Saša Jovanović [1,*]
Snežana Bijelić [1]
Kamenka Živčić [2]
Lucija Milčić [2]
Marijo Možnik [2]

SOME ANTHROPOMETRIC CHARACTERISTICS OF GYMNASTS AND THE INFLUENCE ON APPARATUS PERFORMANCE

NEKATERE ANTROPOMETRIČNE ZNAČILNOSTI TELOVADCEV IN VPLIV NA TEKMOVALNO USPEŠNOST

ABSTRACT

While rules and elite gymnasts have evolved, some anthropometric characteristics still differ from the general populations. This study aims to find the anthropometric factors affecting apparatus scores in men's and women's gymnastics. A total of 62 competitors, 25 female gymnasts and 37 male gymnasts, from 22 countries competed in the World Cup. Scores on the men's and women's all-around apparatus and the competitor's anthropometric characteristics formed the sample of variables. According to the results, the D-score in women's gymnastics is influenced by BMI ($p< 0.005$). The ideal lower BMR (kcal) and BMI levels are also on the floor ($p< 0.005$). In men's gymnastics, the variable FAT% should be lower for a higher D-score for floor ($p< 0.005$) and BMR (kcal) for pommel horse ($p< 0.005$).

Keywords: somatotype, artistic gymnastics, D-score, E-score

[1] ***University of Banja Luka, Faculty of physical education and sport, Banja Luka, Bosna and Herzegovina***

[2] ***University of Zagreb, Faculty of kinesiology, Zagreb, Croatia***

IZVLEČEK

Medtem ko so se pravila in vrhunski telovadci skozi leta razvijali, se nekatere antropometrične značilnosti še vedno razlikujejo od splošne populacije. Ta študija si prizadeva najti antropometrične dejavnike, ki vplivajo na ocene pri orodnih vajah v moški in ženski telovadbi. Skupaj je bilo vključenih 62 tekmovalcev, od tega 25 žensk in 37 moških, iz 22 držav, ki so nastopili na tekmovanju svetovnega pokala. Vzorec spremenljivk so predstavljale ocene v vseh disciplinah ter antropometrične značilnosti telovadcev obeh spolov. Rezultati so pokazali, da je D-ocena pri ženski telovadbi vplivala na BMI ($p < 0,005$). Idealen nižji BMR (kcal) in ravni ITM so tudi na parterju ($p < 0,005$). Pri moški telovadbi bi morala biti spremenljivka % podkožnega maščevja nižja za višjo D-oceno na parterju ($p < 0,005$) in BMR (kcal) za konja z ročaji ($p < 0,005$).

Ključne besede: somatotip, ritmična gimnastika, D-vrednost, E-vrednost

Corresponding author:* Saša Jovanović, Faculty of physical education and sport, University of Banja Luka, 78 000, Banja Luka, Bosnia and Herzegovina.

E-mail: sasa.jovanovic@ffvis.unibl.org

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INTRODUCTION

Gymnastics as an exercise system has roots far back in the human past. It first served as a means of developing the human body and exceeding the limits of its functional capabilities. The International Gymnastics Federation (FIG) was founded in 1881, and Artistic Gymnastics (AG) has been present as a sport since the first Olympic Games in 1896. Although there are several related disciplines today, competitive AG, which consists of the four women's disciplines (vault, uneven bars, balance beam, and floor exercise) and the six men's disciplines (floor exercise, pommel horse, rings, vault, parallel bars, and horizontal bar), is the best known of the gymnastics disciplines. Due to the high loads involved, it is one of the most demanding sports, and young gymnasts belong to a very select group in terms of their specific motor skills, size, and body shape (Baxter-Jones, Thompson, & Malina, 2002).

Research in various sports to determine an athlete's performance has shown that specific potentially successful models of the athlete increase their chances of better athletic performance (Claessens, Lefevre, Beunen, & Malina, 1999). These models are specific to each sport and vary even within the same sport, depending on the characteristics and requirements of the athlete in the position or role that he/she performs due to the specificity of each sport. Specific demands highlight the various factors that can positively impact an athlete's performance, whether motor or anthropometric factors (Claessens et al., 1999). A look at the factors that make up the anthropological model (anthropometric measures, somatotype, body composition) shows that research in gymnastics (Joao & Fernandes, 2002; Bester & Coetzee, 2010; Poliszczuk, Broda, & Poliszcuk, 2012; Massidda, Toselli, Brasili, & Calo, 2013) has contributed positively to the creation of gymnastics models (Baxter-Jones & Helms, 1996; Massidda et al., 2013). Data from previous studies show that female gymnasts tend to be smaller than their chronological peers and have body composition and weight consistent with their biological age. At the same time, their puberty occurs later (Malina, Baxter-Jones, Armstrong, Beunen, Caine et al., 2013). Although available research is not dominated by studies in which the sample consisted of elite gymnasts, authors have examined somatic factors (Claessens, Veer, Stijnen, Lefevre, Maes et al., 1991; Bester & Coetzee, 2010), somatotype (Thorland, Johnson, Fagot, Tharp, & Hammer, 1981; Claessens et al., 1991; Massidda et al., 2013), and body composition (Theintz, Howald, Allemann & Sizonenko, 1989; Deutz, Benardot, Martin, & Cody, 2000). Despite these studies, limiting factors such as representativeness and sample size, different age groups, and differences in the measurement instruments and testing protocols show that finding and creating models of elite gymnasts is still relevant.

At that time, it was stated that all athletes, including those in aesthetic sports, including gymnasts, should develop specific somatotypes very similar to those of athletes who have already achieved excellent results (Carter & Brallier, 1988). Regarding the somatotype of elite gymnasts, the distinct ecto-mesomorphic type is the most common (Araujo & Moutinho, 1978, Claessens, Beunen, Lefevre, Stijnen, Maes et al., 1990; Massidda et al., 2013). On the other hand, a positive correlation between mesomorphism and the level of motor performance (Bale, 1981) or a positive correlation between the anthropometric characteristics of the gymnast and the successful execution of elements on all apparatus has been demonstrated (Claessens et al., 1999). The study by Claessens et al. (1999) showed that 32% to 45% of the total differences in the results were explained by anthropometric personalities or some of the variables derived from them, provided that the results showed endomorphy and chronological age. The authors stated that a gymnast's technical abilities, which depend on anthropometric variables, are a significant predictor of both successful performance and final placement of a gymnast, regardless of his competition level (Claessens et al., 1999; Massidda & Calò, 2012).

However, despite many studies on different sports addressing this issue, successful models have yet to be established, mainly due to the significant differences in the specifics of each sport (Coutinho, Mesquita, & Fonseca, 2016). Such an insufficiently researched area offers many researchers and coaches the opportunity to contribute to the search for the optimal solution. Although the research was conducted on a sample of elite gymnasts, the results have yet to successfully lead to a definitive model due to the lack of a sufficiently reliable distinction between elite and non-elite gymnasts. This is precisely the need for more information that coaches should pay attention to in their work and training process to build a better model for performance in competition (Claessens et al., 1999).

This study aims to determine how anthropometric variables related to men's and women's gymnastics influence apparatus scores.

METHODS

Participants

A sample of 62 competitors from 22 nations (Ukraine, Romania, Croatia, Peru, China, Egypt, Slovakia, Israel, Norway, Slovenia, Vietnam, Italy, Russia, Chile, Lithuania, Turkey, Sweden, Kazakhstan, Bulgaria, Azerbaijan, Austria, Belgium) who was competing in the World Cup finals in Osijek in 2019 participated in this study.

There were 25 female gymnasts (age: 21.32± 4.8 years, height: 159.32 ± 5.2 cm, body mass: 53.42±5.8 kg) and 37 male gymnasts (age: 23.30± 4.1 years, height: 167.78 ± 5.2 cm, body mass: 66.08±5.3 kg). This study was conducted according to the guidelines laid out in the Declaration of Helsinki for research of human subjects, and the protocol was approved by the Ethics Committee of the Faculty of Sport and Physical Education at the University of Banja Luka (11/1.185-1/19).

Variables

The sample of variables consisted of scores on the women's and men's all-around apparatus: D – D-score, E – E-score, TOTAL – final score, and characteristics of the competitors: age – age (years), height (cm) – height, weight (kg) – weight, body composition: BMI (kg/m^2) – body mass index, BMR (Kj) – basal metabolism, BMR (kcal) – basal metabolism, FAT% - % fat, FAT MASS (kg) – fat mass, FFM (kg) – lean mass, TBW (kg) – total water in the body. D-score are difficulty values of the exercise, consisting of the values of each element in the exercise. E-score are execution of the exercise, and TOTAL-final sore is the count D-score and E-score.

Measuring instruments and description of the measurement protocol

Before any testing, the examinees were informed of the nature of the tests. They were asked to adhere to a pretest protocol which included a 12-hr fast, abstinence from alcohol for 24 hrs., and to maintain adequately hydrated. Adherence to these criteria was verbally confirmed with the subjects prior to participation. Each subject provided written informed consent following a full explanation of the study procedures. Body Composition Analyzer Tanita BC-418 MA was used for this research. All body parameters were measured by TANITA body analyzer BC-418MA III. Examinees were tested in sports equipment, barefoot. During the data collection they were standing on the bottom of body analyzer and held electrodes in both arms. Data input contains body height and age, and for the testing Athlete mode was selected. Also, data input contains weight equipment (0.300g). After signal the direct current goes through the body and analyzes necessary body parameters. Body height was taken from the official website of the organizers and federations. Due to the nature of the competition, the protocol was conducted in the gymnasium's auxiliary rooms, with a moderate temperature and no high humidity, during morning hours (8-12h).

Statistical analysis

Basic descriptive parameters (mean ± SD) correlation coefficients, and regression analyses were calculated for all variables. Processing of data and analysis was performed with Statistica 14.0.0.15. (TIBCO Dana Science Software).

RESULTS

Basic descriptive parameters of women's anthropometric characteristics are shown in Table 1. Average age of female gymnasts is 21.32, min=15 and max=30. Average body height (height) was 159.32 cm, min=150 cm, max=168cm. Average body weight (weight) was 53.42 kg, min=41.40 kg, max=63.30 kg. Variable BMI average amounts 21, min=18.40, and max=23.30. BMR kJ amounts on average 5810.12 kJ, min=4996 kJ, max=6962 kJ. BMR kcal average was 1388.68 kcal, min=1194 kcal, max=1664. Average of variable FAT was 15.11%, min=7.40%, max=21.50%. FAT MASS average amount 8.18kg, min=3.70 kg, max=13.50 kg. Average value of variable FFM was 45.25 kg, min=36.20 kg, max=56.50kg. Variable TBW average amounts 33.12 kg, min=26.50 kg, max=41.30 kg. Average age of male gymnasts was 23.30, min=17 and max=33. Mean value of body height was 167.78 cm, min=160 cm, max=178 cm. Average body weight was 66.08kg, min=54.60 kg, max=78.50 kg. Variable BMI mean value was 23.47, min=19.30, a max=27.20. BMR kJ mean value was 7451.06 kJ, min=6347 kJ, max=8531 kJ. BMR kcal mean was 1781.08 kcal, min=1517 kcal, max=2039. Mean value of variable FAT amount 8.10%, min=4 %, max=14.60. FAT MASS mean was 5.39 kg, min=2.30 kg, max=9.60 kg. Mean value FFM was 60.69 kg, min=50.50 kg, max=70.10 kg. Variable TBW mean value was 44.44 kg, min=37 kg, max=51.30 kg.

Table 1. Basic descriptive parameters of anthropometric variables of all gymnasts

Variable	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD
age	25	21.32	15.00	30.00	4.84	37	23.30	17.00	33.00	4.16
height (cm)	25	159.32	150.00	168.00	5.26	37	167.78	160.00	178.00	4.25
weight (kg)	25	53.42	41.40	63.30	5.89	37	66.08	54.60	78.50	5.32
BMI (kg/m^2)	25	21.00	18.40	23.30	1.43	37	23.47	19.30	27.20	1.78
BMR (kJ)	25	5810.12	4996.00	6962.00	492.50	37	7451.06	6347.00	8531.00	542.90
BMR (kcal)	25	1388.68	1194.00	1664.00	117.74	37	1781.08	1517.00	2039.00	129.66
FAT %	25	15.11	7.40	21.50	3.69	37	8.10	4.00	14.60	2.58
FAT MASS (kg)	25	8.18	3.70	13.50	2.58	37	5.39	2.30	9.60	1.81
FFM (kg)	25	45.25	36.20	56.50	4.37	37	60.69	50.50	70.10	4.89
TBW (kg)	25	33.12	26.50	41.30	3.19	37	44.44	37.00	51.30	3.58

Min: minimum; Max: maximum; SD: standard deviation, BMI: body mass index; BMR: basal metabolic rate, FAT MASS—total fat mass, FFM—fat-free mass, TBE: total body water percentage.

The regression analysis results (Table 2) show that consecutively, the predictor variable explains 87.1%, 87.6%, and 93% of the variance of the criterion variables FL D, FL E and FL TOTAL respectively of women's floor scores. The variable BMI contributes to the D score with a coefficient of b*= 3.3. A negative contribution to the D score is in the variable BMR (kJ) b*=-3.2. The variable BMR (kcal) contributes to the E score with a coefficient of b*= 0.94. The variable BMI contributes to the FL TOTAL with a coefficient of b*= 0.53, and the variable BMR (kJ) negatively contributes to the criterion variable of b*=-2.3.

Table 2. Regression analyses of women's floor D, E and TOTAL score

	R	R^2	Ad. R^2	F	b*	SE of b*	b	SE of b	t (3)	p-value
FL D score	.933	.871	.786	10.192						
Intercept							-1.27	1.55	-0.82	0.47
BMI					3.3	0.73	0.79	0.18	4.50	0.02
BMR (kJ)					-3.2	0.73	-0.00	0.00	-4.41	0.02
FL E score	.936	.876	.845	28.338						
Intercept							5.95	0.35	17.05	0.00
BMR (kcal)					0.94	0.18	0.00	0.00	5.32	0.01
FL TOTAL	.964	.930	.884	20.161						
Intercept							3.85	1.40	2.75	0.07
BMI					2.9	0.53	0.86	0.16	5.47	0.01
BMR (kJ)					-2.3	0.53	-0.00	0.00	-4.33	0.02

FL D score: flor D score, FL E score: flor E score, FL TOTAL: flor total scores, BMI: body mass index; BMR: basal metabolic rate.

The results of regression analyses are in Table 3, where the predictor variable explains 99.8% of the variance of the criterion variable FL D of men's floor D score. FAT % contributes to the FL D with a coefficient of b*= 31.18, and the variable FAT MASS (kg) negatively contributes to the criterion variable b*=-30.79.

Table 3. Regression analyses of men's floor D score

	Regression Summary for Dependent Variable: FL D R= .99900544 R^2= .99801186 Adjusted R^2= .99403558 F (2.1) = 250.99 p					
N=4	b*	SE of b*	b	SE of b	t (1)	p-value
Intercept			7.94	0.122	65.09	0.01
FAT %	31.18	1.50	2.08	0.100	20.76	0.03
FAT MASS (kg)	-30.79	1.50	-3.47	0.169	-20.51	0.03

FL D score: flor D score, FAT MASS—total fat mass.

The results of regression analyses of scores for pommel horse are presented in Table 4. The Predictor variable explains 58.4% of the variance of the criterion variable PH D. The variable BMR (kcal) negatively contributes to the PH D with a coefficient of b*=-0.76.

Table 4. Regression analyses of pommel horse D score

	Regression Summary for Dependent Variable: PH D R= .76427143 R^2= .58411082 Adjusted R^2= .51479596 F (1.6) =8.4269 p					
N=8	b*	SE of b*	b	SE of b	t (6)	p-value
Intercept			11.50	2.07	5.56	0.00
BMR (kcal)	-0.76	0.26	-0.00	0.00	-2.90	0.03

BMR: basal metabolic rate.

DISCUSSION

Results that women examine achieved on the floor indicated that BMI contributes to D-score. It was found in women gymnasts that BMR (kcal) contributes to E-score and BMI on a final score on the floor. The average values of BMI are 20.28, which means that lower values of BMI are required on the floor. Our results are consistent with Polish gymnasts' prior findings; their BMI levels were normal and higher for seniors (20.5 kg/m^2 to 25.8 kg/m^2) than for juniors (14.7 kg/m^2 to 24.5 kg/m^2) (Sterkowicz-Przybycień, Sterkowicz, Biskup, Żarów, Kryst, & Ozimek, 2019). Interestingly, top-level gymnasts had a lower BMI in 2015 than in 2000 (Šibanc, Kalichová, Hedbávný, Čuk, & Pajek, 2017).

On the men's floor variable, FAT% contributes to the D-score, while FAT MASS (kg) contributes negatively. Gymnasts with a small percentage of fat will have higher D-scores, but gymnasts with higher fat will have lower D-scores. This supports earlier research findings that gymnasts with higher Final scores had considerably lower fat mass percentages than those with lower Final scores (Claessens et al., 1990). The highest ectomorphy was found in pommel horse specialists, who also had much lower mesomorphy than the floor, vault, horizontal bar, and parallel bars (Sterkowicz- Przybycień et al., 2019).

Both women's and men's gymnasts' floor exercises demand a lean body. The fact that floor competitors are also competing all around is the cause of this. It is pretty apparent that having low body fat levels is necessary for success in AG (Borms & Caine, 2003), and female gymnasts have been found to have deficient body fat percentages when compared to chronologically age-matched non-gymnast groups (Cassell, Benedict, & Specker, 1996; Soric, Misogoj-Durakovic, & Pedisic, 2008). This is in line with previous research, which showed that depending on their sport, most athletes have body fat percentages ranging from 7% to 19% for men and 10% to 25% for women (Poblano-Alcalá & Braum-Zawosnik, 2014). Compared to the reference population, the fat mass percentage of Spanish gymnasts (12–16 years old) was much lower (Amigó, Faciabén, Evrard, Ballarini, & Marginet, 2009). Our results share percent of fat in female gymnasts was around 15.11%, while in male gymnasts was 9.05%.

According to the National Health Institute of the United States of America, healthy adult males should have 6% to 24% body fat, while healthy adult females should have 14% to 31% body fat (Ferreira João & Fernandes Filho, 2015).

The average values for the male gymnasts' body composition were 33.08 kg of lean muscle, 7.44 kg of fat, 57.74 kg of fat-free mass, and 11.39 kg of fat percentage, while the average values for the female gymnasts were 21.7 kg of lean body mass, 7.55 kg of fat, 38.12 kg of fat-free mass, and 15.84 kg of fat percentage (Ferreira João & Fernandes Filho, 2015). In contrast to earlier findings (Ferreira João & Fernandes Filho, 2015), we have found that the male FFM average was 61.70kg, but they are older by six years than previous findings. However, the fat percentage was lower in older gymnasts. Also, our funding for FFM in female gymnasts was 45.25kg, which was four years older than the results of authors Ferreira João & Fernandes Filho (2015), and the fat percentage in our findings was similar to 15.11%. Apart from gymnasts participating on the floor, top-level gymnasts from 2015 have become taller and have less body fat and muscle mass than in 2000 (Šibanc et al., 2017).

Through approximately the 1980s and early 1990s, when the US women's Olympic gymnasts competed in the last four Olympic Games, their size decreased; after that time, it increased (Sands, Slater, McNeal, Murray, & Stone, 2012). Between 2000 and 2015, the percentage of muscle mass in gymnasts increased on the floor but decreased from 2000 to 2015 on the pommel horse, parallel bars, and horizontal bar (Šibanc et al., 2017). The athletes from individual competitions did not have significantly different body weights and heights, according to research by Sterkowicz-Przybycień et al. (2019). This is even though specialists and all-around competitors have different body compositions.

In AG, it is well known that gymnasts, especially elite ones, have small bodies and lower body masses (Bacciotti, Baxter-Jones, Gaya, & Maia, 2017). Additionally, during the past 25 years, gymnasts have become younger, shorter, and lighter than the general population (Jemni, Friemel, Sands, & Mikesky, 2001). These facts can be explained by parents of gymnasts who are shorter than average (Malina, 1999; Baxter-Jones et al., 2002). Findings of small sizes are evident long before any systematic training is started (Peltenburg, Erich, Zonderland, Bernink, Van den Brande, & Huisveld, 1984), so it leads to the conclusion that gymnastics training does not influence body size. With training, we can only change body composition.

Our findings are consistent with those of Amigó et al. (2009), who found that Spanish gymnasts are smaller and lighter than the reference group, and with those of Arkaev & Suchilin (2004), who found that Russian male gymnasts weigh between 56 and 70 kg and stand between 160 and 170 cm tall, while female gymnasts weigh between 150 and 160 cm and 38 to 50 kg. Gymnasts' average height in 1987 was 167 cm, the same as in 1964 (162 cm), and their average weight was about 63.3 kg (Claessens et al., 1991). Those findings are consistent with our results for male gymnast height (167 cm), but they now are heavier than in 1987 (67.75kg). Between

1956 and 1980, American female Olympic gymnasts' average height declined from 161.8cm to 149.1cm, and their average body weight fell from 55.6kg to 40.2kg, gymnasts' sizes had increased since 2008, reaching 153cm and 47.5kg (Sands et al., 2012). Then, following a brief increasing trend, the height began to drop from the Olympic Games in 2012 and 2016 (Sands, Murray, McNeal, Slater, & Stone, 2018). The reason for changing the sizes of gymnasts can be in rules (elements and exercises are changing every four years), and in the minimum-age rule, modifications may have played a role in athlete size (Sands et al., 2012). Our experiments confirm with previous results for the last forty years that body height in male gymnasts was average at 168cm and body weight is 66kg, the highest measured since the Olympic Games in London in 1948 (Čuk, Korenčič, Tomazo-Ravnik, Peček, Bučar, & Hraski, 2007). Authors Georgopoulos, Theodoropoulou, Roupas, Armeni, Koukkou et al., (2012) found similar results: the final height in adult elite male gymnasts was 168.54cm. In 15 years, from 2000 to 2015, gymnasts tended to be taller in 2015 than in 2000, heavier on pommel horse, rings, and parallel bars and lighter on high bar (Šibanc et al., 2017). Between the 1967 European Championship (20.5±2.0 yrs) and the 1987 World Championship (16.5±1.8 yrs), a declining age trend was seen, which was followed by a decline in competitors' average body mass (52.6±4.8kg; 45.5±6.3kg) and height (158.4±5.1cm; 154.3±6.5cm) (Pool, Binkhorst, & Vos, 1969; Claessens et al., 1990; Bacciotti et al., 2017).

CONCLUSION

Results on the floor in women showed that BMI influences the D-score. It was discovered that BMR (kcal) and BMI affect the final floor score for female gymnasts. Average BMI values are 20.28; therefore, lower BMI values are needed on the floor. FAT% contributes positively to the D-score on the men's floor, whereas FAT MASS (kg) contributes negatively. Gymnasts with low-fat percentages will have higher D-scores, whereas those with more significant fat will receive lower D-scores. The floor is the apparatus where rules, especially in women's gymnastics demand performing the high values acrobatic elements. This leads to more explosive power and muscle mass than 15-20 years ago. Gymnasts typically have short statures and low body masses compared to the general population. The look of a gymnast changes over time due to the changing rules involving the new elements, but they are still different regarding the general population. The reason for changing the anthropometric characteristics can also be in the specialization. Further research should constantly follow the anthropometric characteristics of a gymnast. One of the study's shortcomings is that not all gymnasts are willing to participate since they are very shy when it comes time to step the scale.

Declaration of Conflicting Interests

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