The Influence of Anthropometry on the Balance Beam Performance of Young Gymnasts

Aleksandra Aleksić-Veljković[1], Kamenka Živčić Marković[2], Lucija Milčić[2], Marko Veljković[1], Marijo Možnik[2]

[1]*Faculty of Sport and Physical Education, Niš, Serbia*
[2]*Faculty of Kinesiology, Zagreb, Croatia*

Abstract

Achieving the best results in Women's Artistic Gymnastics depends on many factors. The balance beam is one of the four apparatus in women's all-around competition, and it is necessary to identify the factors that are crucial in achieving the best results on this apparatus. A review of the literature showed that a small number of studies dealing with this problem, especially in the younger age categories of gymnasts. The main aim of this research is to determine anthropometry as a factor of success in practicing on the balance beam in young categories of gymnasts. The research included 47 gymnasts, participants of the "Laza Krstić and Marica Dželatović" competition held in Novi Sad. Data analysis was performed using SPSS statistical software version 20.0. For each variable the main central and dispersion parameters are shown, and the normality of distribution was tested using the Kolmogorov-Smirnov test. Regression analysis revealed a statistically significant impact of anthropometry on the success. The scientific contribution of this research is to determine the share of selected variables in achieving success on the balance beam in young gymnasts.

Keywords: *Artistic gymnastics, Regression analysis, Age-group categories*

1. Introduction

Artistic gymnastics is a polystructural, conventional sport based on complex movements, performed in accordance with aesthetic criteria and strictly defined rules. As one of the basic sports, gymnastics has a significant impact on the transformation of the psychosomatic status of an individual. It

is characterized by the extraordinary richness and complexity of the elements, distributed in structural groups, within the competition disciplines.

In recent years, artistic gymnastics have a great popularity, which is partly attributed to the beginning of training at the earliest age. As in other competitive sports, in gymnastics great attention is paid to methods of identifying talents and achieving top results, too. These methods include the application of various physical, functional and psychological measuring instruments, in order to assess the abilities and characteristics of athletes.

As a basic sport, sports gymnastics affects the development of motor skills: strength, coordination, flexibility and balance [1]. In coordination terms, gymnastic elements are the most complex movements. Testing and periodic monitoring of the ability of young athletes is also important for defining training programs adapted to the requirements of sports and age. In this way, a harmonious development of fundamental motor skills is achieved in accordance with the physical development of the athlete [2]. The specificity of athletes in sports disciplines is the result of selection and, on the other hand, the specific effects of the activities that this discipline creates [3]. In Women's Artistic Gymnastic there are four apparatus (the vault, the uneven bars, the balance beam and the floor.

The balance beam is one of the most attractive apparatus in Women's Artistic Gymnastics. When defining exercises on the balance beam it is often stated that most of the content on this apparatus is taken from the floor, but one should bear in mind the differences in the construction of the device, which also leads to differences in the performance technique. Gymnasts perform exercises on the balance beam, which has a markedly reduced surface of the support of 0,1 meters, a height of 1.25 meters and a length of 5 meters [4]. It is known that gymnasts must have certain specific anthropometric characteristics in order to achieve success in sports gymnastics and this research was aimed at determining the influence of selected variables of anthropometry on success on the balance beam.

2. Materials and methods

Participants

The sample of participants consists of 47 female gymnasts, competitors of the International Memorial competition "Laza Krstić and Marica Dželatović",

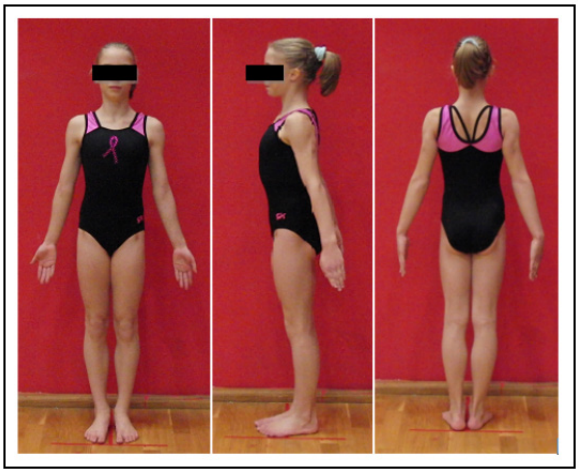
aged 8 to 12 years. The testing was conducted at the Sokol Society "Vojvodina" in Novi Sad, in cooperation with the Gymnastics Federation of Serbia. The competition was attended by gymnasts from eight European countries: Croatia, Slovenia, Austria, Denmark, Sweden, Romania, Bulgaria, and Serbia.

Measurements

This investigation covered 14 anthropometric variables, for assessing and defining the morphological status of participants: longitudinal dimension of the skeleton (5 variables), transversal dimensionality of the skeleton (5 variables), body volume and mass (1 variable) and body composition (3 variables).

To obtain variables, the *ImageJ* software was used, which is very precise, objective and easy to apply. This program is used to calculate the length and angles of anatomic and anthropometric measures [3]. For shooting digital photos, a camera (Casio FX) was set up at a distance of 4 meters and the optimum height in relation to the subjects, so that they were taken under the same conditions. Digital calibration of the system was used for the digital photography of an objectively known length (2 meters). Only body height variable (AVIS) and foot diameter (ADST) were measured by the anthropometer.

Figure 1. The position of the respondents in digital photographs.



Variables were used to estimate the longitudinal dimension of the skeleton:

1. Body height (AVIS) - measured by anthropometer;

2. Arm length (ADUR) - measured from the top of the shoulder (acromion) to the tip of the stretched middle finger. The hand is spring-loaded and tight;

3. The hand length (ADUS) - measured from the laterear eminence to the tip of the extended middle finger. The fist is spun and taut, with a palm placed on the body;

4. Leg length (ADUN) - vertical distance from the top of the spine illiac anterior superior to the floor. The legs are stretched and tight;

5. Foot-Height Length Index (IDNV) - the relationship between leg length and body height.

To estimate the transversal dimension of the skeleton:

1. Shoulder width (AŠRA) - measured horizontally from the points of maximal provision of m.deltoideus, on the upper, outer side of the arm and shoulder;

2. Right-foot diameter (ADSD) - measured by a shortened anthropometer;

3. Left-foot diameter (ADSL) - measured by a shortened anthropometer;

4. Hips width (AŠKU) - horizontal distance between the maximum prochions of the large trochanter major on the femur head (femur).

5. Androgenic index (ANDR) – the ratio between the shoulder and hip width.

Only one variable will be determined for the volume and body weight:

1. Body mass (AMAS) in kg.

For the evaluation of body composition, the digital clinically tested scale Omron BF511 was used. The scale gives a large number of parameters of the body composition, of which were used: Total body fat (0.1%) (AUTM), BMI - Body Mass Index (ABMI) and Basal metabolism (Kcal) (ABAM). All parameters of mass and body composition were obtained by the pressure of the participants on the scale in a vertical position with raised hands in front of the body.

Three variables (Difficulty score - DOCE, Execution score - EOCE and Final score - KOCE) were applied to evaluate the performance on the balance beam, obtained from the official results of the competition.

Procedure

For the needs of the research, in cooperation with the Gymnastics Federation of Serbia, testing was carried out in the small hall. The following optimal conditions for testing are provided:

- Testing was done in the morning hours, before the beginning of the competition;

- The test room was pre-prepared, well lit and with a temperature of 20 to 22°;

- The workplaces and the measurements on each of them were also pre-arranged;

- During the testing, participants were tested in gymnastic leotards and barefoot.

Participants, their trainers, and parents were introduced to the research goal and they signed a consent to participate in the research, in accordance with the Helsinki Declaration on the Rights of the Children. These notifications were sent electronically via gymnastics clubs that participated in the competition.

Statistical analysis

Data processing was performed using the statistical program SPSS version 20.0. For each parameter, the calculated variables are necessary for analyzing and interpreting the results. Following results were calculated:

1. Arithmetic mean - the mean value of the results obtained within each variable;

2. Standard deviation - as an indication of an absolute deviation of the obtained results from their arithmetic mean;

3. Skewness and Kurtosis asymmetry dimensions - show the significance of the deviation from Gaussian curve (which presents the normality of the distribution of results);

4. Kolmogorov - Smirnov test (K-S test) – normality of distribution of all variables;

5. Regression analysis - for prediction of the impact of anthropometry on the performance on the balance beam based on the competition results.

3. Results and discussion

Table 1 shows the variables of the longitudinal dimension of the participants (body height, arm length, arm length, leg length, foot length, height), transversal dimensionality of the skeleton (hip width, shoulder width, left and right foot diameter), volume and weight of the body (body weight),

assessment of body composition (total body fat, body mass index, basal metabolism) in gymnasts aged 8-12 years. For all variables, the following basic descriptive parameters were calculated: minimum and maximum results (Min, Max.), mean (Mean), standard deviation (SD), a coefficient of asymmetry (Skew.), and a coefficient of curvature (Kurt.).

Table 1. Descriptive statistics of anthropometry variables (N = 47)

Var.	Min.	Max.	Mean	SD	Skew.	Kurt.	Z	Sig.
AVIS	119.50	164.00	142.88	10.38	.11	-.66	.73	.66
ADUR	53.60	74.90	63.63	4.96	-.18	-.44	.53	.95
ADUS	12.40	19.10	15.18	1.67	-.09	-.86	.76	.61
ADUN	67.00	92.40	81.58	5.81	-.31	-.06	.46	.99
AINV	49.94	60.69	57.14	1.96	-1.38	3.07	.93	.35
ASKU	20.00	32.70	24.17	2.48	1.11	1.73	1.17	.13
ASRA	25.60	35.00	29.53	2.24	.49	-.37	.99	.29
ANDR	1.07	1.47	1.23	.09	.66	1.03	.96	.31
ADSD	7.20	9.80	8.18	.60	.36	-.19	1.03	.24
ADSL	6.90	9.60	8.03	.62	.08	-.19	.55	.93
AMAS	22.50	62.00	35.59	8.15	.98	.96	1.15	.14
ABMI	14.80	23.10	17.18	1.62	1.29	2.47	.85	.47
AUTM	7.70	21.70	14.42	3.34	.22	-.52	.55	.93
ABAM	1035.00	1424.00	1198.83	85.31	.42	-.14	.78	.58

Legend: Min - minimum score, Max - maximum score, Mean - mean value, SD - standard deviation, Skew. – a coefficient of asymmetry, Kurt. – a coefficient of curvature, z - Kolmogorov-Smirnov Z coefficient; Sig. - level of statistical significance Kolmogorov- Smirnov Z coefficient, AVIS - body height, ADUR – arm lenght, ADUS - hand length, ADUN - leg length, ASKU - hip width, ASRA - shoulder width, ANDR - androgen index, ADDS – Right Foot Diameter, ADLS - Left Foot Diameter, AMAS - Body Mass, AUTM - Total Body Fat, ABMI - Body Mass Index, ABAM - Basal Metabolism.

The average height of the gymnastics is 142.88 ± 10.38 cm, while the body weight is 33.59 ± 8.15 kg. The lowest gymnast was 119.5 cm high and the highest was 164 cm high. The average body mass index was 17.18. The body mass index serves to assess the state of nutrition. These results indicate a lower body mass index compared to the average population, as gymnastics is an aesthetic sport which requires grace and elegance of gymnasts with a low percentage of fat tissue.

Morphological characteristics are very important for gymnastics because during the performance of the composition there is constant movement of the body from one position to another. Different training techniques and a great deal of repetition of the elements increase the ability to control one's own body during exercises and gymnastics, but morphology is also of great importance. Although there are exceptions, in the earliest selection, the trainers take into account the morphological predispositions of the gymnastics.

The hierarchical analysis of the Soviet author Nabatinkov divided gymnasts abilities into three levels of significance [3]. The first level of the most important abilities and characteristics includes physical characteristics (whole body, body structure, posture, foot structure), functional abilities (mobility, vestibular and visual analyzers) and movement abilities (coordination, agility and relative strength). The second level of additional significance consists of physical characteristics (body proportions and structure), functional abilities (peripheral nervous muscular system, auditory analyzers, endocrine system, cardiovascular system, respiratory system, and metabolism), locomotor abilities (specific endurance, explosive force, speed). The third level of significant abilities and characteristics of gymnastics includes physical characteristics (specific body mass), functional ability (thermoregulation) and locomotor abilities (absolute strength and endurance).

The study of Claessens [5] was aimed at identifying anthropometric variables that correlate with success in gymnastics and the prediction of success by combining anthropometric characteristics. The sample of respondents consisted of competitors of the 24th World Gymnastics Championship in Rotterdam (The Netherlands) in 1987. The research involved 168 gymnasts (ages 16.5 ± 1.8 years old). Very significant correlations ($p < .01$) were determined between skin folds and endomorphism's and gymnastic results. Correlations indicate that gymnasts with a higher percentage of subcutaneous fat tissue have lower results. According to the results from this study, 32% to 45% of the variance in gymnastics can be explained by anthropometric characteristics and additional variables, of which the most important are endomorphism and chronological age. Body height and mass in the senior seniors about 14.5 years is about 153 cm and 44 kg. Gymnasts (the average age of 11.7 years) were the easiest and the shortest athletes who participated in the study together with handball players, tennis players and swimmers [6]. The aim of the study was to determine the profile of the top gymnasts, where it was found that besides the low weight and athletic structure of the gymnastics is characterized by good postural control and balance as well as explosive power.

As mentioned earlier, for gymnasts, the relationship between transversal measures of the skeleton in relation to the whole body is important. Thus, numerous studies show that the shoulder width of the gymnastics is significantly higher in relation to the width of the hips. Androgenic index, the ratio of hip width and shoulder width to young gymnasts is 1.23. The anthropometric dimensions are higher in gymnastics compared to the average population of the same age. In relation to patterns of growth and development, shoulder and hip width increases during childhood and the ratio of acromial and crystalline distance remain constant with a slight increase from 6 to 11 years.

Table 2. Descriptive statistics of parameters of success on the balance beam

	N	Min.	Max.	Mean	SD	Skew.	Kurt.	Z	Sig.
DOCE	47	1.00	5.00	3.53	.86	-.20	.05	.80	.54
EOCE	47	1.70	8.50	6.54	1.32	-1.29	2.78	.78	.57
KOCE	47	5.30	13.10	10.07	1.68	-.62	.53	.54	.91

N – a number of respondents, Min - minimum score, Max - maximum score, Mean - mean value, SD - standard deviation, Skew. – a coefficient of asymmetry, Kurt. – a coefficient of curvature, z - Kolmogorov-Smirnov Z coefficient; Sig. - level of statistical significance of Kolmogorov-Smirnov Z coefficients, DOCE – Difficulty score, EOCE – Execution score, KOCE - final score on the balance beam.

The basic central and dispersion parameters and the distribution normality of the three variables for assessing the success on the balance beam are shown in Table 2. All variables have a normal distribution of results.

The increased scoring value for the final score evaluated by the competition (KONO) indicates lower results, while the positive magnified value of the kurtosis indicates the elongation of the curve.

If we compare the results achieved on the balance beam with other competitions, the conclusion is that the results are weaker than at the great gymnastic competitions. In the European Championship 2012 finals in Brussels, the average starting point for juniors (aged 14-15) was 5.57 ± 27 points, while the average E score was 8.1 ± 96 points. The average value and baseline scores and deductions were two points below the European Championship, indicating that the competition was at lower level. However, a sample of 9 to 12-years-olds, competing under international rules, nevertheless shows that they are a representative sample. Table 3 shows the correlation between the criterion variable - the final estimate on the balance beam and the set of predictor variables of anthropometry.

Table 3. Regression analysis parameters in the latent space of anthropometry and KOSE

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	F	p
1	.64	.40	.22	1.48	2.15	**.04**

R - multi-correlation coefficient, R2 - multi-correlation coefficient, Adjusted R2-corrected multi-correlation coefficient, Std. Error of the Estimate.- standard forecast error, F - value of F test that tests the significance of the predictor set to the criterion variable, p - significance level of the multiple correlation coefficient, Predictors: ANDR, AUTM, AINV, ADUR, ASRA, ADUS, ABMI, ADUN, ASKU, AMAS, AVIS

Based on the coefficient of multiple correlations (R), which is equal to .64, a strong relationship between the anthropometry and the final score on the balance beam can be established. According to the value of the multiple correlation squares, which is .403, it can be concluded that the system of predictor variables explains 40.3% of the total variance, while the remainder of 59.7% is under the influence of unexplained factors. The influence of the system of predictor variables statistically significant influence on the criterion variable - the final score of the competition at the level p <.05. However, no variable contributes statistically significant to this effect (value p, Table 4).

Table 4. Partial indicators of the regression of the predictor set and criteria – KOSE

Model		Non-standardized Coefficient		Standardized Coefficient	t	p
		B	Std. Error	Beta		
1	(Constant)	56.59	106.45		.53	.60
	AMAS	-.24	.46	-1.14	-.51	.61
	AVIS	-.27	.70	-1.69	-.39	.70
	ABMI	1.07	1.08	1.03	.99	.33
	AUTM	-.19	.10	-.38	-2.01	.05
	ADUR	.13	.10	.37	1.30	.20
	ADUS	**-.34**	**.22**	**-.34**	**-1.51**	**.14**
	ADUN	.58	1.27	1.99	.45	.65
	AINV	-.65	1.87	-.75	-.34	.74
	ASRA	1.61	1.12	2.14	1.43	.16
	ASKU	-1.70	1.37	-2.51	-1.24	.23
	ANDR	-28.12	26.04	-1.45	-1.08	.29

Legend: Predictor's set of anthropometric variables: Dependent variable: KOCE - Final score at the balance beam.

Earlier research was conducted in order to determine the contribution of various morphological characteristics to the level of technical preparation of gymnasts aged 9-12 years [7]. In the first analysis, the influence was found in the variable body height, body weight, body mass index and Rohrer's index (a measure of leanness of a person calculated as a relationship between mass and height), with a total explanation of 45% in the age category of 9 years (R^2 = .45, r <.01). The value of R^2 was not significant in other age categories (0.15-0.27). In the second analysis, variables were used for the length of the lower extremity, the length of the upper limb, shoulder width, hip width and index of the shoulders and hips. As predictors, these variables explained a significant variation of success in the multiple in boys at age 11 (R^2 = 0.59, p <.01) and 12 years (R^2 = .56, p <.01). The values of R^2 (0.24 - 0.38) were not significant for other age categories.

The success of the performance and achievement in various sports is influenced by various variables, such as morphological characteristics, functional characteristics, adaptations to specific training, development of skills and mental skills [7]. The relationship between the morphological characteristics and the effects of training in gymnastics was confirmed. Studies have confirmed that gymnasts are lower in growth and have more athletic structure compared to other athletes [8]. A large number of researches are needed to examine the impact of certain morphological characteristics and the possibility of achieving top results, both in the all-around and on each apparatus. This data contributes to the improvement of gymnastic training and examination of individual predispositions of gymnastics.

4. Conclusions

Women's Artistic Gymnastics is constantly evolving and changing, through changes to the regulations of the International Federation of Gymnastics. Research in the field of gymnastics is necessary in order to improve gymnastic training and success factors in each of the gymnastics apparatus.

This research involved 47 gymnasts aged 8-12 years, competitors at the international competition, with the aim of determining the anthropometry as a factor of success in exercising on the balance beam. The results obtained by this study cannot be generalized to all ages of gymnastics, as 47 gymnasts aged 8-12 years, participated in the research.

5. References

[1] P. Albuquerque and P. Farinatti, "Development and validation of a new system for talent selection in female artistic gymnastics: the PDGO Battery", Rev. Bras. Med. do Esporte, vol. 13, **(2007)**, pp. 157–164.

[2] L. Ricotti, "Static and dynamic balance in young athletes", Jour. of Human Sport and Exerc., vol. 6, no. 4, **(2011)**, pp. 616-628.

[3] K. Šibanc, M. Kalichová, P. Hedbávný, I. Čuk, and B. Pajek, "Comparison of morphological characteristics of top level male gymnasts between the years of 2000 and 2015", vol. 9, no. 2, **(2016)**, pp. 201–211.

[4] A. A. Veljković, D. Madić, S. Veličković, K. Herodek, and B. Popović, "Balance in Young Gymnasts : Age-Group Differences", Phys. Educ. Sport / Wych. Fiz. i Sport, vol. 12, no. 3, **(2014)**, pp. 289–296.

[5] L. Claessens, F.M. Veer, V. Stijnen, J. Lefevre, H. Maes, G.Steens, G. Beunen. "Anthropometric characteristics of outstanding male and female gymnasts", Journal of Sports Sci, vol. 9, no. 1. **(1991)**, pp. 53–74.

[6] J. Bencke, R. Damsgaard, A. Saekmose, P. Jørgensen, K. Jørgensen, and K. Klausen, "Anaerobic power and muscle strength characteristics of 11 years old elite and non-elite boys and girls from gymnasitcs, team handball, tennis, and swimming", Scand. J. Med. Sci. Sport., vol. 12, no. 3, **(2002)**, pp. 171–178.

[7] A. Kochanowicz, K. Kochanowicz, S. Różański, D. Wilczyńska. "The morphological characteristics and technical preparation of 9-12 years old gymnasts", Journal of Health Sci, vol. 3, no. 13, **(2013)**, pp. 163-177.

[8] L. Louer, M. Elferink-Gemser, and C. Visscher, "The perfect elite gymnast, does he exist? A systematic review", Ann. Res. Sport Phys, no.3, **(2013),** pp 41-61.

Author Info

Corresponding author: aleksic.veljkovic@gmail.com