# Determining the influence of anthropometric indices on balance parameters in young female gymnasts

Denis Petran[1,2ABCDE], Vladimir Potop[1,3,4ABCDE], Ilie Mihai[3BCDE], Anvar Eshtaev[5ADE], Mirela Damian[6ADE], Geanina Toma[3ADE]

[1] *Doctoral School of Sports Science and Physical Education, National University of Science and Technology Politehnica Bucharest, University Center Piteşti, Pitesti, Romania*
[2] *Aurel Vlaicu University of Arad, Arad, Romania*
[3] *Department of Physical Education and Sport, National University of Science and Technology Polytechnic Bucharest, University Center Pitesti, Pitesti, Romania*
[4] *State University of Physical Education and Sport, Chisinau, Republic of Moldova*
[5] *Uzbek State University of Physical Culture and Sport, Chirchik, Uzbekistan*
[6] *Ovidius University of Constanta, Constanta, Romania*

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**Abstract**

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| *Background and Study Aim* | It is increasingly important to know the influence of age characteristics on the development of motor skills necessary for gymnastics. Currently, this influence is taken into consideration in the training of young female gymnasts. This study aims to determine the anthropometric indices impact on static and dynamic balance parameters in young female gymnasts. |
| *Material and Methods* | A group of 24 young gymnasts, from the Arad Municipal Sports Club of Romania, participated in this study. The athletes, aged 6-10 years, were divided into two groups: G1 (6-8 years, n=17) and G2 (9-10 years, n=7). Anthropometric indices were measured by means of Tanita scale. The following indices were monitored: Height (cm), Weight (kg), FATP (%), FATM (kg), FFM (kg), BMI (kg/m²). Balance was evaluated with the Sensamove MiniBoard platform. There were used tests as follows: Static Bipedal Balance (SBB), Lateral Bipedal Balance (LBB) and Vertical Bipedal Balance (VBB). Measured parameters: performance (%); front and back inside (LBB, %); left and right inside (VBB, %); front and back avg. deviation (grade); left and right avg. deviation (degrees). The influence of anthropometric indices on balance parameters was determined using Pearson correlation coefficient. |
| *Results* | The comparative analysis between groups highlights: average age; relation between weight and height; values of body composition indices. The comparative analysis shows better performances by 2.23% in G1 at SBB and values smaller by 0.35 degrees at average vertical deviations. LBB has better performances in G1 by 10.05% and higher values by 1.79% at keeping inside the vertical space. There is a smaller difference between Confidence Limit of Mean (CLM). As for VBB, the performances are better by 0.41% in G2, keeping inside the space to the left in G1 and to the right in G2. The correlation analysis regarding SB reveals 20% strong connections, 83.3% positive connections with performance and 45.8% negative ones with average deviations in G1. The following were noticed in G2: lack of strong connections, 33.3% positive connections and 25% negative influences. In terms of LBB, G1 has no strong connections, but it has 72.2% positive connections and 45.8% negative connections. G2 is characterized as follows: 7.1% strong connections, absence of positive connections, 75% - negative connections. VBB presents the following values in G1: 28.6% - strong connections and 45.8% - negative connections. G2 has 9.5% - strong connections, 94.4% - positive connections and 75% - negative ones. |
| *Conclusions* | By determining the anthropometric indices, the age characteristics of female gymnasts were highlighted. The comparative analysis results of balance parameters reveal better performances and lower values at the average vertical and lateral deviations. Comparing the relationships between anthropometric indices and balance parameters reveals strong connections. It also shows the weight of positive and negative connections with performance, keeping inside the space and value of average deviations. These data can serve as methodological recommendations in future studies. |
| **Keywords**: | female gymnasts, BMI, bipedal balance, performance, deviation, correlation analysis |

## Introduction

Gymnastics involves the successful execution of

complex routines on different apparatus especially during competition. However, the correlation between performance in competition and physical abilities of the gymnasts has not been investigated

enough [1]. By its nature, gymnastics is a balance sport that requires both static and dynamic stability [2]. However, through increased participation, gymnastics exposes athletes to a large number of potential injuries. These ones could be caused by hyperextension and flexion in various postures and excessive stress on back muscles [3]. An analysis of women's sports, such as rhythmic gymnastics (RG) and artistic gymnastics (AG) highlighted some common points. But, at the same time, they present some relevant differences in terms of physical and technical characteristics [4]. The existence of certain minimally developed motor skills is highly important in RG. For example, such skills are the postural control and the capacity to stabilize the body during dynamic movements [5]. Achieving the best results in women's artistic gymnastics depends on many factors. For instance, it is necessary to identify the elements that contribute to high performance on balance beam, one of the four apparatus in women's polyathlon. A review of the specialized literature reveals that there are few studies dealing with this matter, particularly in young gymnasts [6].

To practice performance artistic gymnastics, the female gymnasts must correspond to an anthropometric model. In this sense, studies suggest that athletes who practice sports based on weight and anthropometric aspect are at risk of developing a negative energy balance during the day and at the end of the day as well. Prolonged negative energy balance was associated with lower fat-free mass, higher fat mass and lower bone mineral density [7].

Balance is very important in sports and daily activities and can be related to anthropometric characteristics. However, this relation has rarely been examined in young non-athlete women. Balance has an important place in achieving high performance in all sports branches. The specialists noticed that the exercises for balance and body stabilization help to prevent injuries. But there is not enough evidence about the importance of these exercises in reaching high sports performance. Coaches of young athletes must not neglect the specific training programs for balance. It is especially important for sports where balance is fundamental for performing complex technical movements and for preventing injuries [8-11].

Postural control underlies the performance of fundamental motor skills (FMS). The development of FMS is important for lifelong physical activity practicing. The self-perceived physical competence was proved to be positively correlated with motor skill competence and involvement in physical activity. It was suggested that children go through a critical period of perceptual motor development at the age of 6 – 8 years approximately. Practicing gymnastics in this critical stage could provide children with improved postural control and better prospects of developing FMS [12]. The specialized literature debates largely the specificity of postural balance control in gymnastics which involves complex motor skills [13]. Balance training (BT) is a well-established type of training in many sports and is used to improve postural control. There is evidence that improvements after BT can be also observed in other elements such as muscle strength or vaults performance [14]. Using neuromuscular training for young athletes improves performance and decreases the risk if injury risk during sports activities. These effects are firstly attributed to better muscle strength and power, but also to improved balance, speed and agility [15]. A traditional method of evaluating the dynamic posture of athletes is the Functional Movement Screen (FMS). The validity and reliability of the FMS as a screening tool is controversial. The most important criticism refers to its subjectivity. To the best of authors' knowledge, there is no previous research using Kinovea to accurately assess the FMS scores [12].

No study about the anthropometric indices influence on the static and dynamic balance parameters in young gymnasts was found in the specialized literature. There are only a few studies that investigate this issue separately.

*Purpose of the Study.* The study purpose was to establish the anthropometric indices influence on parameters of static and dynamic balance in young gymnasts.

## Materials and Methods

*Participants*

A number of 24 female gymnasts aged 6-10 years participated in the research. They were divided into two groups (G) as follows: G1 - 6-8 years, n=17 and G2 - 9-10 years, n=7. All gymnasts are registered at the Municipal Sports Club of Arad, Romania. According to the Declaration of Helsinki, the consent of the parents was required and signed before starting the research. It was approved by the Ethics Committee of the Doctoral School of Physical Education and Sport Science (ID: 05/22.07.2023), University of Pitesti, Romania.

*Research Design*

The research was conducted in December 2022.

The Tanita BC-1000 + ANT+ Stick body composition analyzer was used to measure the anthropometric indices. The following indices were monitored: Height (cm), Weight (kg), Fat (%), Fat (kg), FF (kg), BMI (kg/m$^2$).

In that regard, the Sensamove MiniBoard platform (Nederland) was used to determine the static and dynamic balance. The tilting angle was 10 degrees and the balance had to be maintained for 30 sec. Tests used:

– Test 1: Static balance (SB). Parameters used:

performance (%), front, avg. deviation (degree), back, avg. deviation (degree), left, avg. deviation (degree), right, avg. deviation (degree).

– Test 2: Lateral bipedal balance (LBB). Parameters used: performance (%), front, inside (%), back, inside (%), front, avg. deviation (degree), back, avg. deviation (degree), left, avg. deviation (degree), right, avg. deviation (degree).

– Test 3: Vertical bipedal balance (VBB). Parameters used: performance (%), left, inside (%), right, inside (%), front, avg. deviation (degree), back, avg. deviation (degree), left, avg. deviation (degree), right, avg. deviation (degree).

*Statistical Analysis*

The statistical indicators were calculated using the KyPlot 6.0 (©1997-2020, KyensLab Inc) program, in terms of mean, standard deviation (SD), coefficient of variation (CV%), Confidence Level of Mean (0.95) and Confidence Limit of Mean. Pearson's correlation coefficient was applied to evaluate the relationship between anthropometric indices with static and dynamic (lateral and vertical) bipedal balance of the gymnasts. The strong connections between the investigated indices were presented by means of the yEd (2000 - 2023 yWorks GmbH) program. Statistical significance was set at $p < 0.05$.

## Results

For highlighting possible differences in the investigated variables, data were compared between age groups (G1: 6-8 years; G2: 9-10 years). The results of the anthropometric indices are shown in Tables 1 and 2.

The comparative analysis between groups shows the following values. In G1(n=17) the mean and ±SD is 7.06 ± 0.89 years with differences between Confidence Limit of Mean (CLM) of 0.93 years. In the case of G2 (n=7) the values are 9.28 ± 0.48 years and CLM has 0.91 years. As for the differences of height data, there are values higher by 9 cm in G2. The differences in CLM are 9.02 cm in G1 and 10.7 cm in G2. The weight has values higher by 4.89 kg in G2 and differences at CLM of 5.45 kg in G1 and 5.62 kg in G2. Regarding body composition indices, fat mass values (%) are higher by 0.97% in G1. The differences between CLM are 6.06% in G1 and 3.89% in G2. Fat mass (kg) has higher values by 0.7 kg in G2 and CLM differences of 2.5 kg in G1 and 2.09 kg in G2. In terms of FFM (kg), values are higher by 4.19 kg in G2. The CLM has differences of 3.31 kg in G1 and 3.69 kg in G2. BMI shows better values related to weight and height by 0.57 kg/m² in G1. The CLM has differences of 1.69 kg/m² in G1 and 1.41 kg/m² in G2. These comparative data of anthropometric indices

**Table 1.** Anthropometric characteristics of gymnasts aged 6-8 years, n=17

| Variables | mean ± SD | CV (%) | Confidence Level of Mean (0.95) | Confidence Limit of Mean | |
|---|---|---|---|---|---|
| | | | | Lower | Upper |
| Age (year) | 7.06 ± 0.89 | 12.74 | 0.46 | 6.59 | 7.52 |
| Height (cm) | 121.88 ± 8.78 | 7.20 | 4.51 | 117.37 | 126.39 |
| Weight (kg) | 23.88 ± 5.29 | 22.19 | 2.72 | 21.15 | 26.60 |
| FATP (%) | 19.58 ± 5.89 | 30.06 | 3.03 | 16.55 | 22.61 |
| FATM (kg) | 4.87 ± 2.43 | 49.83 | 1.25 | 3.62 | 6.12 |
| FFM (kg) | 19.01 ± 3.22 | 16.93 | 1.65 | 17.35 | 20.66 |
| BMI (kg/m²) | 15.89 ± 1.64 | 10.32 | 0.84 | 15.04 | 16.73 |

Values are expressed as means ± standard deviations (SD), CV – coefficient of variation; FATM- fat mass, FFM- fat free mass, BMI - body mass index.

**Table 2.** Anthropometric characteristics of gymnasts aged 9-10 years, n=7

| Variables | mean ± SD | CV (%) | Confidence Level of Mean (0.95) | Confidence Limit of Mean | |
|---|---|---|---|---|---|
| | | | | Lower | Upper |
| Age (year) | 9.28 ± 0.48 | 5.25 | 0.45 | 8.83 | 9.74 |
| Height (cm) | 132.00 ± 5.54 | 4.19 | 5.12 | 126.88 | 137.58 |
| Weight (kg) | 28.77 ± 3.04 | 10.56 | 2.81 | 25.96 | 31.58 |
| FATP (%) | 19.21 ± 2.10 | 10.94 | 1.94 | 17.26 | 21.15 |
| FATM (kg) | 5.57 ± 1.12 | 20.19 | 1.04 | 4.53 | 6.62 |
| FFM (kg) | 23.19 ± 1.99 | 8.61 | 1.85 | 21.35 | 25.04 |
| BMI (kg/m²) | 16.46 ± 0.76 | 4.61 | 0.70 | 15.76 | 17.17 |

Values are expressed as means ± standard deviations (SD), CV – coefficient of variation; FATM- fat mass, FFM- fat free mass, BMI - body mass index.

highlights differences between the investigated groups regarding both means and CLM.

Tables 3 and 4 show the results referring to the bipedal (lateral/vertical) static and dynamic balance development in young gymnasts.

The results of the comparative analysis between groups for variables of **static balance** (SB) reveal better performances in G1 by 2.23%. There are smaller differences between Confidence Limit of Mean (CLM) of 15.7%. The average vertical deviations in G1 have front smaller values by 0.26 degrees and differences at CLM of 0.94 degrees. The G2 has back values of -0.38 degrees and differences of -0.17 degrees between CLM. The mean of average lateral deviations in G1 has smaller values of -0.38 degrees to the left and differences of 1.13 between CLM. The deviations to the right have a value of 0.42 degrees and the differences between CLM of 1.59 degrees. There were compared the differences between performance means, average deviations and CLM as well. Thus, in G1 were noticed vertical and lateral average deviations smaller by 0.35 degrees. This fact also justifies the better performance of the static balance.

The comparative analysis between groups regarding variables of **lateral bipedal balance** (LBB) shows better performances by 10.05% in G1. There are lower differences of 35.91% between CLM. Forward keeping inside the space has higher values by 1.79% and lower differences of 29.58% in G2 between CLM. Backward maintaining inside the space has higher values by 11.61% in G1 and smaller differences of 11.77% between CLM. The mean of front deviations has lower values in G2 by 0.07 degrees and lower differences between CLM by 1.06 degrees in G1. Backward average deviations have lower values by 1.81 degrees in G2 and differences of 1.28 degrees in G1 between CLM. The mean of left deviations has smaller values in G2 by 0.77 degrees and differences of 0.19 degrees in G1 between CLM. The mean of right deviations has smaller values by 0.72 degrees in G2 and differences of 1.8 degrees in G1 between CLM. Although the means of vertical and lateral deviations have smaller differences in G2, the difference between CLM is smaller in G1. This fact highlights a better dynamic lateral balance in G1 in accordance with the overall performance obtained.

The comparative analysis between groups

**Table 3.** Results of bipedal balance in gymnastics athletes aged 6-8 years, n=17

| Tests | Variables | mean ± SD | CV (%) | Confidence Level of Mean (0.95) | Confidence Limit of Mean | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Static balance | performance (%) | 81.94 ± 10.92 | 13.20 | 5.56 | 76.38 | 87.50 |
| | front, avg. dev. (degree) | 1.06 ± 0.49 | 47.14 | 0.26 | 0.80 | 1.31 |
| | back, avg. dev. (degree) | -1.19 ± 0.84 | -70.81 | 0.43 | -1.63 | -0.76 |
| | left, avg. dev. (degree) | -1.01 ± 0.88 | -87.94 | 0.46 | -1.47 | -0.55 |
| | right, avg. dev. (degree) | 1.05 ± 0.83 | 78.56 | 0.42 | 0.63 | 1.48 |
| Lateral dynamic balance | performance (%) | 79.76 ± 12.64 | 15.85 | 6.49 | 73.26 | 86.26 |
| | front, inside (%) | 37.35 ± 9.65 | 25.83 | 4.96 | 32.39 | 42.31 |
| | back, inside (%) | 42.18 ± 11.27 | 26.72 | 5.79 | 36.38 | 47.97 |
| | front, avg. dev. (degree) | 1.34 ± 0.47 | 35.49 | 0.24 | 1.09 | 1.58 |
| | back, avg. dev. (degree) | -1.54 ± 0.51 | -33.10 | 0.26 | -1.79 | -1.27 |
| | left, avg. dev. (degree) | -4.34 ± 1.56 | -36.06 | 0.80 | -5.14 | -3.53 |
| | right, avg. dev. (degree) | 4.75 ± 1.55 | 32.59 | 0.79 | 3.95 | 5.54 |
| Vertical dynamic balance | performance (%) | 74.59 ± 19.79 | 26.54 | 10.17 | 64.41 | 84.76 |
| | left, inside (%) | 38.70 ± 13.69 | 35.38 | 7.04 | 31.66 | 45.75 |
| | right, inside (%) | 35.88 ± 11.56 | 32.21 | 5.94 | 29.94 | 41.71 |
| | front, avg. dev. (degree) | 4.13 ± 1.12 | 27.22 | 0.58 | 3.55 | 4.71 |
| | back, avg. dev. (degree) | -3.90 ± 1.01 | -25.81 | 0.52 | -4.42 | -3.38 |
| | left, avg. dev. (degree) | -1.88 ± 0.99 | -52.77 | 0.51 | -2.39 | -1.37 |
| | right, avg. dev. (degree) | 1.79 ± 0.98 | 54.74 | 0.50 | 1.29 | 2.29 |

Values are expressed as means ± standard deviations (SD), CV – coefficient of variation, avg. – mean, dev. – deviation

**Table 4.** Results of bipedal balance in gymnastics athletes at 9-10 years, n=7

| Tests | Variables | mean ± SD | CV (%) | Confidence Level of Mean (0.95) | Confidence Limit of Mean | |
|---|---|---|---|---|---|---|
| | | | | | Lower | Upper |
| Static balance | performance (%) | 79.71 ± 13.96 | 17.51 | 12.91 | 66.80 | 93.62 |
| | front, avg. dev. (degree) | 1.32 ± 0.78 | 59.36 | 0.72 | 0.59 | 2.04 |
| | back, avg. dev. (degree) | -0.81 ± 0.37 | -46.18 | 0.35 | -1.16 | -0.46 |
| | left, avg. dev. (degree) | -1.39 ± 1.05 | -75.49 | 0.97 | -2.37 | -0.42 |
| | right, avg. dev. (degree) | 1.47 ± 1.32 | 89.92 | 1.22 | 0.25 | 2.69 |
| Lateral dynamic balance | performance (%) | 69.71 ± 26.44 | 37.93 | 24.45 | 45.26 | 94.17 |
| | front, inside (%) | 39.14 ± 21.36 | 54.56 | 19.75 | 19.39 | 58.89 |
| | back, inside (%) | 30.57 ± 12.63 | 41.33 | 11.68 | 18.89 | 42.25 |
| | front, avg. dev. (degree) | 1.27 ± 0.83 | 65.45 | 0.77 | 0.50 | 2.05 |
| | back, avg. dev. (degree) | -2.09 ± 1.25 | -59.89 | 1.16 | -3.25 | -0.93 |
| | left, avg. dev. (degree) | -3.61 ± 0.97 | -26.99 | 0.90 | -4.51 | -2.71 |
| | right, avg. dev. (degree) | 4.03 ± 1.84 | 45.50 | 1.69 | 2.34 | 5.73 |
| Vertical dynamic balance | performance (%) | 75.00 ± 23.87 | 31.83 | 22.08 | 52.92 | 97.08 |
| | left, inside (%) | 36.43 ± 15.47 | 42.46 | 14.31 | 22.12 | 50.73 |
| | right, inside (%) | 38.71 ± 16.62 | 42.93 | 15.37 | 23.34 | 54.08 |
| | front, avg. dev. (degree) | 4.46 ± 1.04 | 23.43 | 0.97 | 3.49 | 5.43 |
| | back, avg. dev. (degree) | -3.58 ± 0.91 | -25.49 | 0.84 | -4.42 | -2.74 |
| | left, avg. dev. (degree) | -1.76 ± 0.95 | -54.45 | 0.88 | -2.64 | -0.87 |
| | right, avg. dev. (degree) | 1.74 ± 1.10 | 63.06 | 1.02 | 0.73 | 2.76 |

regarding **dynamic vertical bipedal balance** (VBB) reveals better performances by 0.41% in G2. The differences between CLM are smaller in G1 of 23.81%. Forward maintaining inside the space has higher values in G1 by 2.27% and lower differences of 14.52% between CLM. Backward maintaining inside the space has higher values by 2.83% in G2 and lower differences of 18.97% in G1 between CLM. The mean of forward deviations has smaller values by 0.33 degrees in G1 and differences of 0.78 degrees between CLM. Back average deviations have smaller values of -0.32 degrees in G2 and differences of -0.64 degrees in G1 between CLM. The mean of left deviations in G2 has smaller values of -0.12 degrees and differences of -0.75 degrees in G1 between CLM. The average right deviations have lower values of 0.05 degrees in G2 and differences of 1.03 degrees between CLM in G1. Analyzing the differences of variables between groups, better performances are noticed in G2, with 0.56% better means at maintaining inside the space. There are smaller average deviations of 0.16 degrees backward, to the left and to the right, proving the balance development.

A Pearson linear correlation analysis was performed for determining the anthropometric indices influence on the static and dynamic balance parameters. To highlight the possible differences in the connection between the investigated variables, the correlation analysis was done for each group separately. In this sense, 228 correlations were made (114 in G1 and 114 in G2). Thus, in G1 there were 33.3% negative correlations and 66.7% positive ones while in G2 – 55.3% negative and 44.7% positive ones.

Figure 1 (A and B) highlights graphically the strong connections sense and the significance level between variables. These variables reveal the relationship between anthropometric indices and parameters of static balance (SB) and dynamic balance (LBB and VBB). The graphic representation of the positive connections sense shows the direction from the anthropometric indices to the balance parameters. The negative sense is the opposite – from the balance parameters to the anthropometric indices. These directions are clearly presented in the figures to be interpreted.

Figure 1A shows the strong connections between the anthropometric indices and the balance parameters measured in gymnasts of G1 (6-8 years). The following significances and differences were obtained after calculations:

- at *SB* there are 20% strong connections between Height and Performance (R=0.533, $p < 0.05$), with Back avg. deviation (R=0.498, $p < 0.05$) and Right avg. deviation (R=-0.499, $p < 0.05$); between FFM with Performance (R=0.560, $p < 0.05$), with Back avg. deviation (R=0.553, $p < 0.05$) and with Right avg. deviation (R=-0.521, $p < 0.05$). The negative sense of the relation is given by the values opposite to the practical performative significance. Regarding
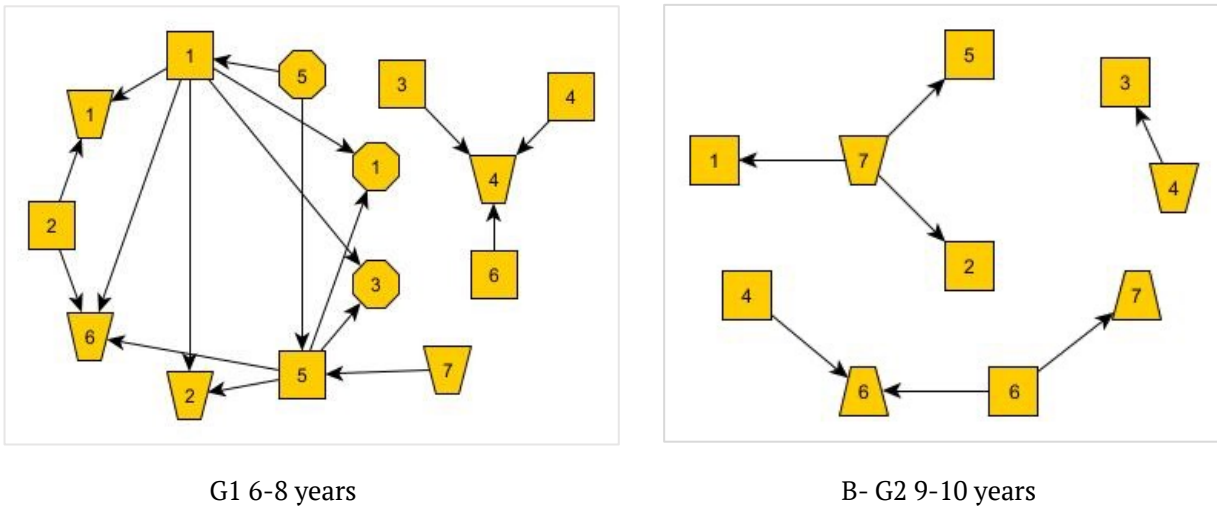
G1 6-8 years                                    B- G2 9-10 years

**Figure 1.** Results of correlation analysis between the anthropometric indices and the static and dynamic bipedal balance parameters in young female gymnasts

Notes:

⬛ - Anthropometric indices: (1 - Height (cm); 2 - Weight (kg); 3 - Fat (%); 4 - Fat (kg); 5 - FF (kg); 6 - BMI (kg/m²)

🔵 - Static balance parameters: 1 - performance (%), 2 - front, avg. dev. (degree), 3 - back, avg. dev. (degree), 4 - left, avg. dev. (degree), 5 - right, avg. dev. (degree);

🔺 - Lateral bipedal balance parameters: 1 - performance (%), 2 - front, inside (%), 3 - back, inside (%), 4 - front, avg. dev. (degree), 5 - back, avg. dev. (degree), 6 - left, avg. dev. (degree), 7 - right, avg. dev. (degree);

🔻 - Vertical Bipedal balance parameters: 1 - performance (%), 2 - left, inside (%), 3 - right, inside (%), 4 - front, avg. dev. (degree), 5 - back, avg. dev. (degree), 6 - left, avg. dev. (degree), 7 - right, avg. dev. (degree).

the sense of influence between variables, one can notice 83.3% positive with performance and 45.8% negative with average deviations;

- at *LBB* the strong connections are absent. Instead, one can observe 72.2% positive influences upon performance and maintaining inside the space and 45.8% negative influences on average deviations;

- at *VBB* there are 28.6% strong connections between Height with performance (R=0.559, p < 0.05), with front inside (R=0.529, p < 0.05), with left avg. deviation (R=0.589,  p < 0.05); between Weight with performance (R=0.521, p < 0.05), with left avg. deviation (R=0.549, p < 0.05); between FATP with front avg. deviation (R= -0.496, p < 0.05); between FATM with front avg. deviation (R= -0.517, p < 0.05); between FFM with performance (R=0.61, p < 0.01), with left inside (R=0.532, p < 0.05), with left avg. deviation (R=0.61, p < 0.01) and with right avg. deviation (R= -0.492, p < 0.05). As for the sense of the connections between variables: total values positive with performance and keeping inside space and 45.8% negative with average deviations.

Figure 1B presents the strong connections between anthropometric indices and balance parameters measured in gymnasts of G2 aged 9-10 years. The results highlight the following significances and differences:

- at *SB* there are no strong connections. But instead it can be observed 33.3% positive connections with performance and 25% negative connections with the mean of deviations;

- *LBB* reveals 7.1% strong connections between FATM with left avg. deviation (R= 0.774, p < 0.05); between BMI with left avg. deviation (R=0.912, p < 0.01) and with right avg. deviation (R= -0.872, p < 0.01). As for the connections between variables, it is highlighted the absence of positive connections with performance. It can be also observed 75% negative connections with the mean of deviations;

- *VBB* shows 9.5% strong connections between Height with right avg. deviation (R= -0.826, p < 0.05); between Weight with right avg. deviation (R=-0.794, p < 0.05), between FATP with front avg. deviation (R= -0.776, p < 0.05), between FFM with right avg. deviation (R= -0.861, p < 0.05). The results concerning the sense of connections between variables highlight 94.4% positive connections with performance and 75% negative connections with average deviations.

The following observations were made after comparing the relations between the anthropometric indices and the variables of the bipedal lateral and vertical static and dynamic balance. Superior performance and maintaining inside the space through positive connections and (better) negative

connections of the average deviations are noticed. The relations sense (positive or negative) of both strong and non-significant connections determines the influence level of the investigated variables.

## Discussion

The study aimed to establish the anthropometric indices influence on the static and dynamic balance parameters in young gymnasts. It is important to know this influence before the development of a training program. Thus, the Tanita scale was used for measuring the anthropometric indices. The balance was evaluated using three tests: SB, LBB and VBB. The purpose was to highlight the differences between variables and their influence depending on age characteristics. That is why the subjects were divided into two age groups: G1 (6-8 years) and G2 (9-10 years).

The comparative analysis between groups reveals an average age of 7.06 years in G1 and 9.28 years in G2. Regarding the relation between weight and height, the values are higher by 9 cm and 4.89 kg in G2. Body composition indices show lower values of fat mass by 0.97% in G2 and higher values by 0.7 kg in G2. As for FFM (kg), it has higher values by 4.19 kg in G2, while BMI has better values of 0.57 kg/m$^2$ in G1. All these differences are related to the weight and height of the gymnasts. They are also related to the value of body composition indices (Tables 1 and 2). Studies showed that the somatic and physical fitness profile of the participants were assessed through anthropometric measures and fitness tests. To this effect, the battery of fitness tests in men's artistic gymnastics was used, namely the International Gymnastics Federation [FIG] age group development program [16]. Evaluating the changes in body composition and physical fitness of 7-year-old gymnasts provide useful information for optimizing the tasks at the initial training stage [17]. Investigation of static and dynamic stability in gymnasts, non-gymnast athletes and non-athletes highlighted significant differences between conditions in all variables both for the static and dynamic tests [18]. Practicing gymnastics involves many possible injuries, including hyperextension and flexion in different positions or an extreme stress on back muscles. The subjects were evaluated for nine anthropometric variables and a performance test regarding back strength. The test results revealed a positive correlation with all selected characteristics, except BMI, body fat percentage and expanded chest circumference [3]. The influence on body development in rhythmic gymnastics athletes aged 10 - 17 years was analyzed. Results regarding certain strength and flexibility abilities and the trace elements status led to a conclusion about training. This one does not change the normal physical development of muscle mass and even enables a decrease of body fat content [19].

The results of the comparative analysis between groups regarding SB variables highlight better performances by 2.23% in G1. Smaller values by 0.35 degrees were noticed at the mean of vertical deviations (to the left and to the right). This fact justifies the higher level of the balance. The LBB differences show better performances by 10.05% in G1 and higher values by 1.79% at maintaining inside the vertical space. Although differences of average vertical and lateral deviations are smaller in G2, a lower difference between CLM is observed in G1. This proves a better LBB in G1, consistent with the performance obtained in general. Regarding VBB differences, there are better performances by 0.41% in G2, keeping inside the space to the left in G1 and to the right in G2. The mean of forward deviations has lower values by 0.33 degrees in G1 and backward by -0.32 degrees in G2. In G2, the mean of lateral deviations has smaller values of -0.12 degrees to the left and 0.05 degrees to the right. The results of differences highlight better performances in G2. The means for maintaining inside the space are superior by 0.56%. The deviations backward, to the left and to the right are smaller by 0.16 degrees on average. This justifies the level of balance development (Tables 3 and 4). So, assessing the contribution of static and dynamic balance to functional movement presents helpful information for training and recovery [20]. Determining the control of body balance keeping in a handstand demonstrates its relationship with sports results. The difficulty and quality of the routines are also taken into account.

The analysis of the tests showed significant differences in terms of body balance in a handstand. Studying the correlations between body balance in a handstand with sports training level of revealed the important role in shaping sports mastery [21]. Specialists also focused on establishing if training amount has an influence on body balance both in sports and daily activities. The results highlighted how the level of expertise did not affect the postural balance control during simple tasks. In contrast, the sport-specific task proved to be more selective in representing the expertise level of young gymnasts [13]. There are studies that determine the differences between young female artistic gymnasts and non-athletes. They demonstrate better functional stability than non-athletes depending on age and gender [22]. The relations between stability indices recorded in standing and in handstand positions by gymnasts of different levels were compared and analyzed. Thus it was highlighted that seniors have a better ability to control body balance in both positions compared to juniors [23]. Research was made on the static and dynamic stability in the case of gymnasts, athletes in other sports and non-athletes. It was found out that all dependent variables were significantly different for both static and dynamic tests [18]. The correlation between static

and dynamic postural balance in young dancers was also analyzed. It was observed in head movements of female dancers in all three directions. In the case of young male dancers, correlations were found only in mediolateral and anteroposterior directions [24]. There are comparative studies that highlight the differences of conditioned skills achieved by rhythmic gymnasts and artistic gymnasts. These ones were tested for joints mobility, balance, explosive strength, speed and endurance [4]. Other study assessed the role, contribution and influence of balance ability on performance scores in rhythmic gymnastics (RG). The results of the multivariate regression analysis show a statistically significant influence of the balance ability on performance scores. Important individual contributions of the balance were observed in the toes test (right foot) and the dynamic balance [5]. It was also investigated whether 4 weeks of dynamic balance training improves static balance performance in school-age gymnasts and soccer players [11]. In this sense, one can emphasize that balance training at specific ages is important for the sensorimotor skills maturation development. These skills are highly important for an elite athlete [25]. The Functional Movement Screen method was used to evaluate the dynamic posture of athletes. The FMS scores were accurately assessed by means of the Kinovea program. None of the factors were found to be statistically significant. However, the FMS general score was close to the significance threshold [12]. A doctoral study explored the effects of educational gymnastics and typical physical education in children during a critical period of perceptual motor development. More precisely, the monitoring focused on the effects on postural control, self-perceived physical competence and Functional Movement Screen competence [26]. A comparison was made between individual athletes and team sports athletes in terms of performances of static and dynamic balance. According to statistical analysis, there is no significant difference between the static and dynamic balance performances of these two types of athletes [9]. The relationship of passive, active and neural mechanisms underlying the balance and spinal posture control with the performances of athletes was identified. Thus, it was provided a basis for a multifaceted approach in designing the training and testing tools. These tools are meant to address the postural and core stability of athletes in specific sports conditions [10]. Other specialists tried to find a relation between quadriceps angle and balance measurement in subjects with previous injuries of lower limb. The analysis aimed at the category of subjects who complained of pain. The research suggests that there is a weak negative correlation between Q-angle and static balance. A moderately negative correlation between Q-angle and dynamic balance was also observed [27]. The

evaluation of the relation between energy balance and body composition in female gymnasts was performed. Significant negative correlations were found between the kcals consumed per kg of body weight and body fat percentage, bone mineral density, fat mass and fat-free body mass [7]. The testing methods used to evaluate the neuromuscular training effect on sports specific performance in young athletes were reviewed. The methods were introduced in the Longlife Sport Diagnostic Model and proposed to further research on this topic [15]. Consequently, a large number of balance tests were developed. However, it is not yet known if these tests can differentiate between athletes with different balance expertise. Three common tests of dynamic balance were studied: single leg landings, Posturomed perturbations and simulated forward falls [28].

The correlation analysis between anthropometric indices and parameters of the bipedal static and dynamic balance reveals the following significances and differences at SB. Thus, in G1 there are 20% strong connections between Height with Performance, with Back avg. deviation and Right avg. deviation; between FFM with Performance, with Back avg. deviation and with Right avg. deviation. One can also observe in G1 83.3% positive connections with performance and 45.8% negative connections with average deviations. G2 has no strong connections but has 33.3% positive connections with performance and 25% negative connections with the average deviations. As for LBB, the strong connections are absent in G1. But G1 has 72.2% positive connections with performance and keeping inside the space and 45.8% negative connections with the average deviations. Regarding G2, there are 7.1% strong connections between FATM with left avg. deviation; between BMI with left avg. deviation and with right avg. deviation. The following facts are noticed: absence of positive connections with performance and 75% negative connections with the mean of deviations. Relating to VBB, G1 shows 28.6% strong connections between Height and performance, with front inside, cu left avg. deviation; between Weight and performance, with left avg. deviation; between FATP and front avg. deviation; between FATM and front avg. deviation; between FFM and performance, with left inside, with left avg. deviation and with right avg. deviation. There are positive connections with performance and maintenance inside the space and 45.8% negative connections with average deviations. In the case of G2, there are 9.5% strong connections between Height and right avg. deviation; between Weight and right avg. deviation, between FATP with front avg. deviation, between FFM and right avg. deviation. One highlights 94.4% positive connections with performance and 75% negative connections with the mean of deviations (Figure 1. A and B). Concerning the correlation analysis of

the investigated indices, specialists focused on the relation between physical capacity and performance score in competition. The physical capacity of female gymnasts was measured in accordance with the physical attributes in the GFMT package (MAG, WAG and TeamGym) [1]. Relationships between postural stability, discipline-specific training experience and anthropometric characteristics were established. Nevertheless, causes and effects were not proven [29]. As for women's artistic gymnastics, the relationship between some anthropometric measurements, balance and technical performance on balance beam was examined. A study conducted in Yarmouk University revealed a negative correlation between dynamic balance and anthropometric measurements in the female students. There is also a positive correlation between static balance, body weight and BMI as well [30]. There were investigated possible gender differences regarding the impact of various positions and use of fingers on the quality, control and general efficiency of hands performance [31]. In the process of training the 6-7-year-old acrobats, the relationship between basic performance elements and indices of static and dynamic balance was determined. It has been found that the static and dynamic balance tests can be used to develop individual training programs [32]. Analyzing the relationship between national level female acrobatic gymnasts aged 10 - 13 years and non-athletes, the differences are insignificant. The only exception is a faster medial-lateral swing, eyes open, in the case of the gymnasts. The body mass of the gymnasts was negatively correlated with their anteroposterior swing speed in both visual conditions [33]. The relationship between anthropometric characteristics and the dynamic and static balance in sedentary students was also analyzed. This analysis highlighted a negative correlation between dynamic balance and shank length. A weak positive correlation was identified between dynamic balance and body mass index [8]. In this regard, another study was analyzed. It determined the anthropometry as a success factor for practicing on the balance beam in the young categories of female gymnasts. The regression analysis showed a statistically significant impact of anthropometry on success [6]. Also, the relationship between body mass index (BMI), body weight (BW) and the variables of height and static-dynamic balance of athletes practicing different sports was determined [34]. Differences between male and female gymnasts in bipedal standing position, back standing scale and stork standing scale testing were examined. The results indicated that there are no differences between boys and girls as for height, weight and body mass index. Differences showed a better performance of girls compared to boys [35]. A comparison of static and dynamic balance was made. Their relationship with anthropometric indices was also studied in the athletes from the selected sports. The results of Pearson correlation coefficient showed that significant difference exists only between some variables and the static balance of athletes. These variables are the height, weight, pelvis perimeter, thigh perimeter and tibia perimeter [36]. The daily variation of balance was analyzed between two groups of teenage girls: elite athletes and untrained students. No correlations were found between chronotype, oral temperature variations and balance tests scores [37]. The relationship between static balance tests (Stork and Flamingo) and dynamic balance tests (for example, star excursion balance test –SEBT- and Y balance test) was determined. Statistically significant weak relationship was found between some directions of SEBT, stork balance test and flamingo balance test. No relationship was identified between the Y balance test and both the Stork and Flamingo balance tests [38].

*All the studies mentioned above complete the research results with additional information. Some of them even confirm, for example, the direction of negative correlations.*

The anthropometric indices and the balance parameters measured per age groups were determined. Also, a comparison of the relations between variables was made. Thus, better performances and maintaining inside the space through positive connections and (better) negative connections of the average deviations were observed. The sense of relations (positive or negative) of both strong and insignificant connections determines the influence level of the investigated variables.

## Conclusions

Determining the anthropometric indices highlights the difference in the average age between groups. The relation between the weight and height of the gymnasts has higher values in G2 (9-10 years). The values of FATP (%) are lower and the values of FAPM (kg) are higher in G2. FFM (kg) has higher values in G2 while BMI has better values in G1 (6-8 years). All these differences show the characteristics of age of the female gymnasts.

The results of the comparative analysis of the balance parameters between groups reveal superior performances. They also show lower values of the average vertical deviations (left and right) and lateral deviations (left and right) in the investigated variables.

Comparing the relations between anthropometric indices with the parameters of the static and dynamic bipedal balance, the following elements are highlighted:

- at SB, the G1 has 20% strong connections. It also has 83.3% positive connections with performance and 45.8% negative connections with the mean of deviations. In the case of G2, it lacks of strong connections. This group has 33.3% positive

connections with performance and 25% negative connections with the average deviations;

- at LBB, the G1 has not strong connections. It has 72.2% positive connections with performance and keeping inside the space. It also has 45.8% negative connections of the average deviations. As for the G2, the strong connections are - 7.1%. It lacks of positive connections with the performance and has 75% negative connections with the mean of deviations;

- at VBB, the G1 28.6% has strong connections, positive connections with performance and maintaining inside the space. It also has 45.8% negative connections with the mean of deviations. Regarding the G2, it has 9.5% strong connections, 94.4% positive connections with performance and 75% negative connections with the mean of deviations.

These concrete data can serve as methodological recommendations for future studies used to develop and implement an experimental program. The purpose of this program is to select exercises for improving the balance required by technical training on gymnastics apparatus.

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## Conflict of interest

There are no conflicts of interest to declare.

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## Information about the authors:

**Denis Petran;** https://orcid.org/0009-0003-5740-1331; denis.petran@yahoo.com; Doctoral School of Sports Science and Physical Education, National University of Science and Technology Polytechnic Bucharest, University Center Piteşti (Pitesti, Romania); Aurel Vlaicu University of Arad (Arad, Romania).

**Vladimir Potop;** (Corresponding Author); https://orcid.org/0000-0001-8571-2469; vladimir_potop@yahoo.com; Doctoral School of Sports Science and Physical Education, National University of Science and Technology Polytechnic Bucharest, University Center Piteşti (Pitesti, Romania);  State University of Physical Education and Sport (Chisinau, Republic of Moldova); Department of Physical Education and Sport, National University of Science and Technology Polytechnic Bucharest, University Center Piteşti (Pitesti, Romania).

**Ilie Mihai;** https://orcid.org/0000-0002-5932-1859; ilie112004@yahoo.com; Department of Physical Education and Sport, National University of Science and Technology Polytechnic Bucharest, University Center Piteşti; Pitesti, Romania.

**Anvar Eshtaev;** https://orcid.org/0009-0005-2817-0575; eshtayev1957@gmail.com; Uzbek State University of Physical Culture and Sport; Chirchik, Uzbekistan.

**Mirela Damian;** https://orcid.org/0009-0001-8620-8157; mireladamian13@gmail.com; Ovidius University of Constanta; Constanta, Romania.

**Geanina Toma;** https://orcid.org/0000-0001-6555-4811; geany_gim@yahoo.com; Department of Physical Education and Sport, National University of Science and Technology Polytechnic Bucharest, University Center Piteşti; Pitesti, Romania.