, IL: Human Kinetics Publishers, 1987.

12. Goulding M. Calculation and analysis. Somatotyping–v.1.2. [Computer software] Mitchell Park, SA: Sweat Technologies, 2010.

13. Moher D, Liberati A, Tetzlaff J, Altman DG. The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. BMJ 2009; 339: b2535.

14. Amigò AI, Faciabén AB, Evrard MM, Ballardini PAG, Marginet MC. Height, weight, somatotype and body composition in elite Spanish gymnasts from childhood to adulthood. Apunts Med Esport 2009; 161: 18-28.

15. Carter JEL. The somatotypes of athletes: A review. Hum Biol 1970; 42: 535-569.

16. Carter JEL. Somatotype characteristics of champion athletes. In V.V. Novotny (Ed.), Anthropological congress dedicated Ales Hrdlicka . Prague, Czechoslovakia: Czechoslovak Academy of Sciences,1971. pp.242-52.

17. Garay (de) AL, Levine L, Carter JEL. Program of genetics and human biology. Genetic and anthropological studies of Olympic athletes. New York, NY: Academic Press, 1974.

18. Lopez A, Rojas J, Garcia E. Somatotype and composition du corps chez les gymnasts di haut niveau. Cinesiologie 1979 ; 72 : 608-18.

19. Carter JEL, Aubry SP, Leet DA. Somatotypes of Montreal Olympic athletes. In J.E.L. Carter (Ed.), Physical structure of Olympic athletes. Part 1. The Montreal Olympic Games anthropological project. Basel, Switzerland: Karger, 1982. pp. 53-80.

20. Zeng L. The morphological characteristics of elite Chinese athletes who participated in gymnastics, swimming, weightlifting and track and field events (Master's Thesis). Cortland, NY: State University of New York, 1985.

21. Rodriguez C, Sanchez G, Garcia E, Martinez M, Cabrera T. Contribution to the study of the morphological profile of highly competitive male Cuban athletes. Boletin Cientifico-tecnico INDER (Cuba) 1986;1-2: 6-24.

22. Withers RT, Craig NP, Norton KI. Somatotypes of South Australian male athletes. Hum Biol 1986; 58: 337-356.

23. Claessens AL, Veer FM, Stijnen V, Lefevre J, Maes H, Steens G, Beunen G. Anthropometric characteristics of outstanding male and female gymnasts. J Sports Sci 1991; 9: 53-74.

24. Lentini NA, Gris GM, Cardey ML, Aquilino G, Dolce PA. Estudio somatotípico en deportistas de alto rendimiento de Argentina [Somatotypic study in high performance sportsmen of Argentina]. Archivos de Medicina del Deporte 2004; 21: 497-509.

25. Čuk I, Korenčič T, Tomazo-Ravnik T, Peček M, Bučar M, Hraski Z. Differences in morphologic characteristics between top level gymnasts of year 1933 and 2000. Coll Antropol 2007; 31: 613–619.

26. Rodriguez XP, Castillo O, Tejo J, Rozowski J. Somatotipo de los deportistas de altorendimiento de Santiago, Chile [Somatotype of high performance athletes of Santiago, Chile]. Rev Chil Nutr 2014; 41: 29-39.

27. João AF, Filho JF. Somatotype and body composition of elite Brazilian gymnasts. SCI GYMNASTICS J 2015; 7: 45–54.

28. Stepnicka J. Somatotypes of Bohemian and Moravian youth. Acta Fac Med Univ Brun 1976; 57: 233-242.

29. Araujo CGS, Moutinho M C. Somatotype and body composition of adolescent Olympic gymnasts. Caderno Artus de Medicina Desportiva 1978; 1: 39-42.

30. Perez B. Los atletas Venezolanos, su tipo fisico [Venezuelan athletes, their physical type]. Caracas, Venezuela: Universidad Central de Venezuela, 1981.

31. Broekhoff J, Nadgir A, Pieter W. Morphological differences between young gymnasts and non-athletes matched for age and gender. In T. Reilly, J. Watkins,& J. Borms (Eds.), Kinanthropometry 3. London, England: Spoon, 1986. pp.204-210.

32. Malina RM, Baxter-Jones AD, Armstrong N, Beunen GP, Caine D, Daly R-M, Lewis RD, Rogol AD, Russell K. Role of intensive training in the growth and maturation of artistic gymnasts. Sports Med 2013; 43:783-802.

33. Norton K, Olds T, Olive S, Craig N. Anthropometry and sports performance. In K Norton and T Olds (Eds) Anthropometrica. Sydney, Australia: University of New South Wales Press; 2000. Pp. 286-364.

34. Barbieri D, Zaccagni L, Babić V, Rakovac M, Mišigoj-Duraković M, Gualdi-Russo E. Body composition and size in sprint athletes. J Sports Med Phys Fitness 2017; 57: 1142-1146. doi: 10.23736/S0022-4707.17.06925-0.

35. Sterkowicz K, Sterkowicz K. Comparative analysis of the Olympic games during men's artistic gymnastics between 1988 and 2000. Revista Mackenzie de Educação Fisica e Esporte 2005; 4: 113-126.

36. 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: 303-313.

37. Sterkowicz-Przybycień K L, Sterkowicz S, Zarów RT. Somatotype, body composition and proportionality in Polish top Greco-Roman wrestlers. J Hum Kinet 2011; 28: 141-154.

38. Żarów R. Prognozowanie dorosłej wysokości ciała chłopców. Model własny i analiza porównanwcza innych metod [Adult height prediction in Polish Boys: The Zarow method and comparative analysis of different methods]. Krakow, Poland: Studia i Monografie AWF w Krakowie 17, 2001.

39. Corbin CB, Pangrazi RP, Franks BD. Definitions: Health, fitness and physical activity. President's Council on Physical Fitness and Sports Research Digest 2000; 3: 1-8.

40. Malina RM. Growth and maturation of elite female gymnasts: is training a factor? In FE Johnston, B Zemel, PB Eveleth (Eds) Human growth in context. London: Smith-Gordon; 1999. Pp.291-301.

TABLE I. Distribution of somatotypes in older and younger artistic gymnasts according to 25 individual samples (19 articles).

Somatotype	**Samples of older gymnasts n.**	**Samples of younger gymnasts n.**	**Total Samples n.**	**Definition (Carter & Heath 1990, p.406)**
Ectomorphic mesomorph	8	7	15	Mesomorphy is dominant, and ectomorphy is greater than endomorphy
Balanced mesomorph	7	0	7	Mesomorphy is dominant, endomorphy and ectomorphy are less and equal (or do not differ by more than one-half unit)
Mesomorph-ectomorph	0	2	2	Mesomorphy and ectomorphy are equal (or do not differ than one half); endomorphy is lower
Endomorphic mesomorph	1	0	1	Mesomorphy is dominant, and endomorphy is greater than ectomorphy
Total	***16***	***9***	***25***	

TABLE II. Distribution of somatotypes before and after 1993 according to 25 samples (19 articles).

Somatotype	**Samples before 1993** **n.**	**Samples after 1993** **n.**	**Total Samples** **n.**
Ectomorphic mesomorph	10	5	15
Balanced mesomorph	1	6	7
Mesomorph-ectomorph	2	0	2
Endomorphic mesomorph	1	0	1
Total	***14***	***11***	***25***

Titles of figures

Fig. 1. Flowchart of the literature search procedure ~~(according to Moher *et al*[27])~~.

Fig. 2. Somatotypes of 16 older groups: 1-Denmark, Carter, 1970→ endomorphic mesomorph; 2-USA Iowa University, Carter, 1970→ ectomorphic mesomorph; 3- American Association U placers, Carter,1971→ balanced mesomorph; 4- Mexico Olympics, Garay (De) *et al*,1974→ ectomorphic mesomorph; 5-Cuba International, Lopez *et al*,1979→ ectomorphic mesomorph; 6-Montreal Olympics, Carter *et al*,1982→ ectomorphic mesomorph; 7-China, Zeng, 1985→ ectomorphic mesomorph; 8-Cuba, Rodriquez *et al*,1986→ ectomorphic mesomorph; 9-South Australia, Withers *et al*,1986→ ectomorphic mesomorph; 10-World Championships in Rotterdam, Claessens *et al*,1991→ ectomorphic mesomorph; 11-Italy, Gualdi-Russo *et al*,1993→ balanced mesomorph; 12-Argentina, Lentini *et al*,2004→ balanced mesomorph; 13-World Cup in Ljubljana, Čuk *et al*, 2007→ balanced mesomorph; 14-Italy, Massida *et al*, 2013→ balanced mesomorph; 15-Chile, Rodriquez *et al*, 2014→ balanced mesomorph; 16-Brazil, João *et al*, 2015→ balanced mesomorph. The largest circle represents the mean somatopoint.

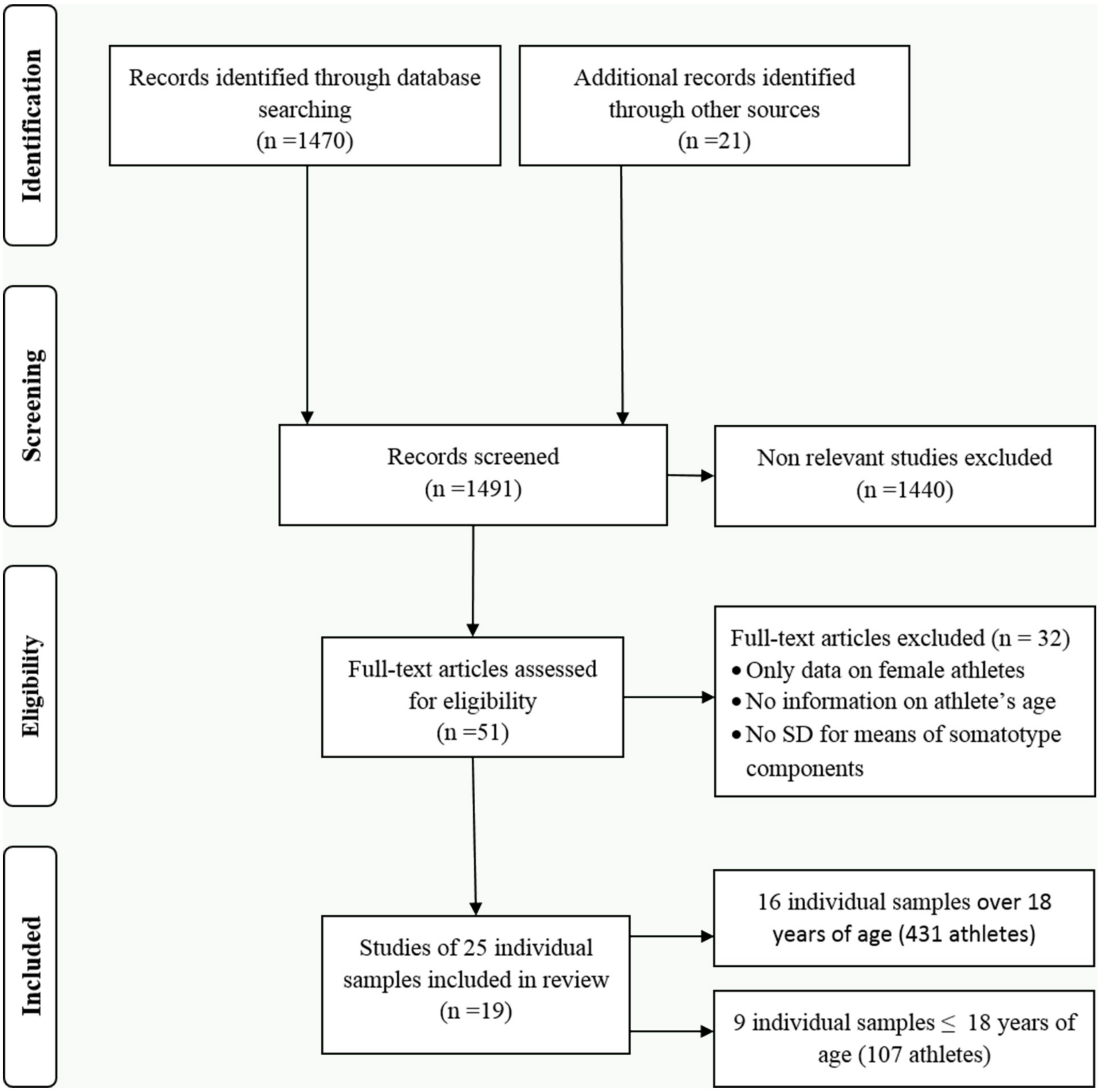
Fig. 3. Somatotypes of 9 younger groups: 17-Brno Czechoslovakia, Stepnicka,1976 → mesomorph-ectomorph; 18-Brazil club, Araujo *et al*,1978→ mesomorph-ectomorph; 19-Venezuela, Perez,1981→ ectomorphic mesomorph; 20-Oregon class II-IV, Broekhoff *et al*,1986→ ectomorphic mesomorph; 21-Spain (12.1 yrs), Amigò *et al*, 2009 → ectomorphic mesomorph; 22-Spain (14.2 yrs), Amigò *et al*, 2009 → ectomorphic mesomorph; 23-Spain (16.1 yrs), Amigò *et al*, 2009→ ectomorphic mesomorph; 24-Spain (18.1 yrs), Amigò *et al*, 2009→ ectomorphic mesomorph; 25-Italy, Massida *et al*, 2013→ ectomorphic mesomorph. The largest circle represents the mean somatopoint.

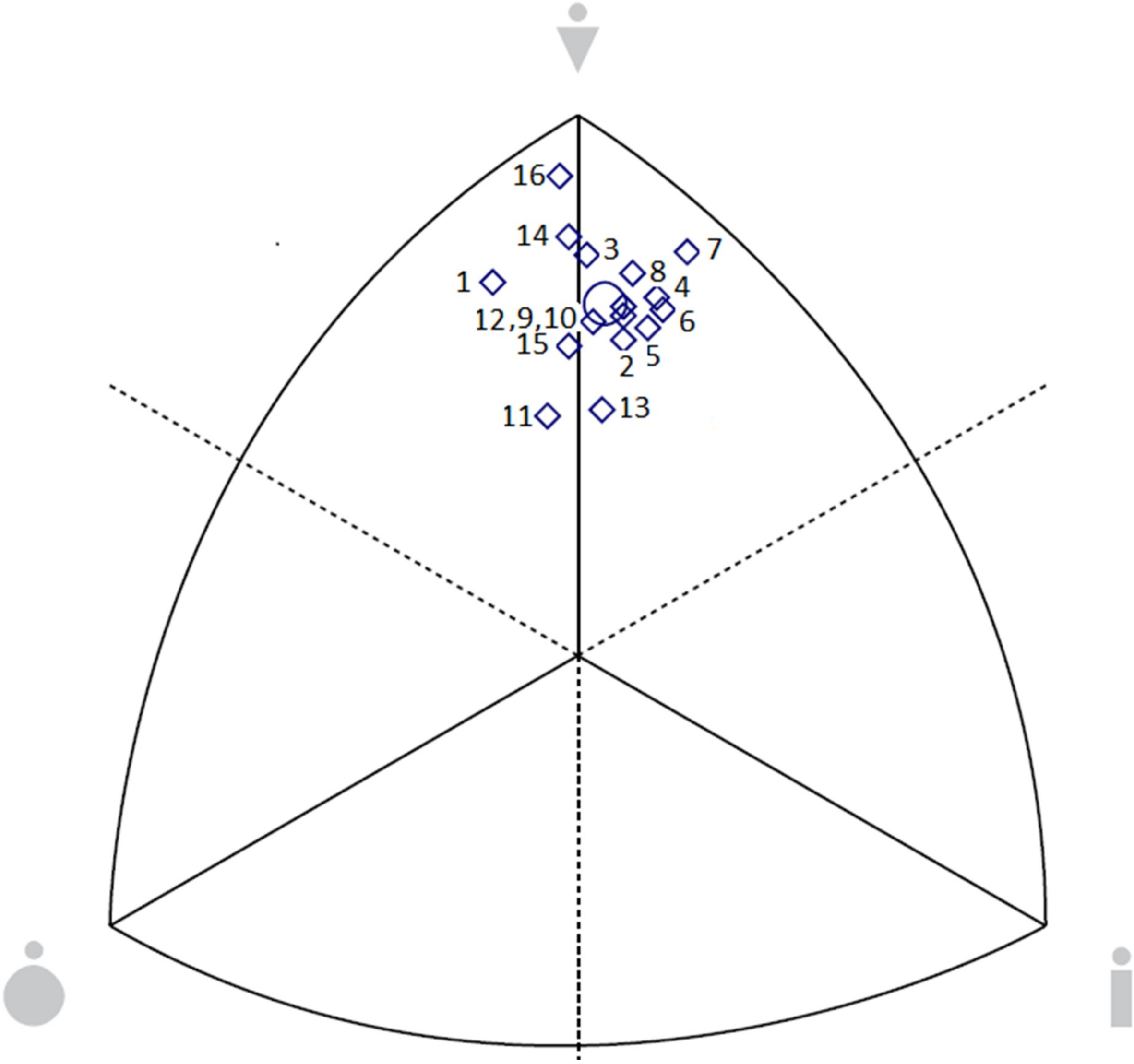
Fig. 4. Comparison of somatotypes of male gymnasts studied before and after 1993.The period since 1993 shows a slight increase in mesomorphic component.

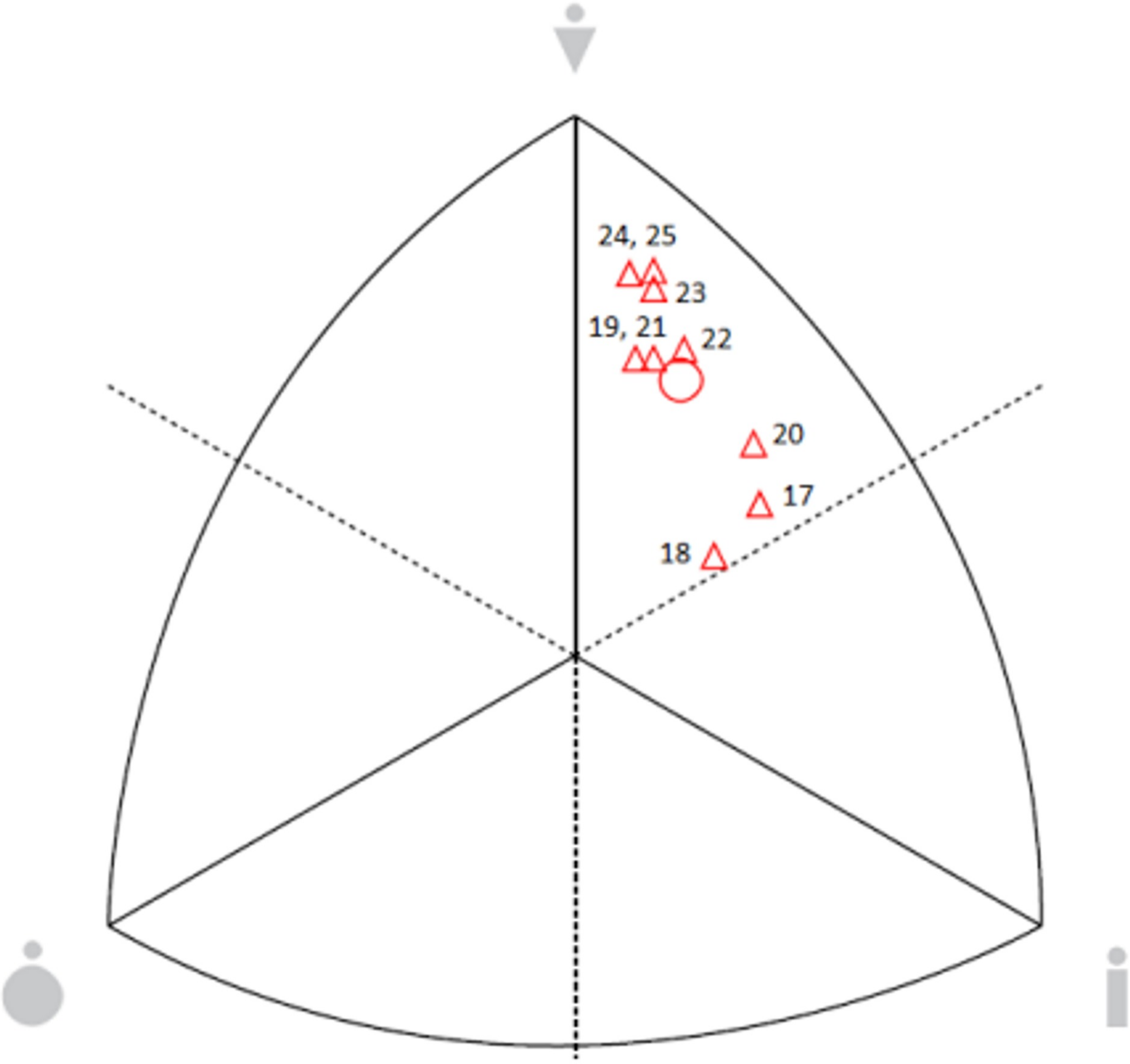
Fig. 5. Forest plot for the endomorphy component.

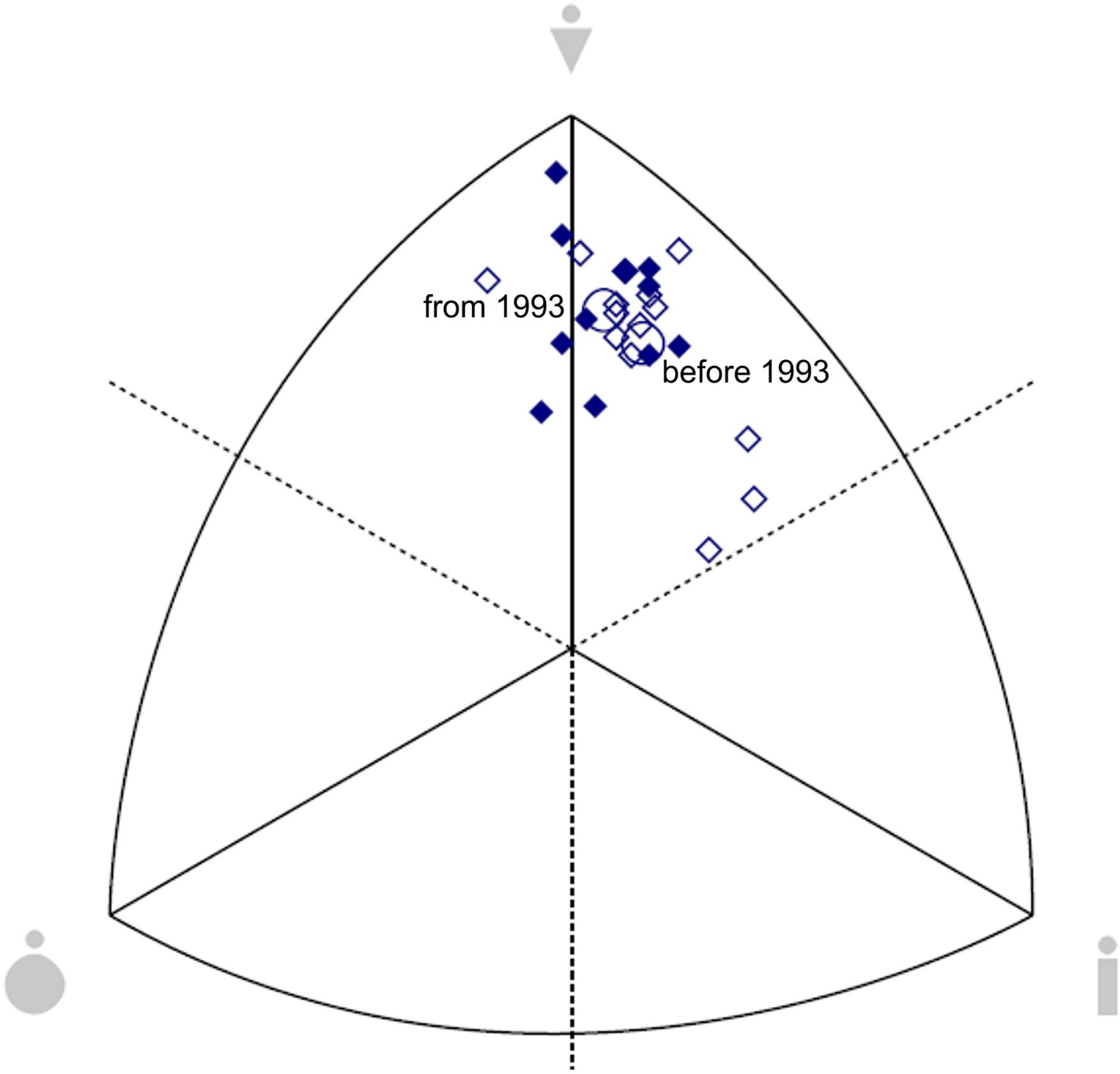
Fig. 6. Forest plot for the mesomorphy component.

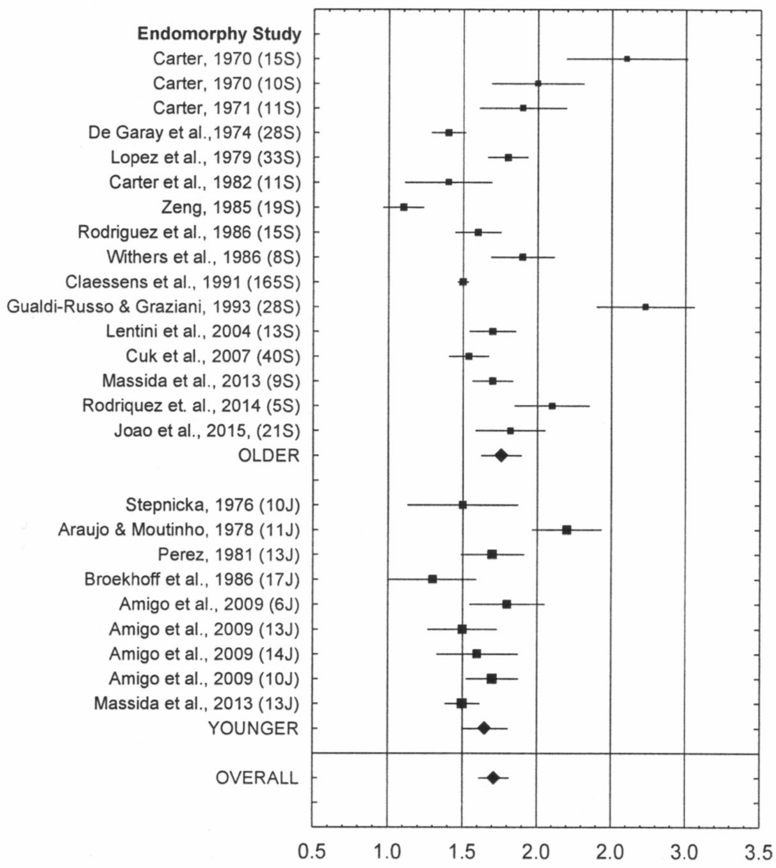
Fig. 7. Forest plot for the ectomorphy component.


Identification
Screening
Eligibility
Included
Records identified through database searching (n =1470)
Additional records identified through other sources (n =21)
Records screened (n =1491)
Non relevant studies excluded (n =1440)
Full-text articles assessed for eligibility (n =51)
Full-text articles excluded (n = 32)
• Only data on female athletes
• No information on athlete's age
• No SD for means of somatotype components
Studies of 25 individual samples included in review (n =19)
16 individual samples over 18 years of age (431 athletes)
9 individual samples ≤ 18 years of age (107 athletes)

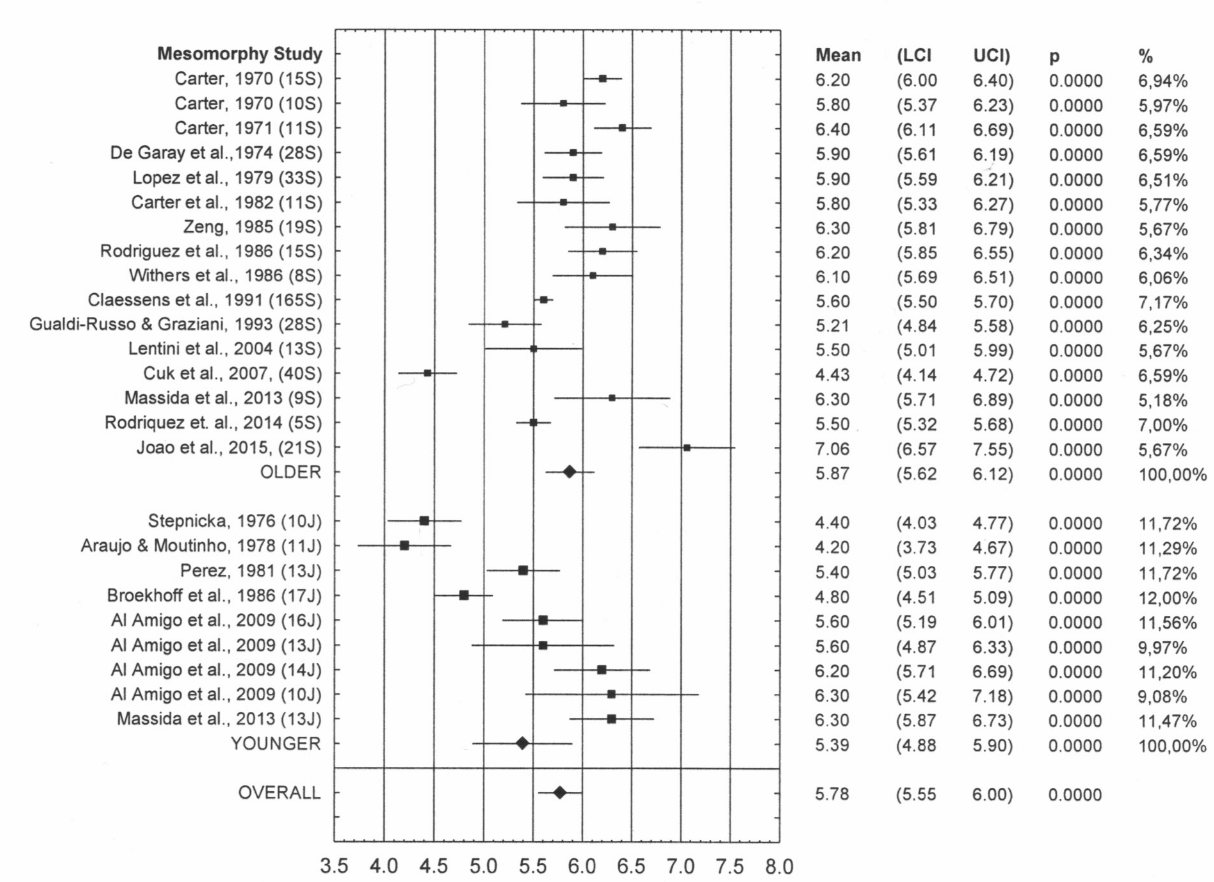

16
14
3
7
8
1
4
12,9,10
6
15
2
5
11
13

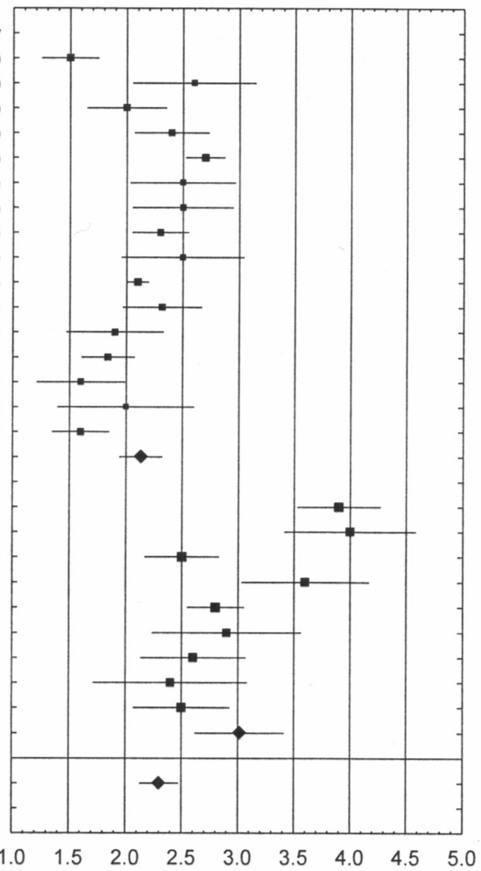

24, 25
23
19, 21
22
20
17
18


from 1993
before 1993



Endomorphy Study	Mean	(LCI	UCI)	p	%
Carter, 1970 (15S)	2.60	(2.19	3.01)	0.0000	4.44%
Carter, 1970 (10S)	2.00	(1.69	2.31)	0.0000	5.34%
Carter, 1971 (11S)	1.90	(1.61	2.19)	0.0000	5.53%
De Garay et al.,1974 (28S)	1.40	(1.28	1.52)	0.0000	7.06%
Lopez et al., 1979 (33S)	1.80	(1.66	1.94)	0.0000	6.92%
Carter et al., 1982 (11S)	1.40	(1.11	1.69)	0.0000	5.53%
Zeng, 1985 (19S)	1.10	(0.96	1.24)	0.0000	6.92%
Rodriguez et al., 1986 (15S)	1.60	(1.44	1.76)	0.0000	6.78%
Withers et al., 1986 (8S)	1.90	(1.68	2.12)	0.0000	6.28%
Claessens et al., 1991 (165S)	1.50	(1.46	1.54)	0.0000	7.40%
Gualdi-Russo & Graziani, 1993 (28S)	2.73	(2.40	3.06)	0.0000	5.16%
Lentini et al., 2004 (13S)	1.70	(1.54	1.86)	0.0000	6.78%
Cuk et al., 2007 (40S)	1.54	(1.40	1.68)	0.0000	6.92%
Massida et al., 2013 (9S)	1.70	(1.56	1.84)	0.0000	6.92%
Rodriquez et. al., 2014 (5S)	2.10	(1.85	2.35)	0.0000	5.91%
Joao et al., 2015, (21S)	1.82	(1.58	2.06)	0.0000	6.10%
OLDER	1.76	(1.62	1.89)	0.0000	100.00%
Stepnicka, 1976 (10J)	1.50	(1.13	1.87)	0.0000	8.19%
Araujo & Moutinho, 1978 (11J)	2.20	(1.96	2.44)	0.0000	11.27%
Perez, 1981 (13J)	1.70	(1.48	1.92)	0.0000	11.74%
Broekhoff et al., 1986 (17J)	1.30	(1.01	1.59)	0.0000	9.88%
Amigo et al., 2009 (6J)	1.80	(1.55	2.05)	0.0000	10.80%
Amigo et al., 2009 (13J)	1.50	(1.26	1.74)	0.0000	11.27%
Amigo et al., 2009 (14J)	1.60	(1.33	1.87)	0.0000	10.34%
Amigo et al., 2009 (10J)	1.70	(1.52	1.88)	0.0000	12.65%
Massida et al., 2013 (13J)	1.50	(1.38	1.62)	0.0000	13.87%
YOUNGER	1.65	(1.49	1.81)	0.0000	100.00%
OVERALL	1.71	(1.61	1.82)	0.0000	


Mesomorphy Study
Mean (LCI UCI) p %
Carter, 1970 (15S) 6.20 (6.00 6.40) 0.0000 6,94%
Carter, 1970 (10S) 5.80 (5.37 6.23) 0.0000 5,97%
Carter, 1971 (11S) 6.40 (6.11 6.69) 0.0000 6,59%
De Garay et al.,1974 (28S) 5.90 (5.61 6.19) 0.0000 6,59%
Lopez et al., 1979 (33S) 5.90 (5.59 6.21) 0.0000 6,51%
Carter et al., 1982 (11S) 5.80 (5.33 6.27) 0.0000 5,77%
Zeng, 1985 (19S) 6.30 (5.81 6.79) 0.0000 5,67%
Rodriguez et al., 1986 (15S) 6.20 (5.85 6.55) 0.0000 6,34%
Withers et al., 1986 (8S) 6.10 (5.69 6.51) 0.0000 6,06%
Claessens et al., 1991 (165S) 5.60 (5.50 5.70) 0.0000 7,17%
Gualdi-Russo & Graziani, 1993 (28S) 5.21 (4.84 5.58) 0.0000 6,25%
Lentini et al., 2004 (13S) 5.50 (5.01 5.99) 0.0000 5,67%
Cuk et al., 2007, (40S) 4.43 (4.14 4.72) 0.0000 6,59%
Massida et al., 2013 (9S) 6.30 (5.71 6.89) 0.0000 5,18%
Rodriquez et. al., 2014 (5S) 5.50 (5.32 5.68) 0.0000 7,00%
Joao et al., 2015, (21S) 7.06 (6.57 7.55) 0.0000 5,67%
OLDER 5.87 (5.62 6.12) 0.0000 100,00%
Stepnicka, 1976 (10J) 4.40 (4.03 4.77) 0.0000 11,72%
Araujo & Moutinho, 1978 (11J) 4.20 (3.73 4.67) 0.0000 11,29%
Perez, 1981 (13J) 5.40 (5.03 5.77) 0.0000 11,72%
Broekhoff et al., 1986 (17J) 4.80 (4.51 5.09) 0.0000 12,00%
Al Amigo et al., 2009 (16J) 5.60 (5.19 6.01) 0.0000 11,56%
Al Amigo et al., 2009 (13J) 5.60 (4.87 6.33) 0.0000 9,97%
Al Amigo et al., 2009 (14J) 6.20 (5.71 6.69) 0.0000 11,20%
Al Amigo et al., 2009 (10J) 6.30 (5.42 7.18) 0.0000 9,08%
Massida et al., 2013 (13J) 6.30 (5.87 6.73) 0.0000 11,47%
YOUNGER 5.39 (4.88 5.90) 0.0000 100,00%
OVERALL 5.78 (5.55 6.00) 0.0000
3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0



Ectomorphy Study	Mean	(LCI	UCI)	p	%
Carter, 1970 (15S)	1.50	(1.25	1.75)	0.0000	7.05%
Carter, 1970 (10S)	2.60	(2.05	3.15)	0.0000	4.88%
Carter, 1971 (11S)	2.00	(1.65	2.35)	0.0000	6.34%
De Garay et al.,1974 (28S)	2.40	(2.07	2.73)	0.0000	6.49%
Lopez et al., 1979 (33S)	2.70	(2.52	2.88)	0.0000	7.54%
Carter et al., 1982 (11S)	2.50	(2.03	2.97)	0.0000	5.45%
Zeng, 1985 (19S)	2.50	(2.05	2.95)	0.0000	5.59%
Rodriguez et al., 1986 (15S)	2.30	(2.05	2.55)	0.0000	7.05%
Withers et al., 1986 (8S)	2.50	(1.95	3.05)	0.0000	4.88%
Claessens et al., 1991 (165S)	2.10	(2.00	2.20)	0.0000	7.88%
Gualdi-Russo & Graziani, 1993 (28S)	2.32	(1.97	2.67)	0.0000	6.34%
Lentini et al., 2004 (13S)	1.90	(1.47	2.33)	0.0000	5.74%
Cuk et al., 2007 (40S)	1.84	(1.60	2.08)	0.0000	7.18%
Massida et al., 2013 (9S)	1.60	(1.21	1.99)	0.0000	6.04%
Rodriquez et. al., 2014 (5S)	2.00	(1.39	2.61)	0.0000	4.48%
Joao et al., 2015, (21S)	1.60	(1.35	1.85)	0.0000	7.05%
OLDER	2.13	(1.94	2.33)	0.0000	100.00%
Stepnicka, 1976 (10J)	3.90	(3.53	4.27)	0.0000	11.99%
Araujo & Moutinho, 1978 (11J)	4.00	(3.41	4.59)	0.0000	10.37%
Perez, 1981 (13J)	2.50	(2.17	2.83)	0.0000	12.24%
Broekhoff et al., 1986 (17J)	3.60	(3.03	4.17)	0.0000	10.52%
Al Amigo et al., 2009 (16J)	2.80	(2.55	3.05)	0.0000	12.69%
Al Amigo et al., 2009 (13J)	2.90	(2.23	3.57)	0.0000	9.74%
Al Amigo et al., 2009 (14J)	2.60	(2.13	3.07)	0.0000	11.28%
Al Amigo et al., 2009 (10J)	2.40	(1.71	3.09)	0.0000	9.59%
Massida et al., 2013 (13J)	2.50	(2.07	2.93)	0.0000	11.57%
YOUNGER	3.02	(2.62	3.42)	0.0000	100.00%
OVERALL	2.30	(2.13	2.47)	0.0000	