



Disponible en ligne sur

ScienceDirect
www.sciencedirect.com

Elsevier Masson France

EM|consulte
www.em-consulte.com



ORIGINAL ARTICLE

Body composition in high-level female rhythmic gymnasts of different age categories



Composition corporelle de gymnastes rythmiques de haut niveau de différentes catégories d'âge

T. Purenović-Ivanović*, R. Popović, S. Bubanj, R. Stanković

University of Niš, Faculty of Sport and Physical Education, Street Čarnojevića 10a, 18000 Niš, Serbia

Received 20 October 2018; accepted 31 October 2018

Available online 30 November 2018

KEYWORDS

Rhythmic Gymnastics;
Body fat percentage;
Muscle mass percentage;
Skeletal mass percentage;
Success

Summary

Objectives. – The objectives of the research were to establish body composition profile in female rhythmic gymnasts of different age categories so as to test and/or determine the possibility of predicting success in Rhythmic Gymnastics performance on the basis of gymnasts' body composition parameters.

Materials and methods. – Eighty-four elite and sub-elite female rhythmic gymnasts (age: 12.9 ± 3.1 years, body height: 152.5 ± 14.6 cm, body mass: 40.6 ± 12.2 kg), distributed in five age categories (10 beginners, aged 7–9 years; 22 intermediate, aged 9–12 years; 18 advanced, aged 12–14 years; 19 juniors, aged 14–16 years; 15 seniors, aged 16 years and older), volunteered to participate in the study. Their baseline characteristics (age, body height, body mass, body mass index, years of training experience, Success) were established, as well as their body composition profile (body fat, muscle mass and skeletal mass percentage).

Results. – By means of multiple regression analysis the body composition profile's statistically significant influence on Success was established only in the group of junior and intermediate gymnasts ($p < 0.03$ and $p < 0.004$, respectively), with explanation of 46%, i.e. 51% of Success in Rhythmic gymnastics. Also, Regression analysis emphasized the significant independent contributions, to the prediction of the dependent variable, of two independent variables: skeletal mass percentage (juniors: $p = 0.02$, and intermediate RGs: $p = 0.005$) and muscle mass percentage (intermediate RGs: $p = 0.03$), with negative relationship among these independent variables and the dependent one.

© 2018 Elsevier Masson SAS. All rights reserved.

* Corresponding author.

E-mail addresses: tijanapurenovic@gmail.com, tijana.purenovic@yahoo.co.uk (T. Purenović-Ivanović).

MOTS CLÉS

Gymnastique
Rythmique ;
Pourcentage de
masse grasse ;
Pourcentage de
masse musculaire ;
Pourcentage de
masse osseuse ;
Réussite

Résumé

Objectifs. — Les objectifs de la recherche étaient d'établir le profil de la composition corporelle chez des gymnastes rythmiques de différentes catégories d'âge afin de tester et/ou de déterminer la possibilité de prédire la réussite dans les performances rythmiques de gymnastes sur la base des paramètres de leur composition corporelle.

Matériels et méthodes. — Quarante-deux gymnastes d'élite et préélite (âge : 12.9 ± 3.1 ans, taille : 152.5 ± 14.6 cm, la masse corporelle : 40.6 ± 12.2 kg), réparties dans cinq catégories d'âge (10 débutantes, âgées de 7–9 ans ; 22 intermédiaires, âgées de 9–12 ans ; 18 cadettes, âgées de 12–14 ans ; 19 juniors, âgées de 14–16 ans ; 15 seniors, âgées de 16 ans et plus), se sont portées volontaires pour participer à l'étude. Leurs caractéristiques de base (âge, taille, masse corporelle, indice de masse corporelle, années d'expérience de formation, réussite) ont été recueillies, ainsi que leur profil de composition corporelle (le pourcentage de masse grasse, de masse musculaire et de masse osseuse).

Résultats. — L'analyse statistique par régression multiple ne montre une influence significative de la composition corporelle sur la réussite que dans le groupe de gymnastes juniors et intermédiaires (46 %, $p < 0.03$ et 51 %, $p < 0.004$, respectivement). En outre, l'analyse de régression a souligné les contributions importantes, à la prédiction de la variable dépendante, de deux variables indépendantes : pourcentage de masse osseuse (juniors : $p = 0.02$, et intermédiaires : $p = 0.005$) et le pourcentage de masse musculaire (intermédiaires : $p = 0.03$), avec une relation négative entre ces variables indépendantes et dépendantes.

© 2018 Elsevier Masson SAS. Tous droits réservés.

1. Introduction

In the course of a sport's development, it becomes highly desirable to perfect the forms and methods of training that would make possible predicting results in the nearest future, consequently making the identification of such factors as effect this outcome crucial. Much time and effort has been invested into trying to identify the predispositions (features, abilities and characteristics) an athlete should possess in order to achieve top sports results [1]. Numerous research studies describe the preferred characteristics for a model elite athlete, including basic anthropometric dimensions and their ratios, body composition components, and somatotype. Namely, athletes are characterized by a certain "biotype", a particular combination of body composition and build, affording them an advantage relating to success in a given sport.

Two decades ago some researches [2–5] showed that body composition profile is one of the most important factors in the selection process, and necessary for success in sports, especially in the aesthetic ones. The term body composition relates to the composition of the human organism presented via the values and groupings of the given measurable components which it comprises. These include skeletal tissue, muscle tissue, adipose tissue, and the rest (internal organs, blood, etc.) [6]. Skeletal mass is a relevant anthropometric factor which is subject to strong genetic influence, whereas muscle mass and body fat are largely environmentally determined and susceptible to training. Also, it is assumed that body height, body mass, body fat, and bone mass are, as passive components of the locomotor apparatus, potential parameters which, if oversize, may impede movement, including the performance of complex movement structures. On the other hand, the amount of muscle mass, typically accompanied by commensurate muscle strength, is a movement-generating factor, which can therefore, along with coordination and other motor

abilities, be positively linked with the ability to perform complex movement structures and compensate in part for any imbalance brought on by certain morphological characteristics. All of the above indicates that body size and build are significant factors for successful sports performance, especially so in aesthetic sports [7].

In the group of aesthetic sports, Rhythmic Gymnastics (RG) is one of the most demanding because it is an artistic, appearance-oriented and body-conscious sport where success is strongly influenced by visual appeal and body aesthetics. This is partly due to indirect encouragement by the Code of Points aesthetic demands [8], and partly due to the fact that elegance, fluidity and amplitude of movement are essential parts of technical skills [9]. Consequently, RG calls attention to the attractiveness of body presentation (i.e., a slim and fit body), harmony of aesthetic movements, as well as technical performance [10].

In view of the fact that RG places high demands on athletes (especially elite ones) in terms of body size, build, body composition, as well as motor abilities, and is a sport with morphology-related limiting factors that can prevent female rhythmic gymnasts (RGs) from reaching elite-levels, determining RGs' body composition profile emerges as a task of great importance. This research aims to explore whether body composition parameters are reliable measures allied to the performance of RGs, as well as to determine whether body composition profile in RGs of different ages is a predictive factor for successful performance.

1. Materials and methods**2. Participants**

Eighty-four elite and sub-elite RGs, distributed in five age categories (10 beginners, aged 7–9 years; 22 intermediate-level, aged 9–12 years; 18 advanced-level, aged 12–14

years; 19 juniors, aged 14–16 years; 15 seniors, aged 16 years and older), volunteered to participate in this cross-sectional study. All participants are in the “A” program, individual competitors at national and/or international level.

2. Ethical considerations

The study protocol was approved by the local ethics committee (No. 04-610). Written requests were promptly sent to the Expert Committee of the Gymnastics Federation of Montenegro, as well as to the Gymnastics Federation of Serbia, and, after being informed about the study, its scientific value and multiple benefits, approvals were given for the testing to be conducted during the 6th “Montenegro Cup” in 2013 (Budva, Montenegro), and during the 2012 and 2014 National Championships (Belgrade, Serbia). The testing was performed in accordance with the ethical standards of the Helsinki Declaration [11].

2. Measures and procedures

The first part of the testing included 40 top-level Serbian gymnasts and it was performed on December 16th, during the 2012 National Championships held in Belgrade (Serbia). The second one was conducted at the end of June 2013 in Budva (Montenegro), when a further 16 elite gymnasts were tested. During the 2014 National Championships held in Belgrade (Serbia) on October 25th, the testing included 28 top-level Serbian gymnasts.

All the measurements were taken by the authors in optimal climatic conditions, with the participants in their underwear, and according to the methods proposed by the International Biological Program [12]. The Martin anthropometer was used for obtaining the RGs’ body height (in cm), while for obtaining the four diameters (humerus, wrist, femur and ankle breadth; in cm) a bone caliper (Martin type) was used. Most of the body composition parameters (body mass [in kg]), body mass index (BMI, in $\text{kg}\cdot\text{m}^{-2}$), body fat percentage (BF%) and muscle mass percentage (Muscle%) were assessed with a tetrapolar bioelectrical impedance device, Omron BF511 (Kyoto, Japan), and skeletal mass percentage (Skelet%) was obtained via the equation proposed by Matiegka [13]. Data on years of training experience were collected by interviewing the participants. The criterion, i.e. dependent variable, was the participants’ competitive/performance score (Success), which can range from 0.0 to 20.0, according to the Code of Points [8].

2. Statistical analysis

Data were analyzed using the Statistical Package for the Social Sciences, version 21.0 (IBM SPSS 21.0, SPSS Inc, Chicago, USA). Descriptive statistics [average value (Mean), standard deviation (SD), range] were summarized for all variables. Normality was tested using the one-sample Kolmogorov-Smirnov test (K-S). Multiple regression analysis (R: multiple correlation coefficient; R^2 : coefficient of determination of multiple correlation; F: F-test; p : significance of multiple regression) was performed with the aim

of determining the amount of variance in body composition parameters’ influence on the success rate in RGs performance, and for the purpose of determining the independent contributions of each independent variable to the prediction of the dependent variable, i.e. Success, regression analysis was performed (b: regression coefficient; p : statistical significance). The level of significance was set at $p < 0.05$.

1. Results

The baseline characteristics of the sample in total, and subsamples (age categories) are presented in Table 1, and the descriptive statistics data of the measured body composition parameters are presented in Table 2.

Based on the BMI cut-off points for girls of different ages [14], it can be stated that BMI value of most of the RGs ($n = 78$, or 92.86%) is within the normal range, and few of them are below the recommended BMI values (7.14%, i.e. one beginner, four from the intermediate group and one from the advanced group; in the junior and senior groups there are no RGs with low BMI values). Regarding body fat percentage (BF%) established among high-level RGs, compared with the standards of a healthy age- and gender-matched population [15], the situation is as follows: most of the RGs have low body fat ($n = 57$, or 67.86%), 30.95% have normal values of BF% (12 seniors, 11 juniors, one from the advanced group and two from the intermediate group), and only one senior gymnast has high BF%.

Multiple regression analysis revealed the existence of significant influence of the RGs’ body composition profile on the dependent variable (Success) when considering the sample in total [$R = 0.38$, $R^2 = 0.15$, $F(3,80) = 4.5280$, $p < 0.006$] and for the following subsamples: intermediate RGs [$R = 0.71$, $R^2 = 0.51$, $F(3,18) = 6.2235$, $p < 0.004$] and junior RGs [$R = 0.67$, $R^2 = 0.46$, $F(3,15) = 4.1658$, $p < 0.03$]. At univariate level regression analysis revealed significant independent contribution of skeletal mass percentage to the prediction of Success for the sample in total ($p = 0.001$) and in the intermediate and junior group ($p = 0.005$ and $p = 0.02$, respectively), as well as of muscle mass percentage in the intermediate group ($p = 0.03$), with negative relationship among these independent variables and dependent variable ($b = -0.9741$ for Skelet% in juniors, then $b = -0.98961$ and $b = -1.39777$, for Muscle% and Skelet% in intermediate RGs, respectively).

Because RGs’ skeletal mass percentage was established by formula, we have evaluated the possible relations and predictive values of each of the four joints, i.e., bone diameters, on the Success (Table 3). Multiple regression analysis revealed the existence of significant influence of the RGs’ bone diameters on the Success when considering the sample in total [$R = 0.59$, $R^2 = 0.35$, $F(4,63) = 8.6179$, $p < 0.00001$] and for the following subsamples: beginners [$R = 0.98$, $R^2 = 0.97$, $F(4,5) = 38.459$, $p < 0.0006$], advanced RGs [$R = 0.93$, $R^2 = 0.87$, $F(4,11) = 18.503$, $p < 0.00008$] and senior RGs [$R = 0.95$, $R^2 = 0.89$, $F(4,8) = 16.791$, $p < 0.0006$]. At univariate level significant independent contribution of femur breadth (i.e. knee, $p < 0.03$) was established in each subsample but junior RGs, and in the group of senior RGs humerus (i.e. elbow) and wrist breadth, came

Table 1 Baseline characteristics of the study participants.

Age Categories	Variables	Age (yrs)	Body Height (cm)	Body Mass (kg)	BMI (kg·m ⁻²)	Training experience (yrs)	Success (score)
Beginners (<i>n</i> = 10)	Mean ± SD	7.88 ± 0.65	128.84 ± 5.15	23.84 ± 2.18	14.35 ± 0.75	3.35 ± 1.33	9.77 ± 2.91
	Range	7.04–8.94	123.3–138.5	21.2–28.7	12.9–15.3	1.5–5.0	5.65–13.02
	K-S (Sig.)	0.991	0.603	0.783	0.996	0.802	0.473
Intermediate (<i>n</i> = 22)	Mean ± SD	10.73 ± 0.91	142.16 ± 8.01	30.67 ± 4.91	15.09 ± 0.97	5.18 ± 1.32	12.19 ± 3.69
	Range	8.71–11.92	125.1–158.4	22.7–44.5	13.4–17.7	3.0–8.0	7.58 ± 17.81
	K-S (Sig.)	0.842	0.957	0.583	0.954	0.429	0.020 ^a
Advanced (<i>n</i> = 18)	Mean ± SD	12.77 ± 0.85	153.74 ± 7.59	38.82 ± 5.86	16.33 ± 1.33	6.44 ± 1.34	13.08 ± 4.64
	Range	11.38–14.03	142.2–166.4	30.2–50.0	14.5–19.3	4.0–8.0	7.45–19.23
	K-S (Sig.)	0.719	0.850	0.983	0.464	0.367	0.141
Juniors (<i>n</i> = 19)	Mean ± SD	14.62 ± 0.53	164.09 ± 6.22	50.18 ± 4.87	18.62 ± 1.15	8.16 ± 1.86	10.99 ± 1.65
	Range	14.14–15.82	154.4–176.7	41.9–62.7	16.0–20.4	3.0–11.0	7.18–13.38
	K-S (Sig.)	0.305	0.467	0.933	0.751	0.054	0.529
Seniors (<i>n</i> = 15)	Mean ± SD	17.64 ± 1.37	167.34 ± 6.66	56.32 ± 5.28	20.11 ± 1.41	10.6 ± 1.64	13.77 ± 3.53
	Range	16.22–20.34	154.4–178.2	48.8–67.0	17.4–23.3	8.0–14.0	9.45–18.28
	K-S (Sig.)	0.723	0.978	0.988	0.378	0.339	0.392
Total (<i>N</i> = 84)	Mean ± SD	12.94 ± 3.13	152.51 ± 14.61	40.59 ± 12.24	16.96 ± 2.35	6.88 ± 2.72	12.1 ± 3.62
	Range	7.04–20.34	123.3–178.2	21.2–67.0	12.9–23.3	1.5–14.0	5.65–19.23
	K-S (Sig.)	0.935	0.263	0.224	0.079	0.222	0.004 ^a

n, *N*: number of study participants; Mean: average value; SD: standard deviation; K-S: Kolmogorov-Smirnov test; Sig.: significance; yrs: years; BMI: Body Mass Index.

^a Absence of normal distribution (significant at $p=0.05$).

Table 2 Body composition profile of high-level RGs of different age categories.

Variables	Beginners(n= 10)	Intermediate(n= 22)	Advanced(n= 18)	Juniors(n= 19)	Seniors(n= 15)	Total (N= 84)
BF%						
Mean ± SD	8.55 ± 2.75	10.9 ± 3.58	10.05 ± 3.41	16.58 ± 3.57	22.5 ± 4.89	13.79 ± 6.11
Range	5.0–13.0	5.2–20.8	5.4–16.4	8.5–22.8	12.9–32.6	5.0–32.6
K-S (Sig.)	0.955	0.758	0.777	0.966	0.887	0.221
Muscle%						
Mean ± SD	32.7 ± 1.59	34.91 ± 1.54 ^d	37.4 ± 2.2	36.45 ± 1.53	33.55 ± 2.47	35.29 ± 2.47
Range	30.5–36.4	32.4–37.4	31.7–40.0	33.6–39.9	28.9–39.2	28.9–40.0
K-S (Sig.)	0.692	0.883	0.672	0.294	0.753	0.333
Skelet%						
Mean ± SD	20.61 ± 0.39	19.39 ± 1.42 ^b	18.88 ± 0.83	17.14 ± 1.14 ^c	15.8 ± 0.54	18.28 ± 1.86 ^a
Range	19.82–21.47	17.11–23.85	17.59–20.96	15.5–20.64	14.81–16.79	14.81–23.85
K-S (Sig.)	0.084	0.224	0.432	0.538	0.846	0.757

n, N: number of study participants; Mean: average value; SD: standard deviation; K-S: Kolmogorov-Smirnov test; Sig: significance; BF%: body fat percentage; Muscle%: muscle mass percentage; Skelet%: skeletal mass percentage. Note. All measures are in %.

^a Statistically significant influence on the Success ($p < 0.05$): $p = 0.001$.

^b Statistically significant influence on the Success ($p < 0.05$): $p = 0.005$.

^c Statistically significant influence on the Success ($p < 0.05$): $p = 0.02$.

^d Statistically significant influence on the Success ($p < 0.05$): $p = 0.03$.

Table 3 Upper and lower limbs' joints diameters in high-level RGs of different age categories.

Variables	Beginners(n= 10)	Intermediate(n= 22)	Advanced(n= 18)	Juniors(n= 19)	Seniors(n= 15)	Total(N= 84)
Humerus B						
Mean ± SD	5.39 ± 0.46	5.66 ± 0.49	6.02 ± 0.45	6.3 ± 0.27	6.18 ± 0.23 ^d	5.94 ± 0.5
Range	4.8–6.04	4.93–6.84	5.3–6.88	5.7–6.64	5.7–6.48	4.8–6.88
K-S (Sig.)	0.920	0.925	0.957	0.849	0.895	0.120
Wrist B						
Mean ± SD	4.91 ± 0.07	4.96 ± 0.44	5.09 ± 0.39	5.48 ± 0.36	5.47 ± 0.43 ^c	5.22 ± 0.45
Range	4.85–4.99	4.45–6.1	4.5–5.63	4.9–6.12	4.8–6.02	4.45–6.12
K-S (Sig.)	0.040 ^e	0.720	0.999	1.00	0.984	0.000 ^e
Femur B						
Mean ± SD	6.9 ± 0.86 ^b	7.07 ± 0.84 ^d	7.81 ± 0.81 ^a	7.93 ± 0.98	8.55 ± 0.74 ^d	7.67 ± 1.01 ^a
Range	5.66–7.7	5.78–8.4	6.57–9.0	6.1–9.5	7.34–9.5	5.66–9.5
K-S (Sig.)	0.409	0.577	0.861	0.781	0.890	0.763
Ankle B						
Mean ± SD	5.92 ± 0.12	6.17 ± 0.33	6.37 ± 0.29	6.58 ± 0.37	6.59 ± 0.28	6.39 ± 0.37
Range	5.76–6.05	5.65–6.87	5.8–6.8	5.8–7.5	5.99–7.0	5.65–7.5
K-S (Sig.)	0.040 ^e	0.720	1.00	0.933	1.00	0.000 ^e

n, N: number of study participants; Mean: average value; SD: standard deviation; BF%: body fat percentage; Muscle%: muscle mass percentage; Skelet%: skeletal mass percentage. All measures are in cm.

^a Statistically significant influence on the success ($p < 0.05$): $p = 0.00002$.

^b Statistically significant influence on the success ($p < 0.05$): $p = 0.0001$.

^c Statistically significant influence on the success ($p < 0.05$): $p = 0.003$.

^d Statistically significant influence on the success ($p < 0.05$): $p = 0.02$.

^e Absence of normal distribution ($p < 0.05$): $p = 0.02$.

up also as significant predictive factors of performance in RG ($b = -7.9$, $p = 0.02$ and $b = 6.8$, $p = 0.003$, respectively).

1. Discussion

The "ideal" ratio of body composition parameters in a healthy individual implies 15% of skeletal mass, 40% of muscle mass, 20% of body fat, and 25% of the rest. According

to Durašković [16], the relative amount of these tissues in females is as follows: 15–16% of bone tissue, 40–45% of muscle tissue, and 18–20% of fat tissue. The problem is that the paradigms of health and sport are different, and this distinction is important when it comes to the application of body composition data [17]. This means that defining the "normal" or "ideal" body composition standard is very complex if we take into account every single influential factor (genetics, gender, growth and aging, physical activity, health status, etc.). Also, the values of body composition

Table 4 Comparison of this study's and previously reported body composition profiles of RGs of different age categories.

Studies	Sample (n)	Level of performance	Age (yrs)	BF%	Muscle%	Skelet%
This study	10	National and international	7–9	8.55 ± 2.75	32.7 ± 1.59	20.61 ± 0.39
	22		9–12	10.9 ± 3.58	34.91 ± 1.54	19.39 ± 1.42
	18		12–14	10.05 ± 3.41	37.4 ± 2.2	18.88 ± 0.83
	19		14–16	16.58 ± 3.57	36.45 ± 1.53	17.14 ± 1.14
	15		16–20	22.5 ± 4.89	33.55 ± 2.47	15.8 ± 0.54
Quintero et al. [21]	21	National	8–10	10.61 ± 1.6	49.22 ± 2.3	19.24 ± 1.5
	15		11–13	11.01 ± 1.4	48.16 ± 1.9	19.93 ± 2.3
	19		13–14	12.39 ± 2	46.47 ± 10	17.84 ± 1.7
	15		15–19	11.99 ± 1.5	49.89 ± 1.1	17.23 ± 0.8
Vernetta et al. [22]	12	National	9–11	8.88 ± 9.4	50.32 ± 1.8	19.99 ± 1.42
	8		12–15	9.52 ± 0.62	50.4 ± 1.55	19.19 ± 1.54

n: number of study participants; yrs: years; BF%: body fat percentage; Muscle%: muscle mass percentage; Skelet%: skeletal mass percentage. All measures are Mean ± SD, except for Age which is presented as Range.

parameters in athletes are contingent not only upon gender, but upon level of competition, as well as sports discipline [18].

Although we cannot deny the fact that the assessment of body composition in the growing and developing individual is fraught with difficulties because of a range of issues [19], quantifying body composition plays an important role in monitoring athletes' performance, but especially so in RG as a highly aesthetic sport where the tissue composition of the body profoundly affects performance or adjudication [7,20]. Purenović-Ivanović's [10] in-depth review of a number of studies on RGs' morphological characteristics revealed that most authors emphasized the significance of RGs' morphological attributes and body shape. Out of 32 reviewed research papers, only two [21,22] took into account the same body composition model (percentage of body fat, muscle mass and skeletal mass) in RGs of different age categories as in this ongoing study (see Table 4), providing us with an opportunity for some kind of results comparison.

Mostly, elite RGs are characterized by low fat mass essentially caused by the current aesthetic ideal required for complex movements in this sport [23]. It is not rare for RGs to purposely initiate a restrained eating regimen to achieve a desired body fat level or body weight, because they commonly believe that a reduction in weight or body fat will improve sports performance, even when they are well within the norms for elite-level athletes [24]. The origin of this type of behavior lies in the fact that fat provides mass without adding to strength and, as low fat percentage means mechanically more efficient movements, a low body fat percentage is common in elite-level gymnasts. However, too little body fat may result in the deterioration of both health and performance [25], which is something the RGs, as well as their coaches, must also bear in mind. In the current study, the body fat percentage in RGs of the three youngest age categories ranges between 9% and 10%, which is below the cut-off point for healthy age- and gender-matched population [15], but within the range of BF% results (9% to 20%) reported in other similar studies. The situation with BF% in junior and senior RGs in this study implies the presence of higher levels of body fat percentage (>16.5% and >22.5%,

respectively), which is not the case with Spanish RGs of the same age where BF% was around 12%. Regression analysis indicated negative relationship between BF% and Success (except for the group of junior RGs), but not the statistically significant independent contribution of this variable to the prediction of Success.

Most of the body composition studies in general have the quantity and proportion of body fat as the focal point in body composition analysis due to perceived negative relationship of fatness to health, fitness and sports performance [13]. However, this approach overlooks the importance of another body composition component. Namely, knowledge about the changes in an athlete's total and regional skeletal muscle mass is an equally, if not more, significant factor in sport performance. Our study results have confirmed this partially. The regression indicated Muscle% as a significant independent contributor to the prediction of Success in intermediate RGs, but with negative relationship between these two variables. The average value of relative muscle mass among 84 study participants was $35.3 \pm 2.5\%$, with a discernible muscle mass growth trend as one progressed toward the older age categories. Compared with the international level RGs in our study, higher values were identifiable for this parameter in national level RGs from Spain, but increase in muscle mass with development was not. It can be argued that the rise in the level of RG performance demands muscle mass percentage to be within the range of the general female population. Alternatively, these inter-study differences could be attributed to the different types of body composition assessment.

Unlike fat and muscle tissues, which are active components of the locomotor apparatus and highly susceptible to environmental influences, the skeleton is a passive part of the locomotor apparatus and highly influenced by genetic. However, bone tissue is a dynamic type of tissue responding to environmental and endocrine changes. Nevertheless, it is less volatile than either muscle or fat tissue, and its influence upon human performance has been largely neglected [13]. This neglect of and disregard for the importance of determining the role of bone tissue was also identified in the studies considered in the review study by Purenović-Ivanović [10], where only three out of 32 studies took into account

this body composition parameter. This study has confirmed the unjustified neglect of bone tissue, because, according to regression analysis results, Skelet% is a significant independent contributor to the prediction of Success, in intermediate and junior RGs, but with negative relationship between these two variables. The average values of skeletal mass in senior RGs are in the range of suggested values for the population of healthy adult females, with a discernible trend toward decrease in bone tissue percentage, from 20% in younger categories to 15% identified in seniors. Also, when considering upper and lower limbs' joints diameters, their influence on the performance scores was noticed, especially of knee diameter (except in the group of junior RGs), but as well as of elbow and wrist in senior RGs. Namely, Rhythmic Gymnastics is a weight-bearing activity with profound effect on growing bones, resulting in higher bone mass in RGs [26–28]. This “bone loading” sport is enriched by jumps which are osteogenic [29], and can improve bone mineral density (BMD) in young gymnasts [30]. Since one of the typical RG requirements and characteristics is apparatus handling, which implies a high-level of wrist and elbow engagement [31], it's no wonder we obtained these study results.

1. Conclusion

Regarding body composition in athletes in general, the dominant expectations are for low, below-average fat percentage, high muscle mass percentage, and higher bone mass percentage, since it is well documented that exercise helps maintain a “positive” body composition, by maintaining the integrity of bones, maintaining muscle mass and helping to maintain energy balance, without which the progression to excess body fat is more apparent. In Rhythmic Gymnastics, which is an aesthetic, body-conscious sport, in addition to talent, adequate body build and constitution are prerequisites for achieving success. In order to determine the significance and influence of body composition as a predictive factor for successful RG performance, we applied regression analysis on a sample of 84 high-level gymnasts. The confirmation came in the form of 46%, i.e. 51% of explanation of the success in RG performance by body composition profile in junior and intermediate group. Statistical analysis has identified and marked muscle and skeletal mass percentage as significant independent contributors to the prediction of successful RG performance, while the contribution of body fat percentage is missing. However, almost all of the selected body composition parameters have exhibited negative relationship with the sport performance, indicating that under-average body fat, long and slim limbs, but also light weight, are desirable morphological characteristics for high-level performance in RG.

1. Study limitations

This type of profiling can generate a useful database against which talented groups may be compared, although body composition assessment of the growing and developing individual is fraught with difficulty because of a range of issues. However, anthropometric measurement alone does not provide a representative assessment of gymnasts' physical

capabilities necessary for successful performance in Rhythmic Gymnastics. The fact that statistically significant influence of body composition parameters on RG performance was identified only in two subsamples (juniors and intermediate RGs), which are subsamples with a higher number of participants than in the remaining three ($n=19$ and $n=22$, respectively), problematizes the study's results and points to a basic limitation of this study: had a larger number of participants of the appropriate age category been included, different results may have been obtained. The relative skeletal mass assessment by formula is also one of the few study limitations, so as the study design: a longitudinal study design, instead of cross-sectional one, would have enhanced the study's results and conclusion. Also a nutrition survey would have been of great help for evaluation of RGs' dietary intake, its influence on their body composition profile, which would have improved the discussion of the obtained results.

Disclosure of interest

The authors declare that they have no competing interest.

Acknowledgments

This research is part of a project of the Ministry of Science and Technological Development of the Republic of Serbia (No: 179019, Head researcher: Prof. R. Stanković).

The authors would like to thank Ms. Vesna Radonić, the president of the Gymnastics Federation of Montenegro, the organizer of the 6th “Montenegro Cup 2013”, the participating rhythmic gymnasts and coaches of the following RG clubs: “Baltic Flower” (Jelgava, Latvia), “Budva” (Budva, Montenegro), “Ryazan” (Ryazan, Russia), “Sinegoria” (Moscow, Russia), “SDUSHOR N1” (Voronezh, Russia), “Viljandi Sports School” (Viljandi, Estonia) and “Vladimir” (Vladimir, Russia). The authors would also like to extend their deepest gratitude to the Gymnastics Federation of Serbia and its esteemed president Mrs. Milena Reljin Tatić, the organizer of the 2012 and 2014 National Championships, the rhythmic gymnasts and coaches of Serbian RG clubs: “Palilula” (Belgrade), “Paraćin” (Paraćin), “Radnički” (Belgrade), “Ritam” (Belgrade), “Ritam-Pinki” (Belgrade) and “TiM” (Belgrade), who made this study possible.

References

- [1] Baxter-Jones ADG. Growth, maturation, and training. In: Caine DJ, Russell K, Lim L, editors. *Handbook of sport medicine and science, gymnastics*. Oxford, UK: John Wiley & Sons; 2013. p. 17–27.
- [2] López-Benedicto AM, Franco L, Terreros J. Gimnasia rítmica. Evolución fisiológica y antropométrica en una temporada. *Arch Med Deporte* 1991;8(30):127–33 [Rhythmic gymnastics. Physiological and anthropometrical evolution in the season. In Spanish].
- [3] Canda AS, Martín MP, Rubio S. Composición corporal según diferentes métodos antropométricos: un estudio en gimnastas elites. *Arch Med Deporte* 1993;10(37):11–7 [Body composition according to different anthropometric methods: a study in elite gymnasts. In Spanish].
- [4] Lapienza MG, Nuviala RJ, Castillo MC, Giner A. Características morfológicas en gimnastas i en nedadores adolescents.

- Apunts Med Esport 1993;30(118):255–63 [Morphological characteristics in adolescent rhythmic gymnasts and swimmers. In Spanish].
- [5] Berral de la Rosa FJ, Michels G, Berral de la Rosa CJ, Escribano A, Lancho JL. Composición corporal en gimnasia rítmica de elite. *Arch Med Deporte* 1995;12(49):353–9 [Body composition in elite rhythmic gymnastics. In Spanish].
- [6] Ugarković D. Biomedicinske osnove sportske medicine. Novi Sad: FB Print; 2004. RS, [Biomedical foundations of sports medicine. In Serbian].
- [7] Misigoj-Durakovic M. Anthropometry in premenarcheal female esthetic sports athletes and ballerinas. In: Preedy VR, editor. *Handbook of anthropometry*. New York: Springer; 2012. p. NY, 1817–1836.
- [8] International Gymnastics Federation. 2013-2016 code of points (Rhythmic gymnastics). Lausanne, CH: FIG; 2013.
- [9] Purenović-Ivanović T, Popović R, Stefanović N, Aleksić D. Anthropometric profile of Serbian rhythmic gymnasts of different age categories. In: Mokryš M, Badura Š, Lieskovský A, editors. *Proceedings of the 2nd Electronic International Interdisciplinary Conference*. Žilina, SK: EDIS; 2013. p. 291–6.
- [10] Purenović-Ivanović T. Morphological profile of rhythmic gymnasts: systematic review. In: Štěpánek M, Volek R, editors. *Proceedings of the Interdisciplinary scientific international conference for PhD students and assistants "QUAERE 2014"*, 4. Hradec Králové: Magnanimitas; 2014. p. CZ, 955–968.
- [11] World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects; 2002 [Accessed on May 5th 2013. Available from: <http://www.fda.gov/ohrms/dockets/dockets/06d0331/06D-0331-EC20-Attach-1.pdf>].
- [12] Weiner JS, Lourie JA. Human biology, a guide to field methods. *International Biological Programme*. Edinburgh, UK: Blackwell Scientific Publications; 1969.
- [13] Eston R, Hawes M, Martin A, Reilly T. Human body composition. In: Eston R, Reilly T, editors. *Kinanthropometry and exercise physiology laboratory manual: test, procedures and data*. 3rd ed New York: Taylor & Francis e-Library; 2009. p. NY, 3–53.
- [14] Centers for Disease Control Prevention. CDC growth charts: United States. USA: CDC, National Center for Health Statistics; 2000 [Accessed on February 2nd 2017. Available from: <http://www.cdc.gov/growthcharts/data/set2/chart-16.pdf>].
- [15] McCarthy HD, Cole TJ, Fry T, Jebb SA, Prentice AM. Body fat reference curves for children. *Int Journal Obesity* 2006;30(4):598–602.
- [16] Đurašković R. Sportska medicina. Niš, RS: Centar za izdavačku delatnost Fakulteta sporta i fizičkog vaspitanja Univerziteta u Nišu; 2009 [Sports medicine. In Serbian].
- [17] Stewart AD. The concept of body composition and its applications. In: Stewart AD, Sutton L, editors. *Body composition in sport, exercise and health*. New York: Routledge; 2012. p. NY, 1–19.
- [18] Slaughter MH, Christ CB. The role of body physique assessment in sports science. In: Davies PSW, Cole TJ, editors. *Body composition techniques in health and disease*. Cambridge, UK: Cambridge University Press; 1995. p. 166–94.
- [19] Goosey-Tolfrey VL, Sutton L. Body composition in chronic disease and disability. In: Stewart AD, Sutton L, editors. *Body composition in sport, exercise and health*. New York: Routledge; 2012. p. 166–86.
- [20] Ackland TR, Lohman TG, Sundgot-Borgen J, Maughan RJ, Meyer NL, Stewart AD, et al. Current status of body composition assessment in sport. *Sports Med* 2012;42(3):227–49.
- [21] Quintero BR, Martín AP, Henríquez JGG. El perfil antropométrico de la gimnasia rítmica. *Apunts Educ Fis Deporte* 2011;1(103):48–55 [The anthropometric profile of rhythmic gymnasts. In Spanish].
- [22] Vernetta M, Fernández E, López-Bedoya J, Gómez-Landero A, Oña A. Estudio relacional entre el perfil morfológico y estima corporal en la selección Andaluza de gimnasia rítmica deportiva. *Motricidad Eur J Hum Mov* 2011;26:77–92 [The relations between morphological profile and body esteem of Andalusian rhythmic gymnastics team. In Spanish].
- [23] Courteix D, Rieth N, Thomas T, Van Praagh E, Benhamou CL, Collomp K, et al. Preserved bone health in adolescent elite rhythmic gymnasts despite hypoleptinemia. *Horm Res Paediatr* 2007;68(1):20–7.
- [24] Bale P, Goodway J. Performance variables associated with the competitive gymnast. *Sports Med* 1990;10(3):139–45.
- [25] Fornetti WC, Pivarnik JM, Foley JM, Fiechtner JJ. Reliability and validity of body composition measures in female athletes. *J App Physiol* 1999;87(3):1114–22.
- [26] Cassell C, Benedict M, Specker B. Bone mineral density in elite 7–9 yr-old female gymnasts and swimmers. *Med Sci Sports Exerc* 1996;28(10):1243–6.
- [27] Dyson K, Blimkie CJR, Davison KS, Webber CE, Adachi JD. Gymnastics training and bone density in pre-adolescent females. *Med Sci Sports Exerc* 1997;29(4):443–50.
- [28] Courteix D, Lespessailles E, Loiseau Peres S, Obert P, Germain P, Benhamou CL. Effect of physical training on bone mineral density in prepubertal girls: a comparative study between impact-loading and non-impact loading sports. *Osteoporos Int* 1998;8(2):152–8.
- [29] MacKelvie KJ, Khan KM, McKay HA. Is there a critical period for bone response to weight-bearing exercise in children and adolescents? A systematic review. *Br J Sports Med* 2002;36(4):250–7.
- [30] Gruodytė R. Relationships between bone parameters jumping height and hormonal indices in adolescent female athletes. Tartu, EE: Tartu University PRESS; 2010 [Doctoral dissertation].
- [31] Purenović-Ivanović T, Popović R, Stefanović N, Stojiljković N. Morphological characteristics of club-level rhythmic gymnasts: influence of sports experience length. *Facta Univ Phys Educ Sport* 2013;11(3):307–16.