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# Morphofunctional Characteristics of Elite Male Artistic Gymnasts Assessed by Bioelectrical Impedance

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## Abstract

Artistic gymnastics requires a specific morphological profile characterized by high muscle mass and low body fat. Understanding body composition in elite gymnasts is essential for optimizing performance and guiding specialization. Therefore, the aim of the present study was to describe the body composition characteristics of current elite male artistic gymnasts competing at the international level, and to compare all-around gymnasts with upper-body and lower-body specialists, while also analyzing the variability of selected anthropometric and bioelectrical parameters. Thirty-one elite male artistic gymnasts were assessed using a multi-frequency bioelectrical impedance analyzer (InBody 770). Basic anthropometric data, whole-body and segmental composition, somatotype indices, and phase angle were evaluated. Athletes were divided into four subgroups: all-around, floor and vault specialists, pommel horse specialists, and ring specialists. Based on somatotype classification, the gymnasts demonstrated a homogeneous mesomorphic profile with high fat-free and skeletal muscle mass and low body fat percentage. Significant inter-group differences were observed in BMI, obesity degree, hip and thigh circumferences, and age ($p<0.05$). Floor and vault specialists had higher BMI (24.3 vs. 22.2 kg/m²) and larger thigh circumferences (52.4 vs. 49.0 cm) than pommel horse specialists, while ring specialists were older (28.0 vs. 20.0 years) than other groups. Segmental analysis provided additional insight into the distribution of fat-free and fat mass and phase angle in the limbs. Elite male artistic gymnasts exhibit a consistent mesomorphic body type with event-specific adaptations reflecting the biomechanical and functional demands of each apparatus. The inclusion of segmental analysis and non-parametric variability indices adds methodological value and enhances understanding of morphological characteristics in elite gymnastics. These results may serve as reference data for athlete monitoring, selection, and training optimization.

**Keywords:** *anthropometry, artistic gymnastics, body composition, InBody, phase angle, specialization*

## Introduction

Artistic gymnastics is a sport discipline characterized by high demands on strength, power, coordination, and precision, where success strongly depends on the athlete's morphological and body composition profile (Atikovic, 2020). Previous studies have consistently shown that gymnasts present specific anthropometric features, including short stature, low body fat percentage, and high relative muscle mass, which provide biomechanical advantages in performance and facilitate complex acrobatic movements (Bandara & Chandana, 2022; Sterkowicz-Przybycień et al., 2019). These characteristics distinguish gymnasts from athletes in other sports and have been linked to both performance potential and apparatus specialization.

Previous research has highlighted the relevance of morphological traits for gymnastics success. Atiković et al. (2017) analyzed finalists of the Rio 2016 Olympic Games and reported differences in basic anthropometric parameters such as body height, weight, and somatotype, not only between sexes but also across apparatus, suggesting their influence on apparatus-specific performance. In a longitudinal perspective, Atiković (2020) showed that the profiles of male Olympic gymnasts remained relatively stable between 1996 and 2016, whereas more pronounced changes were observed in female athletes. Similarly, Šibanc et al. (2017) documented

subtle shifts in top-level gymnasts between 2000 and 2015, including a tendency toward greater body height and fat-free mass, reflecting both technical evolution and changes in the Code of Points.

The relationship between anthropometry and performance outcomes has also been studied. Jovanović et al. (2024) demonstrated that parameters such as BMI, basal metabolic rate, and fat percentage significantly influence the D- and E-scores on specific apparatus, underlining the direct impact of body composition on competition results. Evidence from acrobatic gymnastics further illustrates how body composition determines functional specialization: bases are characterized by greater body mass and fat-free mass, while flyers are lighter and leaner (Salas-Morillas et al., 2022). Although artistic and acrobatic gymnastics differ, these findings support the general notion that morphological profiles are closely related to performance roles, whether between bases and flyers in acrobatics or between apparatus specialists in artistic gymnastics.

Beyond descriptive anthropometry, recent research has focused on somatotype and body composition indices as predictors of performance. González-Macías & Flores (2024) confirmed strong associations between somatotype, anthropometric parameters, and flexibility in gymnasts, while Martínez-Mireles et al. (2025) identified artistic gymnasts among the most mesomorphic athletes across elite sports. Sterkowicz-Przybycień et al. (2019) further noted that specialization influences morphological features, with floor and vault specialists showing higher mesomorphy and superior jumping ability compared to other apparatus specialists. This highlights the importance of considering intra-sport variability in body composition.

Body composition in elite athletes is now routinely assessed using modern methods such as bioelectrical impedance analysis (BIA), which is non-invasive, accessible, and validated against reference techniques such as DXA (Campa et al., 2022; Giovanelli et al., 2024). Specific indices derived from BIA, including fat-free mass index (FFMI) and fat mass index (FMI), have been proposed as reliable markers of training status and health in athletes (Giovanelli et al., 2024). Importantly, the International Olympic Committee has emphasized the need for responsible use of body composition data to avoid health risks such as Relative Energy Deficiency in Sport (RED-S) (Mathisen et al., 2023).

Among novel BIA-derived parameters, the phase angle (PhA) has attracted increasing attention as a marker of cellular integrity, hydration status, and training adaptation. PhA has been positively associated with muscle strength, particularly in the lower limbs (Cirillo et al., 2023), and suggested as a tool for monitoring overtraining and muscle damage (Annunziata et al., 2024). Recent work confirmed its validity as an indirect predictor of muscle and fat mass when compared with DXA (Rojano-Ortega et al., 2025), while studies in adolescent athletes revealed associations with maturation and training status (de Araújo Jerônimo et al., 2020). These findings position PhA as a promising integrative marker of performance and health in gymnasts.

Despite the wealth of evidence on gymnasts' morphology, current literature lacks systematic comparisons between all-around gymnasts and event specialists, particularly when considering the functional distinction between apparatus that predominantly load the upper body (e.g., rings, parallel bars) versus those emphasizing the lower limbs (e.g., floor exercise, vault). Addressing this gap may help clarify how specialization shapes body composition profiles within elite gymnastics.

Therefore, the aim of the present study was to describe the body composition characteristics of current elite male artistic gymnasts competing at the international level, and to compare all-around gymnasts with upper-body and lower-body specialists, while also analyzing the variability of selected anthropometric and bioelectrical parameters.

## Methods

### *Research sample*

A total of 31 elite male artistic gymnasts participated in the study. The athletes represented 17 different countries (Albania, Armenia, Australia, Azerbaijan, Bulgaria, China, Croatia, Czech Republic, Finland, Georgia, Greece, Iceland, Qatar, Serbia, Slovakia, Slovenia, and Turkey). Their mean age was 23.6±4.6 years (range: 17.5–36.0), body height 170.2±5.8 cm (range: 156.5–178.5), and body weight 67.3±5.9 kg (range: 52.0–78.8). All gymnasts were actively competing at the international level at the time of testing and had a minimum of several years of continuous elite-level training. All measurements were conducted during the competitive season in 2025.

Although the sample was relatively small, it represents a unique group of national-level elite athletes. Due to the limited number of participants, gymnasts were not divided according to all apparatus events but were classified into four main groups: all-around competitors (All-around; n=11), lower-body specialists – floor and vault (Spec leg; n=6), ring specialists (Spec arm ri; n=5), and pommel horse specialists (Spec arm ph; n=9).

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Masaryk University, Brno, Czech Republic. All participants were informed about the purpose and procedures of the study and provided written informed consent prior to participation.

### *Testing procedures and variables*

Body composition was assessed using a multi-frequency segmental bioelectrical impedance analyzer (InBody 770, InBody Co., Ltd., Seoul, Korea). The device also provided direct measurement of body weight. Body height was measured with a certified anthropometer (Seca, Germany), and the obtained value was entered into the InBody device prior to analysis. Measurements were performed under standardized laboratory conditions, with athletes barefoot and wearing light clothing, following the manufacturer's guidelines. From the full output of the InBody 770, a comprehensive set of variables was selected for further evaluation (see Table 1).

**Table 1.** Overview of analyzed variables

| Category | Variables |
|---|---|
| Basic anthropometric data | Body height, body weight, BMI |
| Whole-body composition | TBW, FFM, BFM, SMM, PBF, BMR, BCM |
| Indices and somatotype indicators | SMI, SMM/WT, FFMI, FMI, WHR, VFL, obesity degree |
| Overall indicators | InBody score, phase angle (50 kHz) |
| Circumference measurements | Hip, thigh, arm circumference |
| Segmental composition – arms | FFM, FFM%, TBW, BFM, BFM%, ECW/TBW, phase angle |
| Segmental composition – legs | FFM, FFM%, TBW, BFM, BFM%, ECW/TBW, phase angle |

*Note.* Abbreviations: TBW = total body water; FFM = fat-free mass; BFM = body fat mass; SMM = skeletal muscle mass; PBF = percent body fat; BMR = basal metabolic rate; BCM = body cell mass; SMI = skeletal muscle index; SMM/WT = skeletal muscle mass relative to body weight; FFMI = fat-free mass index; FMI = fat mass index; WHR = waist–hip ratio; VFL = visceral fat level; ECW/TBW = extracellular-to-total body water ratio.

### *Statistical analysis*

Descriptive statistics are presented as mean ± standard deviation (SD), including minimum and maximum values. The normality of the data distribution within each group (all-around, upper-body specialists, lower-body specialists) was tested using the Shapiro–Wilk test. Although some deviations from normality were observed in selected variables, a one-way analysis of variance (ANOVA) was applied to compare the three groups, as this method is considered robust to moderate violations of normality in balanced designs. Tukey's post-hoc test was used for pairwise comparisons when significant main effects were detected.

To ensure robustness of the findings, non-parametric Kruskal–Wallis tests with Dunn–Bonferroni post-hoc procedures were additionally performed for variables with markedly non-normal distributions. Effect sizes were calculated using partial eta-squared ($\eta^2$). As a non-parametric equivalent of the coefficient of variation, the coefficient of quartile variation (CQV) was calculated as $100\times(Q3-Q1)/(Q3+Q1)$. All statistical analyses were performed using Statistica 12 software (StatSoft, Inc., Tulsa, OK, USA). Statistical significance was set at $p<0.05$.

## Results

The descriptive statistics of anthropometric, body composition, and segmental parameters for the total sample of elite male artistic gymnasts (n=31) are presented in Table 2. The sample was relatively homogeneous in terms of body height and weight. Whole-body composition indicated high levels of fat-free and skeletal muscle mass together with low body fat percentage, reflecting the typical morphological profile of top-level gymnasts. Indices and somatotype indicators confirmed this trend, with elevated FFMI and SMI values and low FMI and obesity degree.

In addition to whole-body measures, selected circumference measurements and segmental parameters are presented. Circumferences of the hip, thigh, and arm reflected muscular development and corresponded with the functional demands of the sport. Segmental analysis further detailed the distribution of fat-free mass, body fat, water compartments, and phase angle in the upper and lower extremities, providing complementary information on body composition symmetry. Overall, the values demonstrate the mesomorphic, muscular profile characteristic of elite artistic gymnasts, with generally low variability across the group.

**Table 2.** Descriptive characteristics of elite male artistic gymnasts (n=31)

| Variable | Median | Min | Max | Q1 | Q3 | CQV (%) |
|---|---|---|---|---|---|---|
| Height (cm) | 171.20 | 156.50 | 178.50 | 167.20 | 175.00 | 2.28 |
| Weight (kg) | 67.80 | 52.00 | 78.80 | 61.90 | 70.80 | 6.71 |
| BMI ($kg\cdot m^{-2}$) | 23.30 | 20.70 | 27.50 | 22.00 | 24.00 | 4.35 |
| TBW (L) | 46.00 | 34.40 | 52.00 | 41.30 | 48.10 | 7.61 |
| FFM (kg) | 62.60 | 46.70 | 71.00 | 56.20 | 65.60 | 7.72 |
| BFM (kg) | 5.30 | 2.60 | 12.60 | 3.80 | 6.20 | 24.00 |
| SMM (kg) | 35.90 | 26.40 | 41.00 | 32.30 | 37.90 | 7.98 |
| PBF (%) | 7.90 | 3.80 | 16.20 | 6.10 | 10.30 | 25.61 |
| BMR (kcal/day) | 1723.00 | 1379.00 | 1904.00 | 1584.00 | 1787.00 | 6.02 |

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**Table 2.** Descriptive characteristics of elite male artistic gymnasts (n=31)

| Variable | Median | Min | Max | Q1 | Q3 | CQV (%) |
|---|---|---|---|---|---|---|
| BCM (kg) | 41.60 | 31.20 | 47.20 | 37.60 | 43.80 | 7.62 |
| SMI (kg·m⁻²) | 8.80 | 7.40 | 9.50 | 8.30 | 9.00 | 4.05 |
| SMM/WT (%) | 53.10 | 48.20 | 55.50 | 50.70 | 53.80 | 2.97 |
| FFMI (kg·m⁻²) | 21.40 | 18.50 | 23.60 | 20.40 | 22.00 | 3.77 |
| FMI (kg·m⁻²) | 1.90 | 0.80 | 4.30 | 1.30 | 2.10 | 23.53 |
| WHR | 0.81 | 0.75 | 0.91 | 0.79 | 0.85 | 3.66 |
| VFL | 1.00 | 1.00 | 5.00 | 1.00 | 2.00 | 33.33 |
| Obesity degree (%) | 106.00 | 94.00 | 125.00 | 100.00 | 109.00 | 4.31 |
| InBody Score | 88.00 | 76.00 | 93.00 | 84.00 | 90.00 | 3.45 |
| Phase Angle (°) | 7.00 | 6.20 | 8.20 | 6.90 | 7.40 | 3.50 |

*Note.* Abbreviations: BMI = body mass index; TBW = total body water; FFM = fat-free mass; BFM = body fat mass; SMM = skeletal muscle mass; PBF = percent body fat; BMR = basal metabolic rate; BCM = body cell mass; SMI = skeletal muscle index; SMM/WT = skeletal muscle mass relative to body weight; FFMI = fat-free mass index; FMI = fat mass index; WHR = waist–hip ratio; VFL = visceral fat level; CQV = coefficient of quartile variation.

Differences in body composition and anthropometric indicators between all-around gymnasts and apparatus specialists are presented in Table 3. Statistically significant differences were observed in age, BMI, obesity degree, and selected circumferences (hip, right and left thigh). Post-hoc analysis revealed that specialists on floor and vault (spec leg) had significantly higher BMI, obesity degree, and larger hip and thigh circumferences compared to pommel horse specialists (spec arm ph) (all $p<0.05$). In addition, ring specialists (spec arm ri) were significantly older than pommel horse specialists ($p<0.05$). No other body composition or somatotype parameters differed significantly between groups.

**Table 3.** Group comparisons of anthropometric and body composition parameters in elite male artistic gymnasts

| Variable | All-around (n=11) | Spec leg (n=6) | Spec arm ri (n=5) | Spec arm ph (n=9) | H | p-value | Post-hoc (p<0.05) |
|---|---|---|---|---|---|---|---|
| Age (years) | 21.0 (20.0–25.0) | 23.0 (22.0–26.0) | 28.0 (26.0–34.0) | 20.0 (20.0–22.0) | 10.036 | 0.018 | spec arm ri > spec arm ph (p=0.016) |
| BMI (kg/m²) | 23.3 (22.0–24.1) | 24.3 (23.8–24.5) | 23.3 (23.3–23.6) | 22.2 (21.7–22.9) | 12.215 | 0.006 | spec leg > spec arm ph (p=0.003) |
| Obesity degree (%) | 107.0 (100.0–111.0) | 110.0 (108.0–112.0) | 106.0 (106.0–107.0) | 101.0 (99.0–104.0) | 11.224 | 0.011 | spec leg > spec arm ph (p=0.006) |
| Hip circumference (cm) | 95.1 (93.2–96.4) | 97.6 (96.5–98.8) | 93.2 (92.2–95.9) | 92.9 (92.0–94.8) | 9.893 | 0.020 | spec leg > spec arm ph (p=0.013) |
| Thigh circumference (cm) | 50.7 (48.8–51.3) | 52.4 (51.9–53.6) | 48.7 (48.4–51.2) | 49.0 (47.9–50.4) | 22.695 | 0.000 | spec leg > spec arm ph (p=0.000); spec leg > spec arm ri (p=0.002); spec leg > all (p=0.004) |
| FFM% arm | 128.2 (124.0–130.2) | 123.4 (119.2–126.9) | 133.4 (123.5–136.1) | 121.8 (110.0–127.1) | 14.254 | 0.003 | all > spec arm ph (p=0.029); spec arm ri > spec arm ph (p=0.010) |
| FFM leg (kg) | 9.1 (7.6–9.3) | 9.6 (9.2–10.0) | 7.9 (7.4–8.2) | 8.3 (7.9–9.3) | 15.428 | 0.002 | spec leg > spec arm ph (p=0.044); spec leg > spec arm ri (p=0.001) |
| FFM% leg | 104.0 (99.0–106.1) | 106.7 (103.6–110.9) | 97.6 (96.8–100.8) | 99.2 (97.8–103.3) | 14.499 | 0.002 | spec leg > spec arm ph (p=0.013); spec leg > spec arm ri (p=0.003) |

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**Table 3.** Group comparisons of anthropometric and body composition parameters in elite male artistic gymnasts

| Variable | All-around (n=11) | Spec leg (n=6) | Spec arm ri (n=5) | Spec arm ph (n=9) | H | p-value | Post-hoc (p<0.05) |
|---|---|---|---|---|---|---|---|
| TBW leg (L) | 7.0 (5.9–7.2) | 7.5 (7.1–7.8) | 6.1 (5.7–6.4) | 6.5 (6.1–7.2) | 15.381 | 0.002 | spec leg > spec arm ph (p=0.048); spec leg > spec arm ri (p=0.000) |
| ECW/TBW leg | 0.365 (0.360–0.367) | 0.367 (0.360–0.373) | 0.362 (0.357–0.364) | 0.367 (0.364–0.371) | 15.382 | 0.037 | spec arm ph > spec arm ri (p=0.048) |
| Arm phase angle (°) | 6.9 (6.6–7.1) | 6.65 (6.2–7.5) | 7.25 (6.9–7.6) | 6.70 (6.4–6.9) | 10.859 | 0.013 | spec arm ri > spec arm ph (p=0.009) |
| Leg phase angle (°) | 7.2 (6.8–7.5) | 7.3 (6.6–7.9) | 7.3 (7.1–7.9) | 6.8 (6.4–7.0) | 10.521 | 0.015 | spec arm ri > spec arm ph (p=0.020) |

*Note.* Values are presented as median (Q1–Q3); H = Kruskal–Wallis test statistic. Significance level p<0.05; Group abbreviations: spec leg = floor and vault specialists; spec arm ri = rings specialists; spec arm ph = pommel horse specialists.

## Discussion

The analysis of anthropometric and body composition characteristics confirmed that elite male artistic gymnasts present a highly specific morphological profile, characterized by high levels of fat-free and skeletal muscle mass, low body fat percentage, and overall mesomorphic build. This reflects the well-documented requirements of the sport, where muscularity and leanness are essential for performance. This morphological specialization likely results from the high mechanical demands of repeated acyclic upper- and lower-body efforts characteristic of artistic gymnastics, where strength-to-mass efficiency is a key performance determinant. Despite the general homogeneity of the sample, significant differences emerged between subgroups of specialists. Leg event specialists (floor and vault) demonstrated higher BMI values and larger hip and thigh circumferences. These characteristics indicate greater lower-body muscle mass needed for explosive movements. In contrast, ring specialists were on average older than pommel horse specialists, suggesting that prolonged training experience may be advantageous in strength-dominant apparatus.

These morphological characteristics align with previous reports describing elite gymnasts as predominantly mesomorphic, with muscle mass clearly predominating over fat mass. According to Atiković et al. (2017), Olympic finalists exhibited uniform morphological characteristics, with muscle mass clearly predominating over fat mass. Similarly, a longitudinal study by Šibanc et al. (2017) revealed that although gymnasts grew taller between 2000 and 2015, their body fat remained low and muscularity high. Reviews further support this picture, highlighting mesomorphy as the predominant somatotype in artistic gymnasts (Bandara & Chandana, 2022) and confirming that gymnasts are among the most mesomorphic athletes across sports disciplines (Martínez-Mireles et al., 2025). Our results thus confirm previous evidence that elite gymnasts represent a relatively homogeneous group in terms of morphology, with low variability in fat-related indices and strong development of fat-free compartments. Importantly, the use of bioelectrical impedance analysis (BIA) with the InBody 770 device is supported by recent validation studies that have demonstrated good agreement with reference methods when using athlete-specific equations (Campa et al., 2022). In addition, Giovanelli et al. (2024) confirmed the relevance of FFMI and FMI as reference indicators in Olympic athletes, reinforcing the applicability of our results in the context of elite sports.

Differences between apparatus specialists reflected the distinct biomechanical and functional demands of individual events. Gymnasts specializing in floor exercise and vault (spec leg) showed higher BMI values together with larger hip and thigh circumferences, consistent with the need for greater lower-limb muscle mass to support explosive strength and jumping ability. This observation aligns with previous reports linking higher mesomorphic characteristics and enhanced leg power in floor and vault performers (Sterkowicz-Przybycień et al., 2019) as well as with the association between anthropometric profiles and apparatus-specific performance outcomes (Jovanović et al., 2024). In contrast, pommel horse specialists (spec arm ph) displayed lower BMI and slimmer profiles, which may represent a biomechanical advantage in supporting movements and continuous circular actions that require optimal strength-to-mass ratio of the upper body. Finally, ring specialists (spec arm ri) were on average older than other subgroups, suggesting that success in this apparatus is facilitated by prolonged specialization, technical maturity, and long-term strength development. Such patterns resonate with the idea that ring routines, which emphasize maximal static and dynamic strength, demand extended training histories and may allow longer competitive longevity compared to other events.

Beyond whole-body assessments, this study also incorporated segmental body composition analysis, providing insight into fat-free mass, body fat mass, and phase angle separately for the arms and legs. Such an approach is relatively novel in gymnastics research and offers a more nuanced perspective on muscular development and symmetry than traditional global measurements. These data may help to identify discipline-specific adaptations or potential asymmetries relevant to performance and injury prevention. In addition, we applied the coefficient of quartile variation (CQV) as a non-parametric indicator of variability. Unlike the conventional coefficient

of variation, which relies on mean and standard deviation and assumes normality, CQV provides a robust measure of relative dispersion based on quartiles. Its use allowed for more accurate comparisons of variability across parameters with different scales and distributions, thereby complementing the descriptive analysis of this elite athlete cohort.

The CQV observed in the present study was generally very low across most morphological and body-composition parameters (CQV≈2–8%), indicating a high degree of morphological uniformity within the group. This pattern is consistent with long-term sport-specific adaptation and selection typical of elite-level gymnasts and aligns with evidence that morphological differences tend to diminish with training age and specialization (Čaušević et al., 2023). By contrast, fat-related indices showed higher variability, with CQV for body fat mass ≈24%, percentage body fat ≈25.6%, and fat mass index ≈23.5%, suggesting greater inter-individual differences in adiposity. Such variation likely reflects individual nutritional management, recovery strategies, or minor differences in competitive phase at the time of testing. Extremely low CQV in hydration-related indicators (ECW/TBW ≈1%) further confirms stable fluid balance and consistent cellular integrity across athletes. Taken together, the CQV outcomes underline the exceptional morphological consistency of elite gymnasts while highlighting small but meaningful variations in fat-related parameters that may reflect personal or seasonal modulation of body composition.

From a practical perspective, the findings of this study can support coaches and sport scientists in the monitoring and optimization of training in elite gymnastics. Regular assessment of body composition enables the tracking of muscle mass development and the early detection of unfavorable changes in fat-related indicators. In particular, phase angle has recently been emphasized as a sensitive marker of cellular integrity, recovery status, and overall adaptation to training load (Annunziata et al., 2024; Cirillo et al., 2023). Regular monitoring of phase angle may help coaches to detect early signs of maladaptation or insufficient recovery before performance decline becomes apparent. Moreover, new prediction models confirm its value in estimating muscle and fat compartments against reference methods (Rojano-Ortega et al., 2025). Integrating such measures into athlete monitoring systems may therefore provide actionable information for both performance enhancement and health protection. In addition, morphological profiling may assist in the identification of apparatus-specific predispositions, supporting decisions about specialization and long-term development pathways in male artistic gymnasts.

In summary, the present study confirmed that elite male artistic gymnasts exhibit a highly consistent mesomorphic body profile with high levels of muscle mass and low body fat. Beyond these global characteristics, meaningful differences were identified between apparatus specialists, reflecting the specific biomechanical and functional demands of individual events. The inclusion of segmental body composition analysis and the application of the CQV provided additional methodological value, offering a more nuanced view of morphological variability. The generally low CQV values across most parameters further indicate stable long-term morphological adaptation within this elite population, with only limited inter-individual dispersion despite apparatus-specific demands. Overall, these findings integrate methodological innovation with practical relevance, reinforcing the importance of comprehensive morphological profiling in elite artistic gymnastics.

Future research should expand to longitudinal designs, include female gymnasts, and further explore the role of bioelectrical phase angle as a marker of adaptation and health status.

This study has several limitations that should be acknowledged. First, the relatively small sample size and uneven distribution among apparatus-specialized subgroups may limit the generalizability of the findings. However, such constraints are typical in elite athlete research, as access to international-level gymnasts is inherently limited. In this context, the value of the present study lies in the detailed characterization of a unique, hard-to-access population rather than in sample size.

Second, the study focused exclusively on male gymnasts and employed a cross-sectional design, which precludes conclusions about longitudinal adaptations or sex-related differences. Future investigations should therefore aim to include female athletes and adopt longitudinal monitoring across competitive seasons to capture dynamic changes in body composition and performance.

## Conclusion

Elite male artistic gymnasts display a consistent mesomorphic profile with apparatus-specific differences reflecting functional demands. Segmental composition and CQV add methodological value beyond whole-body metrics, and the results can inform monitoring, specialization, and training optimization. Future studies should validate these findings in larger, more diverse, and longitudinal samples.

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**Conflict of interest**
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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