RESEARCH ARTICLE

INTERNATIONAL JOURNAL OF KINANTHROPOMETRY

DOI: 10.34256/ijk25113

Anthropometrical and Physiological characteristics of Indian National Artistic Gymnasts: A Gender-Based Perspective

Riya Ghosh [1], Shreya Sinha [1,*], Snehunsu Adhikari [1]

[1] Sports Authority of India, Netaji Subhas Eastern Centre, Kolkata, India
* Corresponding author email: shreyasinha256@gmail.com
DOI: https://doi.org/10.34256/ijk25113
Received: 20-12-2024; Revised: 02-04-2025, Accepted: 10-04-2025; Published: 19-04-2025

Abstract

Introduction: Artistic gymnastics is a type of sport in which physiological and anthropometric characteristics play a substantial role in performance which differ by gender. Severa studies are carried out on these aspects internationally, but very limited studies were concentrated on Indian gymnasts. Therefore, the aim of our study is to assess and compare the anthropometric and physiological characteristics of national-level male and female artistic gymnasts. **Methods:** The study was carried out among 38 gymnasts (20 males and 18 females). Anthropometric parameters such as height, weight etc. were measured according to standard protocols followed by ISAK manual. Physiological assessments included flexibility (sit-and-reach test), VO_{2max} (treadmill test with gas analyzer), and anaerobic power (Wingate Anaerobic Test). Results: Male gymnasts had significantly higher values in height ($p = 0.005$), weight ($p = 0.037$), lean mass ($p = 0.009$), VO_{2max} ($p < 0.001$), and maximum power ($p = 0.006$) compared to female gymnasts. Female gymnasts had higher body fat percentage ($p = 0.006$). Flexibility and BMI showed no significant gender difference. Effect size analysis indicated large differences in strength and aerobic/anaerobic capacities, with males outperforming females. **Conclusions:** The study highlights clear gender-based differences in the anthropometric and physiological profiles of Indian artistic gymnasts.

Keywords: Anthropometric characteristics, Artistic Gymnastics, Gender, Physiological profile

Resumen

Introducción: La gimnasia artística es un tipo de deporte en el que las características fisiológicas y antropométricas juegan un papel sustancial en el rendimiento, que difiere según el género. Se han realizado varios estudios sobre estos aspectos a nivel internacional, pero muy pocos se han centrado en gimnastas indios. Por lo tanto, el objetivo de nuestro estudio es evaluar y comparar las características antropométricas y fisiológicas de gimnastas artísticos masculinos y femeninos a nivel nacional. **Métodos:** El estudio se llevó a cabo entre 38 gimnastas (20 hombres y 18 mujeres). Los parámetros antropométricos como la altura, el peso, etc. se midieron de acuerdo con protocolos estándar seguidos por el manual ISAK. Las evaluaciones fisiológicas incluyeron flexibilidad (prueba de sentarse y alcanzar), VO_2max (prueba en cinta rodante con analizador de gases) y potencia anaeróbica (prueba anaeróbica de Wingate). **Resultados:** Los gimnastas masculinos presentaron valores significativamente mayores de altura ($p = 0,005$), peso ($p = 0,037$), masa magra ($p = 0,009$), $VO_2máx$ ($p < 0,001$) y potencia máxima ($p = 0,006$) en comparación con las gimnastas femeninas. Las gimnastas femeninas presentaron un mayor porcentaje de grasa corporal ($p = 0,006$). La flexibilidad y el IMC no mostraron diferencias significativas entre los sexos. El análisis del tamaño del efecto indicó grandes diferencias en fuerza y capacidad aeróbica/anaeróbica, con un rendimiento superior entre los hombres y las mujeres. **Conclusiones:** El estudio destaca claras diferencias de género en los perfiles antropométricos y fisiológicos de las gimnastas artísticas indias.

Palabras Clave: Características antropométricas, Gimnasia artística, Género, Perfil fisiológico

Introduction

Elite athletes require different physiological and anthropometrical characteristics depending on various sports. The most crucial impact of sports performance, which focuses on the athlete's abilities, is the selection time for the particular sport (Arazi et al.,2011). Previous research indicates that gymnastics performance may depend on various anthropometric and physiological factors (Cagno et al., 2009).

Artistic gymnastics is a type of sport that uses both energy system anaerobic and aerobic, with a stronger contribution of anaerobic factors than aerobic because of their explosive sprinting, jumping, balance, artistic ability, and pushing and pulling capacity. In artistic gymnastics performed four events- uneven bar, the floor, the balance beam, the vault for women and five for men- parallel bar, horse, the high bar, vault, and floor. These sports also demand flexibility and strength with a combination of dynamic body movement and precision. The duration of a gymnastics performance is less than 90 seconds for both genders (male and female); its intensity is not maximal and can be used as a mix of static and dynamic exercises (Bradshaw, E. J. 2010).

The anthropometric profile helps to develop a better knowledge of the total activity of the human body to the measurements of height, weight, and body composition (Claessens et al.,1991, Muqarram, M., 2015, Chamorro et al., 2012). It helps to identify the young talent which is evident by the study carried out by Bradshaw & Rossignol (2004). Gymnasts usually have lesser skin fold thickness and body mass index (BMI). Gymnasts also have less body fat than athletes in other sports. According to previous research, gymnasts have normal fat-free mass (Taaffe et al., 1997).

Åstrand & Rodahl (1976) and Goswami & Gupta (1998) states that gymnastics performance is maximal effort and short duration, high-intensity anaerobic sports. According to the nature of the exercise and the short duration of the performance, previous research suggests that physiological data during authentic gymnastics performance demand elevated (179 bpm) heart rate (Jemmi et al., 2000, Viana & Lebre, 2005). In gymnastic competitions, the most essential qualities necessary to achieve success are improved anaerobic capacity, strength, explosive power, flexibility, balance, and endurance. Previous research carried out by Claessens et al., (1999) and Russell, K. (1987) indicates that anthropometrical and physiological features of gymnastics can be evaluated for talent identification. To measure the level of aerobic endurance, the anaerobic threshold (lactate) can be used (Allen et al., 1985). Anthropometric and physiological features have an impact on performance at national-level gymnastic competitions, which often vary on gender. This article aims to observe the anthropometric and physiological profiles of national-level artistic gymnasts, showing the variations due to gender and their inference on sport.

Materials and Methods

Participants

A cross-sectional study was conducted on total 38 national-level artistic gymnasts out of which male gymnasts (n=20) and female gymnasts (n=18) to assess gender-based differences in anthropometrical and physiological variables. All the athletes belonged to the National Centre of Excellence of Sports Authority of India (SAI), Kolkata. The inclusion criteria were gymnasts in the age group 10-20 year, with a minimum of 5 years of training experience within the standard body mass index for male and female gymnasts (19.8±3.2 kg/m², 18.6±2.6 kg/m²) respectively. All the subjects were informed of the purposes, procedure, risk and benefits of the tests prior taking the assessments and written consent was obtained.

Procedures

Height was measured in cm using a stadiometer (Seca Leicester, UK). The gymnasts were asked to remove their shoes and stand upright. Body mass was measured in kg using an electronic weight scale (Seca 770 UK). The subjects were asked to remove their shoes and metallic ornaments and wear only training shorts. The harpenden skinfold caliper (UK) was used to measure the percentage of body fat in the biceps, triceps, subscapular, and suprailiac sites. Body fat percentage and lean body mass were determined utilizing the method given by (Ávila-Carvalho et al., 2012). Body mass in kg / (height in meters)^2 was the formula utilized to compute the BMI (Slaughter et al., 1988). Flexibility was measured in cm using a standard sit-and-reach box (cranlea, UK). The gymnasts were asked to remove their shoes sit on the floor in front of the box and extend their legs. The other side asked to stretch their hand placed one hand over the others, and reached slowly forward until they could stretch no further and hold for 30 seconds (Nieman, D. C. 1990). Upper body strength and right and left-hand grip strength in kg were tested by using a Jamar hydraulic dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, USA). The subject was instructed to stand with back straight and arm at a 90-degree angle respecting to body (Koley et al.,

2012). The participants were asked to grip the dynamometer handle as hard as they could, apply maximum grip strength, and hold for 30 seconds (España-Romero et al., 2010). Back and leg strength in kg were tested by using a back, leg, and chest dynamometer. The participant was told to place their feet on the dynamometer platform, adjust the handle to the appropriate height for each, and be instructed to keep their knee straight not locked and their backs bent. Grasp the handle with both hands raise the upper body without bending the knees pull up gently and hold 2s (Sener et al., 2016).

The gymnasts were instructed to perform a short continuous incremental treadmill test with a metabolic gas analyzer (Germany and K5 Cosmed) for the determination of VO2 max. The Subjects were instructed to follow a 5-minute warm-up then treadmill velocity was increased by 1km/h every 2 min until volitional fatigue (Hill & Rowell, 1996).

Anaerobic power [Wingate anaerobic test (WAnT)] in watts was measured by using a cycle ergometer (Monark 894E, Sweden). The seat was adjusted according to their height to allow for complete knee extension with the ankle flexed at 90 degrees. For 5min, the participants warmed up at a pedalling pace of 50–60 rpm with a 1 kg resistance. End of the warmed-up last 3 to 4 minutes, two unloaded 5-second sprints were performed. During the sprints, the maximum pedalling rate (LFmax) was recorded. Against the resistance of 0.075 kg per kg body mass, after 2 min rest gymnasts performed 6-sec WAnT. Throughout the test, participants were instructed to boost the pedal frequency until they reached 80-100 revolutions per minute and then move forward as much as they could while resistance was applied. Throughout the second interval, the individuals were verbally urged to keep their pedalling rate as high as possible. The highest figure recorded during the initial 5-second testing session was the subjects' peak power (PP). The exam lasts for six seconds. Recorded at 1 pedal rotation were tracked at a resolution of 0.025 revolutions (Inbar et al., 1996).

Statistical Analysis

To assess the differences between male and female artistic gymnasts regarding anthropometrical and physiological variables, univariate analysis of variance (ANOVA) was performed where effect sizes (Cohen's d) were computed to interpret the magnitude of differences between male and female gymnasts. All data was presented as means ± standard deviation (SD). The Statistical Program for the Social Sciences (SPSS) version 25.0 for Windows (SPSS Inc., Chicago, II, USA) was used for data analysis. The value of $p< 0.05$ was considered to be statistically significant.

Results

Our current study involved gymnastics players from the Sports Authority of India (SAI), National Centre of Excellence (NCoE), Kolkata. The players represented all events of artistic gymnastics. Among the 38 gymnasts surveyed, 18 (47%) were female gymnast and, 20 (53%) were male gymnasts. These findings are summarized in Figure 1. Physical parameters of Indian gymnasts on the basis of gender are depicted in Table 1. It has been observed that male gymnasts had significantly higher height, weight, lean mass, grip strength, back and leg strength, aerobic capacity, and power output ($p < 0.05$). (Table 2)

Table 3 represents the comparative analysis of anthropometric parameters between male and female gymnasts. It was observed that male gymnasts were significantly taller than female counterparts with a large effect size (Cohen's d = 1.10). In case of body fat %, fat mass, females had significantly higher values compared to males. In contrast, lean mass was significantly greater in female gymnasts than in males.

Table 1. Representation of Physical Parameters of gymnasts according to Gender (n=38)

Physical Parameters	Gender	Mean	Minimum	Maximum
Age (year)	Female(n=18)	15.1±3.8	11	18
	Male(n=20)	16.3±3.2	11	20
Height (cm)	Female(n=18)	149.5±6.9	137	160
	Male(n=20)	158.8±9.6	145	181
Weight (kg)	Female(n=18)	42.0±8.4	27.1	55.9
	Male(n=20)	50.5±12.4	32.4	76.7

Values are shown in (mean ± standard deviation)

Table 4 represents the comparative analysis of physiological parameters between male and female gymnasts. It has been found that male gymnasts have higher strength than their counterpart with a large effect size for hand grip strength (Cohen's d = 0.98–1.23), back (d = 1.32) and leg strength (d = 1.32) respectively.Similarly, maximum aerobic capacity (d = 1.47) and power output (d = 1.14–1.39) were significantly greater in males. On the other hand, flexibility showed minimal differences (d = -0.17), suggesting that both genders maintain similar levels.

Table 2. Univariate ANOVA Results for Anthropometric and Physiological Parameters by Gender (n=38)

Parameter	F-Value	p-Value
Height (cm)	8.91	0.005*
Weight (kg)	4.70	0.037*
BMI (kg/m²)	1.25	0.270
Body Fat (%)	6.45	0.016*
Fat Mass (kg)	1.93	0.173
Lean Mass (kg)	7.64	0.009*
Flexibility (cm)	0.19	0.668
Right Hand Grip Strength (kg)	6.45	0.016*
Left Hand Grip Strength (kg)	10.25	0.003*
Back Strength (kg)	11.81	0.002*
Leg Strength (kg)	11.83	0.001*
Maximum Aerobic Capacity (ml/kg/min)	14.84	0.000*
Max Power (Watt)	8.72	0.006*
Min Power (Watt)	13.52	0.001*
Fatigue Index	1.72	0.198

(*) denotes significant at $p < 0.05$

Table 3. Comparison of Anthropometric Parameters Between Male and Female Gymnasts with Effect Size (Cohen's d)

Anthropometrical Parameter	Mean Female	SD Female	n Female	Mean Male	SD Male	n Male	SD pooled	Cohen D
Height (cm)	149.5	6.9	18	158.8	9.6	20	8.4334	1.10276
Weight (kg)	42.0	8.4	18	50.5	12.4	20	10.6991	0.79446
BMI (kg/m²)	18.6	2.6	18	19.8	3.2	20	2.9320	0.40928
Body fat %	13.5	6.5	18	9.4	3.6	20	5.1760	-0.79211
Fat Mass (kg)	6.0	3.7	18	4.7	1.9	20	2.8931	-0.44935
Lean Mass (kg)	45.8	11.5	18	36	6.1	20	9.06035	-1.08164

Table 4. Comparison of Physiological Parameters Between Male and Female Gymnasts with Effect Size (Cohen's d) * n =Number of subjects

Physiological Parameter	Mean Female	SD Female	Number Female	Mean Male	SD Male	Number Male	SD pooled	Cohen D
Flexibility (cm)	42.7	3.6	18	42.0	4.6	20	4.158	-0.16836
Right Hand grip Strength (kg)	23.2	6.4	18	33.7	13.5	20	10.748	0.97688
Left Hand grip Strength (kg)	21.2	6.3	18	34.1	13.1	20	10.455	1.23382
Back Strength (kg)	71.8	16.5	18	107.6	33.9	20	27.113	1.32042
Leg Strength (kg)	68.7	18.8	18	109.2	38.4	20	30.743	1.31737
Maximum Aerobic Capacity (ml/kg/min)	40.7	1.7	18	45.0	3.7	20	2.931	1.46714
Max Power (watt)	272.6	75.1	18	426.0	171.0	20	134.522	1.14034
Min Power (watt)	137.8	51.4	18	241.4	90.3	20	74.506	1.39049
Fatigue Index	3.8	1.5	18	5.6	4.4	20	3.359	0.53594

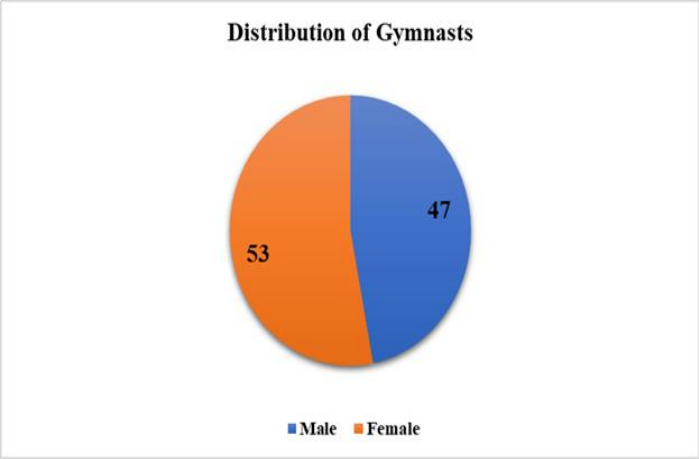

Figure 1. Distribution of gymnasts according to gender

Discussion

The present study focuses on the anthropometrical and physiological characteristics of national level gymnastic players in artistic gymnastics. Anthropometric characteristics, some physiological components such as flexibility, explosive strength, aerobic capacity, anaerobic power are important components for successful performance. Gymnastic is unique sports than other in such a way that smallest and lightest athletes are beneficial for competitive opportunities (Manna et al., 2017). In gymnastics, greater body weight is not an advantage in performing better (Arazi et al., 2013). It was observed in the present study that male artistic gymnasts have significantly higher height and body weight than females. This is consistent with previous studies carried out by Atiković, A. (2020) and Claessens et al., (1999), where elite male artistic gymnasts have generally been greater height and body mass compared to female gymnasts. Findings of our study are also consistent with the findings of other studies reported that female gymnasts are shorter and had lower body weight than their counterparts (Dallas et al., 2013 and Daly et al., 2005). The observed large effect size in height underscores the structural differences that are likely influenced by both gender and selection criteria in this sport. A gymnast's strength to weight ratio is very important in their performance. The body mass index of an individual is related to their body weight. There is insignificant difference was observed between male and female gymnasts which is similar to other research's finding as well (Manna et al., 2017). Regarding fat mass, it was observed from the study that there is significant difference observed in the values of body fat% and lean mass between two groups. In the present study it was observed that female gymnasts body fat percentage was higher than male gymnasts, whereas lean mass was notably greater in male gymnasts which is similar to their international male and female peers (João & Filho, 2015). This fat accumulation generally increases due to changes in female hormone levels (Manna et al., 2017). These findings consistent with previous studies where gender differences in fat distribution and lean body mass, often attributed to hormonal and developmental differences (Dallas et al., 2017).

It was observed primarily gymnasts have higher upper body strength to capable of move their bodies through different positions than many other sports. Strength is one of the important characteristics of gymnasts which has influence on speed and power as well and provide the endurance. (Arazi et al., 2013) Both hand grip strength was significantly higher in male gymnasts than counterparts in the present study which has been found similar with this study (Mass-Westropp et al., 2011). Male gymnasts have greater maximal strength and power, possibly due to greater muscle mass. The effect sizes in our study ranging from d = 0.98 to 1.47 further emphasize the substantial physiological performance gap between genders in strength-dependent activities. Flexibility is an important aspect of gymnastics performance. From the scientific evidence it was proved that chances of injury decrease due to having good predisposing factor i.e. flexibility which enhance the ability of movement through wider ROM (Brodie & Royce, 1998). In contrast, there is no significant difference was observed between male and female gymnasts (d = -0.17). This aligns other studies suggest that both genders in artistic gymnastics are trained intensively in flexibility to meet the sport's technical demands, leading to similar outcomes regardless of gender (Georgopoulos et al., 2001). Wingate test is frequently used test for the assessment of maximum power and anaerobic capacity (Inbar et al., 1996). There are limited studies on anaerobic abilities in gymnasts. The data from the present study showed there is significant difference in maximum power between groups.

Conclusions

In summary, this study revealed the gender-specific anthropometric and physiological characteristics in artistic gymnastics. Within the limitations of our study (small number of elite athletes and investigation of a complex and demanding sport), our results revealed that anthropometric characteristics, flexibility, explosive strength, aerobic capacity, body dimensions, and anaerobic metabolism are important factors and lead to better execution of gymnastic routines. While males demonstrated superior strength, power, and aerobic capacity, both genders showed comparable levels of flexibility and balance. Body composition and strength has an influence on balance performance by which an integrative nature of gymnastics training is noted. The aforementioned findings shall help the coaches, sports scientists, and paddlers with detailed insight into the anthropometry and physiology in Indian context.

References

Allen, W. K., Seals, D. R., Hurley, B. F., Hurley, E. F., Ehsani, A. A., Hagberg, J. M. (1985). Lactate threshold and distance running performance in young and older endurance athletes. *Journal of Applied Physiology,* 58: 1281–1284. 10.1152/jappl.1985.58.4.1281

Arazi, H., Faraji, H., Mehrtash, M. (2013). Anthropometric and physiological profile of Iranian junior elite gymnasts. *Physical Education and Sport,* 11(1): 35–41. https://doi.org/10.52165/sgj.12.2.187-193

Arazi, H., Faraji, H., Mohammadi, S.M. (2011). Anthropometric and physiological profiles of elite Iranian junior rowers. *Middle-East Journal of Scientific Research,* 9(2): 162–166.

Åstrand, P.O., Rodahl, K. (1976). Textbook of work physiology. *McGraw-Hill.*

Atiković, A. (2020). Anthropometric characteristics of Olympic female and male artistic gymnasts from 1996 to 2016. *International Journal of Morphology,* 38(4): 990–996. https://doi.org/10.4067/S0717-95022020000400990

Ávila-Carvalho, L., Klentrou, P., Palomero, M. D. L., & Lebre, E. (2012). Body composition profile of elite group rhythmic gymnasts. *Science of Gymnastics Journal,* 4(1): 21–32.

Bradshaw, E. J. (2010). Performance and health concepts in artistic gymnastics. *In Proceedings of the 28th International Symposium of Biomechanics in Sports Marquette, Michigan*, USA.

Bradshaw, E. J., & Rossignol, P. (2004). Anthropometric and biomechanical field measures of floor and vault ability in 8 to 14-year-old talent-selected gymnasts. *Sports Biomechanics,* 3(2): 249–262. 10.1080/14763140408522844

Brodie, D. A., Royce, J. (1998). Developing flexibility during childhood and adolescence Pediatric anaerobic performance. *Human Kinetics*.

Cagno, A.D., Baldari, C., Battaglia, C., Monteiro, M. D., Pappalardo, A., Piazza, M., Guidetti, L. (2009). Factors influencing the performance of competitive and amateur rhythmic gymnastics: Gender differences. *Journal of Science and Medicine in Sport,* 12: 411–416. 10.1016/j.jsams.2008.01.006

Chamorro, G.R., Belando, S.E., Lorenzo, G.M., Lafarga, B.C., Roche, E. (2012). Skinfolds sum: Reference values for top athletes. *International Journal of Morphology,* 30(3): 803–809. https://doi.org/10.4067/S0717-95022012000300005

Claessens, A. L., Lefevre, J., Beunen, G., Malina, R. M. (1999). The contribution of anthropometric characteristics to performance scores in elite female gymnasts. *The Journal of Sports Medicine and Physical Fitness,* 39, 355–360.

Claessens, A.L., Lefevre, J., Beunen, G., Stijnen, V., Maes, H., Veer, M. F. (1991). Gymnastic performance as related to anthropometric and somatotype characteristics in male gymnasts. *Anthropologiai Kozlemenyek,* 33: 243–247.

Dallas, G., Mavidis, S., Dallas, C., & Papouliakos, S. (2017). Gender differences of high-level gymnasts on postural stability: The effect of ankle sprain injuries. *Science of Gymnastics Journal,* 9(3): 291–301.https://doi.org/10.52165/sgj.9.3.291-301

Dallas, G., Zacharogiannis, E., & Paradisis, G. (2013). Physiological profile of elite Greek gymnasts. *Journal of Physical Education and Sport,* 13(1): 27.

Daly, R. M., Caine, D., Bass, S., Pieter, W., & Broekhoff, J. (2005). Growth of highly versus moderately competitive female artistic gymnasts. *Journal of the American College of Sports Medicine,* 37: 1053–1060.

España-Romero, V., Ortega, F. B., Vicente-Rodríguez, G., Artero, E.G., Rey, J. P., Ruiz, J. R. (2010). Elbow position affects handgrip strength in adolescents: Validity and reliability of Jamar, DynEx, and TKK dynamometers. *Journal of Strength and Conditioning Research,* 24(1): 272–277. https://doi.org/10.1519/JSC.0b013e3181b296a5

Georgopoulos, N.A., Markou, K.B., Theodoropoulou, A., Vagenakis, A.G., Benardot, D. (2001). Height, velocity and skeletal maturation in elite female rhythmic gymnasts. *Journal of Clinical Endocrinology & Metabolism,* 86(11): 5159–5164. https://doi.org/10.1210/jcem.86.11.8041

Goswami, A., & Gupta, S. (1998). Cardiovascular stress and lactate formation during gymnastic routines. *Journal of Sports Medicine and Physical Fitness,* 38: 317–322.

Hill, W., Rowell, A. L. (1996). Running velocity at VO_2max. *Medicine and Science in Sports and Exercise,* 28, 114–119. https://doi.org/10.1097/00005768-199601000-00022

Inbar, O., Bar-Or, O., Skinner, J.S. (1996). The Wingate anaerobic test. *Human Kinetics*.

Jemmi, M., Friemel, F.C., Lechevalier, J.M., Origas, M. (2000). Heart rate and blood lactate concentration analysis during a high-level men's gymnastics competition. *Journal of Strength and Conditioning Association,* 14(4): 389–394. https://doi.org/10.1519/00124278-200011000-00004

João, A.F., Filho, J.F. (2015). Somatotype and body composition of elite Brazilian gymnasts. *Science of Gymnastics Journal,* 7(2): 45–54. https://doi.org/10.52165/sgj.7.2.45-54

Koley, S., Kumaar, B. S., Shadagopan, S.P. (2012). Anthropometric, physical strength, body composition and performance test profiles of inter-district level male cricketers of Punjab, India. *The Anthropologist,* 14(5): 445–451.

Manna, T., Goswami, A., Karmakar Chatterjee, S., Dhingra, M., Dey, S. K. (2017). Comparison of various physical and body composition profiles between Indian elite male and female gymnasts. *Baltic Journal of Health and Physical Activity,* 9(2): 4.

Mass-Westropp, N.M., Gill, T.K., Taylor, A. W, Bohannon, R.W., Hill, C.L. (2011). Hand grip strength: Age and gender stratified normative data in a population-based study. *BMC Research Notes, 4:* 127–135. https://doi.org/10.1186/1756-0500-4-127

Muqarram, M. (2015). Comparative study on lower arm length of athletes at different levels of competition. *Journal of Physical Education Research,* 2(1): 40–46.

Nieman, D.C. (1990). Fitness and sport medicine: An introduction. *Bull Publishing Company*. 150–151.

Russell, K. (1987). Gymnastic talent from detection to perfection. In World identification systems for gymnastic talent. *Sport Psyche Editions*, 151–159.

Sener, U., Uçok, K., Ulasli, A. M., Genc, A., Karabacak, H., Coban, N.F., Simsek H., Akkurt, H.E. (2016). Evaluation of health-related physical fitness parameters and association analysis with depression, anxiety, and quality of life in patients with fibromyalgia. *International Journal of Rheumatic Diseases,* 19(8): 763–772. https://doi.org/10.1111/1756-185X.12237

Slaughter, M. H., Lohman, T. G., Boileau, R. A., Horswill, C. A., Stillman, R. J., Van Loan, M. D., & Bemben, D. A. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human Biology,* 60: 709–723.

Taaffe, D. R., Robinson, T. L., Snow, C. M., & Marcus, R. (1997). High-impact exercise promotes bone gain in well-trained female athletes. *Journal of Bone and Mineral Research,* 12, 255–260. https://doi.org/10.1359/jbmr.1997.12.2.255

Viana, J., Lebre, E. (2005). Heart rate analysis during men's and women's artistic gymnastics routines. *5th International Conference of the FRAGA. Association Française de Recherche en Activités Gymnastiques et Acrobatiques.*

Funding

There is no external funding to declare

DOI: 10.34256/ijk25113

Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Informed Consent Statement

All the athletes included in the study provided written informed consent.

About the License