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Original article

BIOELECTRICAL IMPEDANCE ANALYSIS OF BODY COMPOSITION IN FITNESS AND BODYBUILDING COMPETITORS AND RECREATIONAL EXERCISERS

Gligoroski Adam, Zivkovic Vujica, Todorovic Miodrag, Aleksovska Velichkovska Lenche

Faculty of Physical Education, Sport and Health, Ss. Cyril and Methodius University, Skopje, North Macedonia

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Abstract: **Introduction**: Bodybuilding and fitness are sports in which the primary goal is to build and shape a desirable body figure. Consequently, achieving the ideal body composition is the ultimate aspiration of every participant in these sports. Body composition analysis is a valuable tool for assessing body structure and quantifying data for this specific athletic population. **The aim** of this study was to determine and compare the body composition characteristics of fitness and bodybuilding exercisers, both competitive and recreational.

Material and Methods: This study included 89 adult women and men, aged 18 to 37, who were categorized into four groups: female competitors (N = 9), female recreational participants (N = 30), male competitors (N = 15), and male recreational participants (N = 35). Body composition was assessed using the bioelectrical impedance method, specifically the InBody720.

Results: The comparison of bioelectrical impedance analysis (BIA) obesity parameters revealed that BMI did not significantly differ between competitors and recreational participants in both male and female groups. However, competitors (both male and female) displayed a higher volume of body fluids (ICW and ECW). Body fat mass (BFM) was statistically greater in recreational participants when compared to competitors, with females having 18.58 kg vs. 12.47 kg, and males having 16.64 kg vs. 9.81 kg. Mean values of body fat percentage were also statistically higher in recreational participants compared to competitors, with women at 27.25% vs. 16.39% and men at 19.49% vs. 11.97%.

Conclusions: Fitness competitors had a significantly higher fat-free mass and a significantly lower fat component. Recreational exercisers exhibited significantly higher obesity parameters, body fat percentage, and waist-to-hip ratio (WHR) compared to competitors in fitness and bodybuilding.

Keywords: bodybuilding, body fat mass, competitors, fitness, recreational, skeletal muscle mass.

INTRODUCTION

Bodybuilding and fitness are sports focused on achieving a desirable body figure, making optimal body composition the ultimate goal for competitors in these disciplines. The criteria for required muscle mass and body fat levels vary among competitive categories within fitness (1). Competitive bodybuilding assesses the visual presentation of muscle mass, symmetry, muscle definition, and overall physique. The sport primarily emphasizes achieving 'aesthetic' muscle hypertrophy (2). It demands rigorous, years-long training to develop muscular shape, size, definition, and symmetry. During the off-season, many bodybuilders increase their body mass and fat to facilitate lifting heavy weights and intensifying training for muscle mass gains (3, 4). This phase of muscle hypertrophy is succeeded by a shorter phase called muscle definition, wherein subcutaneous fat deposits are reduced, and exercises are aimed at enhancing muscle bundle separation, resulting in an improved visual presentation (5).

Competitors with the lowest body fat percentage, often referred to as the 'leanest,' tend to receive higher rankings. The second crucial factor is muscularity, where competitors with comparable muscle development favor those displaying greater muscle definition. Additionally, proportionality plays a pivotal role; well-developed chest and arm muscles, coupled with a narrow waist, contribute significantly to an appealing body shape among competitors (6).

The primary distinction between recreational and competitive exercisers in various sports, including fitness and bodybuilding, lies in the ultimate objective of their physical activities. Exercise is characterized as planned, regular, repetitive, and structured physical activity (7). When exercise aims to maintain and/or enhance overall health and fitness, it falls under the recreational category (8). Conversely, if the purpose is competition, the physical activity is classified as a sport. Physical activities for competitive purposes typically involve significantly higher volume compared to recreational activities (9).

The current epidemic of physical inactivity and increased awareness of the importance of regular physical activity have led to a surge in individuals engaging in recreational fitness. Moreover, an expanding number of exercise enthusiasts are venturing into the realm of competitive fitness and bodybuilding. Utilizing body composition analysis as a valuable and effective tool for assessing body structure and morphological components allows gathering data for this population of athletes (3).

The aim of this study is to determine and compare the body composition characteristics of fitness and bodybuilding exercisers, both competitive and recreational. Our hypothesis suggests that competitors will exhibit higher fat-free mass and subsequently lower obesity parameters compared to recreational participants.

MATERIAL AND METHODS

Participants

Participants were recruited from the 'Atleta Bodybuilding and Fitness Center' in Skopje, North Macedonia. The study involved 89 adults aged 18 to 37, with a mean age of 26 ± 5.1 years. They were divided into four groups: female competitors (n = 9), female recreational participants (n = 30), male competitors (n = 15), and male recreational participants (n = 35). Competitors had engaged in at least one bodybuilding or fitness competition within the past 12 months; females participated in fitness categories, while males competed in bodybuilding categories. Recreational participants had committed to regular resistance training for a minimum of 12 months, averaging 3 to 5 sessions per week.

Procedure

The body composition analysis took place at the Institute of MEP Physiology and Anthropology, Faculty of Medicine, Skopje, Republic of North Macedonia. This study received approval from the Faculty of PESH, UKIM, Ethical Committee (2021/08-121) and was conducted in adherence to the Code of Ethics of the World Medical Association, also known as the Declaration of Helsinki.

Methods

Height measurements were obtained using a stadiometer, while body mass was recorded using an electronic weighing scale. To assess the body composition of the subjects, bioelectrical impedance analysis (BIA) was performed using the InBody 720 device. This non-invasive technique involves emitting a very low multi-frequency current and measuring the resistance to current flow through various body parts and tissues.

The BIA method considers that tissues with high fluid and electrolyte content, such as blood, conduct electricity well, while fatty tissue and bones impede the electrical signal's conduction. This allows for an assessment of tissue composition.

While the BIA device offers a wealth of information about body composition, this study specifically analyzed the following parameters:

- Body weight (BW)
- Body mass index (BMI)
- Body fluids: intracellular water (ICW) and extracellular water (ECW)
- Protein and mineral components
- Body fat percentage (BF%)
- Body fat mass (BFM)
- Skeletal muscle mass (SMM)
- Waist-to-hip ratio (WHR)
- Soft lean mass (SLM)
- Fat-free mass (FFM)

Data analysis

The analysis was performed using the Statistical Package for Social Sciences (SPSS) version 23.0. For all variables examined, the following statistical parameters were calculated: Arithmetic means (X), Standard deviations (SD), Minimum scores (min), Maximum scores (max), Skewness to assess the distribution of results, Kurtosis to evaluate the distribution of results, The Kolmogorov-Smirnov test (according to Liliefors) to test the normality of the result distribution, Differences in anthropometric variables were determined through analysis of variance (ANOVA). The level of statistical significance was set at $p < 0.05$.

RESULTS

The variables derived from anthropometry and BIA analysis are categorized for male and female par-

ticipants, and divided into subgroups based on their training levels in recreation and competition.

Table 1 presents descriptive statistics for the anthropometric indicators of competitive and recreational women. A comparison of height between female competitors and recreational women revealed a statistically significant difference in favor of female competitors (170.9 cm vs. 164.7 cm). However, there was no statistically significant difference in weight between recreational women and competitive women (62.3 kg vs. 62.5 kg).

The difference in body mass index (BMI) between recreationally exercising men and competitive men was not statistically significant (25.86 vs 25.81). A similar pattern was observed in the female group (23.03 vs 22.51). Female competitors displayed sig-

Table 1. *Descriptive statistics for BIA indicators in the group of women: recreational and competitive*

	Women recreationists			Women competitors			Sig.
	Mean ± SD	min	max	Mean ± SD	min	max	p
Height * (cm)	164.73 ± 5.87	155.0	179.0	170.89 ± 6.2	164.0	182.0	0.005
Weight (kg)	62.54 ± 10.16	49.0	87.6	62.27 ± 7.5	55.0	76.0	0.943
BMI (kg/m^2)	23.03 ± 3.91	18.6	34.2	22.51 ± 2.5	20.8	28.0	0.659
ICW * (l)	20.23 ± 1.93	17.2	24.9	23.45 ± 3.1	20.0	28.6	0.010
ECW * (l)	12.36 ± 1.19	10.3	15.5	14.23 ± 1.8	12.2	17.5	0.009
Protein * (kg)	8.79 ± 0.83	7.4	10.8	10.17 ± 1.5	8.6	12.8	0.041
Mineral * (kg)	3.22 ± 0.36	2.7	4.1	3.81 ± 1.1	2.9	6.6	0.009
BFM * (kg)	18.58 ± 8.67	6.3	40.4	12.47 ± 5.4	3.7	23.0	0.027
SMM * (kg)	24.4 ± 2.29	20.4	29.9	29.03 ± 4.3	24.0	37.4	0.019
BF% *	27.25 ± 9.09	12.5	46.1	16.39 ± 2.7	13.4	21.8	0.000
WHR	0.87 ± 0.07	0.8	1.0	0.83 ± 0.04	0.8	0.9	0.117
SLM * (kg)	41.93 ± 3.79	35.4	51.1	49.23 ± 8.2	41.3	66.4	0.003
FFM * (kg)	44.51 ± 4.04	37.6	54.3	52.22 ± 8.7	43.9	70.4	0.002

BMI – body mass index; ICW – Intracellular water; ECW – extracellular water; BFM – body fat mass; SMM – skeletal muscle mass; BF% - body fat percent; WHR – waist to hip ratio; SLM – soft lean mass; FFM – fat free mass; * - statistically significant difference ($p < 0.05$)

Table 2*. Descriptive statistics for BIA indicators in the group of men: recreationists and competitors*

	Men recreationists			Men competitors			Sig.
	Mean ± SD	min	P	Mean ± SD	min	max	p
Height (cm)	178.60 ± 4.9	168.0	188.0	177.23 ± 6.1	165.5	187.0	0.430
Weight (kg)	82.78 ± 10.5	61.8	105.0	81.04 ± 10.6	62.6	97.8	0.578
BMI (kg/m^2)	25.86 ± 2.7	20.8	34.1	25.81 ± 2.1	22.4	29.4	0.955
ICW (l) *	30.06 ± 3,4	23.8	37.5	33.03 ± 4.5	24.4	39.8	0.003
ECW (l) *	17.55 ± 1.9	13.9	22.1	19.54 ± 2.4	14.4	22.8	0.001
Protein (kg)	13.62 ± 2.2	10.3	19.3	14.35 ± 1.9	10.6	17.2	0.179
Mineral (kg) *	4.43 ± 0.5	3.4	5.6	4.81 ± 0.7	3.4	5.8	0.037
BFM (kg)*	16.64 ± 7.3	5.1	35.0	9.81 ± 2.9	3.7	14.6	0.003
SMM (kg)*	37.48 ± 6.5	29.0	65.6	40.71 ± 5.7	29.9	49.9	0.043
PBF% (kg)*	19.49 ± 6.5	8.1	34.8	11.97 ± 3.5	5.3	20.0	0.001
WHR (kg)*	0.90 ± 0.1	0.8	1.2	0.82 ± 0.05	0.7	0.9	0.001
SLM (kg)*	60.75 ± 7.0	48.5	76.8	70.41 ± 7.3	61.8	80.7	0.000
FFM (kg) *	64.49	51.3	81.3	75.19 ± 7.4	65.3	85.5	0.000

BMI – body mass index; ICW – Intracellular water; ECW – extracellular water; BFM – body fat mass; SMM – skeletal muscle mass; BF% - body fat percent; WHR – waist to hip ratio; SLM – soft lean mass; FFM – fat free mass; * - statistically significant difference ($p < 0.05$)

nificantly higher amounts of intracellular and extracellular water (ICW: 23.5 liters vs. 20.2 liters; ECW: 14.2 liters vs. 12.3 liters). Moreover, female competitors exhibited higher levels of the protein component (10.2 kg vs. 8.8 kg) and mineral component (3.8 kg vs. 3.2 kg). Skeletal muscle mass (SMM), lean body mass, and soft lean mass (SLM) were significantly higher in female competitors compared to recreational women.

Regarding body fat, recreational women had higher levels in kilograms (18.6 kg vs. 12.5 kg), while female competitors had significantly lower body fat percentage (16.4% vs. 27.3%). However, the waist-to-hip ratio did not show a statistically significant difference between the two groups (0.83 vs. 0.87).

Table 2 displays descriptive statistics and significant differences in anthropometric indicators obtained by BIA analysis among male respondents, including competitors and recreational exercisers. Both male groups, competitors and recreationists, showed similar average height (177.2 cm vs. 178.6 cm) and weight, with no statistically significant difference. BMI values did not significantly differ between men exercising recreationally and those who competed (around 25.8).

Male competitors demonstrated significantly higher amounts of body water (ICW = 33.3 liters vs. 30.05 liters; ECW = 19.5 liters vs. 17.5 liters) and a higher mineral component (4.8 kg vs. 4.4 kg). In contrast, recreational male participants had higher body fat in kilograms (16.6 kg vs. 9.8 kg) and a higher body fat percentage (19.5% vs. 11.9%) compared to male competitors.

DISCUSSION

The study aimed to explore morphological characteristics using bioelectrical analysis of body composition in individuals engaged in fitness or bodybuilding, either recreationally or competitively.

Analysis of female fitness competitors revealed optimal body composition, with a lean component (FFM) constituting approximately 84% of their total body mass. Their skeletal muscle mass accounted for about 47% of their total weight, signifying well-developed musculature. Female competitors maintained an average body fat percentage of 16%, showcasing their fitness. In contrast, recreational female athletes, despite similar average weight and normal BMI, displayed a high average body fat percentage of around 27%, indicating a wider range of values (ranging from 16% to 46%). Their relative lean body mass and skeletal muscle mass were 71% and 39%, respectively.

In the case of male fitness competitors, an analysis of their body composition showed that they had a normal body mass index but were near the upper limit (BMI = 25.08) due to a notably high lean component. The average muscle mass accounted for approximately 50% of their total weight. The fat component was at the lower end of BIA values for healthy, inactive individuals, and was appropriate for fitness athletes, averaging around 12% (ranging from 5% to 20%). The thickest skinfold measurement among the competitors was observed on the thigh, while the thinnest was on the forearm.

For recreational exercisers, an analysis of their body composition indicated an average value of the body mass index slightly above the upper limit of normal values (BMI = 25.8). The average body fat percentage was approximately 19%, which falls within the normal BIA values (ranging from 15% to 20%). The relative value of lean body mass and skeletal muscle mass was 78% and 45%, respectively.

In the realm of competitive bodybuilding, the lack of adipose tissue, or a low percentage of the fat component, is a sought-after characteristic. Competitors often employ nutritional strategies to reduce body fat well below normal levels, frequently not exceeding 7% (10, 11). A study of anthropometric traits in professional and amateur bodybuilders in Poland revealed that professionals typically had larger limb circumferences and smaller skinfold sizes. BMI was significantly higher in professionals, while body fat percentage was notably higher in amateurs, measuring 10.67% vs. 20.05%, as determined by BIA (12).

According to the recommendations of the American College of Sports Medicine (ACSM), the optimal representation of adipose tissue in athletes should be around 12%. It's important to note that this recommendation is relatively general because different types of sports, based on their physical demands, result in varying body compositions in athletes (13). Notably, bodybuilders in the immediate pre-competition phase often showcase extremely low body fat levels, well below the recommended ranges for healthy sedentary individuals (10-20% for men and 15-25% for women according to the BIA method). This drastic reduction in body fat is a characteristic strategy observed in bodybuilders as they approach competition, emphasizing the aesthetic aspect of their physique over standard health-related guidelines.

Numerous studies on body fat percentage in bodybuilders from different countries have consistently shown very low body fat percentages. For instance, in the USA in 1992 (14), men in 1990 had 6.0 ± 1.8% body fat, and women had 9.8 ± 1.5% (15). In Great Britain, body fat percentages ranged from 4.1% to 10.9% (16), and in Poland, men had 5.68% body fat according to skinfold measurements or 10.67% according to the BIA method (12). A study in Brazil found that male

physique competitors had body fat percentages of 4% and 8.6%, while in the wellness category, percentages of 17.3% and 8.9% were observed (17).

During competitions, the representation of adipose tissue in the body composition of bodybuilders typically ranges from 3% to 6% in men and 9% to 12% in women (18). This extremely low body fat percentage is necessary for achieving good muscle separation and definition, which is a crucial factor for successful performance and placement in both bodybuilding and fitness competitions (19).

Morphological characteristics and body composition have been analyzed in bodybuilders in relation to different phases of training. In one of the initial studies on this topic, where body mass was estimated using the Brozek anthropometric method, it was found that during the off-season, bodybuilders had a body fat percentage of 9.7 ± 3.1%, whereas during the competitive season, their body fat percentage dropped to 5.9 ± 3.2%. The change in female bodybuilders was from a body fat percentage of 16.8 ± 4.5% in the off-season to 9.5 ± 3.5% during competition. Furthermore, the subjects in this study experienced a slight decrease in lean body mass, with men going from 82.7 kg to 81.1 kg and women from 48.5 kg to 47.4 kg (20).

An examination of eating habits and self-perception among 120 bodybuilders from Turkey, divided into two groups, competitors and non-competitors, revealed the following morphological characteristics: Fat-Free Mass Index (FFMI) was 24.09 ± 3.05 kg/m^2 for competitors and 21.18 ± 1.93 kg/m^2 for non-competitors. The percentage of fat tissue in the entire group was 13.57 ± 4% (21). An analysis of Tunisian weightlifters showed that they had a BMI of 21.5 ± 3.35, body fat percentage (BF%) of 12.28 ± 5.22, and lean body mass (LBM) of 87.73 ± 5.22 kg (22). Heyward's research in 1989 compared the body composition of recreational and professional athletes, revealing that in men, the percentage of fat tissue was 9.7% for recreational athletes and 5.9% for professionals, while in women, it was 16.85% for recreational athletes and 9.5% for professionals (20).

A case study of a natural bodybuilder tracked changes in the cardiovascular system, body composition, muscle strength, and blood parameters over 12 months, including 6 months pre-competition and 6 months post-competition. During the pre-competition period, fat tissue decreased from 14.8% to 4.5% and then returned to the initial value of 14.6%. Muscle strength, blood pressure, and heart rate all decreased. Psychometric parameters of mood disturbance increased from 6 to 43 units during the preparation period and then corrected to 4 units during the 6-month post-competition period (23). In another case study of a natural bodybuilder, a 21-year-old Englishman reduced his body fat percentage from 14.8% to 6.8% during 14 weeks of training. Muscle strength showed a slight decline, while the mood swing test showed no significant difference (24).

Physique competitions are sporting events in which aesthetic appearance and posing ability are prioritized over physical performance. Female physique competitors are required to have a very lean body mass (LBM) and an extremely low fat component for the competition. Achieving this requires competitors to reduce their energy intake over an extended period, followed by intensive training regimes that result in a sudden weight loss at the end of the pre-competitive phase (25). In a study on the anthropometric profile of five elite Australian female bodybuilders, it was found that 12 weeks before the competition, the percentage of fat tissue determined by the densitometric method (DEXA) was 18.9 ± 4.6%, and 24 hours before the competition, it reduced to 12.4 ± 4.6%. The thickest skinfold measurement was on the front of the thigh, measuring 19.8 ± 5.1 mm, and before the competition, it decreased to 13.3 ± 3.2 mm. In this group of female bodybuilders, the mesomorphic somatotype dominated, followed by the endomorphic and least ectomorphic (26).

While published data in the field of anthropometry and body composition analysis may vary due to different techniques used, the majority of reports concur that bodybuilding and fitness competitors, both male and female, achieve exceptionally low values of body fat.

CONCLUSIONS

The majority of our participants, whether they were recreational exercisers or competitors, exhibited body components within the normal range for a healthy population. Fitness competitors displayed a significantly higher fat-free (muscle) component and a notably lower body fat component. In contrast, recreational exercisers had significantly higher obesity-related parameters, including BMI, body fat percentage (BF%), and waist-to-hip ratio (WHR), compared to their counterparts in fitness and bodybuilding competitions. The body composition parameters obtained through bioelectrical impedance analysis proved to be sensitive indicators of differences between the two studied groups, competitors and recreational exercisers.

Considering the comprehensive findings of this research, it can be concluded that engaging in fitness activities positively influences body composition. This effect is characterized by the optimization of body components, such as an increase in muscle mass and the maintenance of the fat component within desired

limits. Those who participate in competitive activities in the fields of bodybuilding and fitness tend to achieve the ideal body components, particularly a high muscle component and lower fat component.

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Sažetak

ANALIZA TELESNOG SASTAVA POMOĆU BIOELEKTRIČNE IMPEDANSE KOD FITNES I BODIBILDING TAKMIČARA I REKREATIVACA

Gligoroski Adam, Zivkovic Vujica, Todorovic Miodrag, Aleksovska Velichkovska Lenche

Fakultet fizičkog vaspitanja, sporta i zdravlja, Univerzitet Sv. Ćirila i Metodija, Skoplje, S. Makedonija

Uvod: Bodibilding i fitnes su sportovi u kojima je primarni cilj izgraditi i oblikovati željeni telesni izgled. Shodno tome, postizanje idealne telesne kompozicije je krajnja aspiracija svakog učesnika u ovim sportovima. Analiza telesne kompozicije je vredan alat za procenu strukture tela i kvantifikaciju podataka za ovu specifičnu sportsku populaciju. Cilj ovog istraživanja bio je da se utvrde i uporede karakteristike telesne kompozicije vežbača fitnesa i bodibildinga, kako konkurentnih tako i rekreativnih.

Materijal i metode: U ovo istraživanje bilo je uključeno 89 odraslih žena i muškaraca, uzrasta od 18 do 37 godina, koji su bili kategorizovani u četiri grupe: ženski takmičari (N = 9), ženski rekreativni učesnici (N = 30), muški takmičari (N = 15) i muški rekreativni učesnici (N = 35). Telesna kompozicija je procenjena korišćenjem metode bioelektrične impedancije, posebno uređajem InBody720.

Rezultati: Poređenje parametara gojaznosti bioelektričnom impedancijom (BIA) pokazalo je da indeks telesne mase (BMI) nije značajno razlikovao takmičare i rekreativne učesnike, kako kod muškaraca tako i kod žena. Međutim, takmičari (i muški i ženski) su pokazali veći volumen tečnosti u telu (ICW i ECW). Masno tkivo tela (BFM) je bilo statistički veće kod rekreativnih učesnika u poređenju sa takmičarima, pri čemu su žene imale 18,58 kg naspram 12,47 kg, a muškarci 16,64 kg naspram 9,81 kg. Srednje vrednosti procenta telesne masti su takođe statistički bile više kod rekreativnih učesnika u poređenju sa takmičarima, pri čemu su žene imale 27,25% naspram 16,39%, a muškarci 19,49% naspram 11,97%.

Zaključak: Takmičari u fitnesu imali su značajno veću masu bez masti i značajno niži procenat masnog tkiva. Rekreativni vežbači su pokazali značajno više parametre gojaznosti, procenat telesne masti i odnos struka i bokova (WHR) u poređenju sa takmičarima u fitnesu i bodybuildingu.

Ključne reči: bodibilding, telesne masti, takmičari, fitnes, rekreativci, skeletna mišićna masa.

REFERENCES

1. Silva PT, de Soza T R, De Rose EH. Body composition and proportionality of elite bodybuilders in Brazil. Rev Bras Med Esporte. 2003; 9(6): 403-7.

2. Linder F. Life is art and seeing the promise of big bodies. Am Ethnol. 2007; 34(3): 451-72. doi: 10.1525/ae.2007.34.3.451.

3. Graybeal JB, Moore LM, Cruz MR, Tinsley GM. Body composition assessment in male and female bodybuilders: A 4-Compartement model comparison of dual-energy X-ray absorptiometry and impedance-based devices. J Strength Cond Res. 2020; 34(6): 1676-89. doi: 10.1519/JSC.0000000000002831.

4. Iraki J, Fitschen P, Espinar S, Helms E. Nutrition recommendations for bodybuilders in the off-season: A narrative review. Sports (Basel). 2019; 7(7): 154-73. doi: 10.3390/sports7070154.

5. Ogita S. The effects of body composition differences on placement at bodybuilding competition among male amateur bodybuilders. Research Papers. 2010. Available on: https://opensiuc.lib.siu.edu/gs_rp/26/.

6. Tykhorskyi T, Dzhym V, Mykolay G, Dzhym E. Analysis of the morphological changes in beginning bodybuilders due to resistance training. J Phys Edu Sport. 2018; 18(supp 1): 382-6. doi: 10.7752/jpes.2018.s152.

7. World Health Organization (WHO). Global recommendations on physical activity for health. Geneva (Switzerland). World Health Organization; 2010. Available: https://www.who.int/publications/i/item/9789241599979.

8. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 1985; 100(2), 126-31.

9. Can S, Demirkan E, Ercan S. The effects of exercise preference on body fat and body mass index by self-report. Univ J Edu Res. 2019; 7(1): 293-7. doi:10.13189/ujer.2019.070137.

10. de Moraes WMAM, de Almeida FN, Dos Santos LEA, Cavalcante KDG, Santos HO, Navalta JW, et al. Carbohydrate loading practice in bodybuilders: effects on muscle thickness, photo silhouette scores, mood states and gastrointestinal symptoms. J Sports Sci Med. 2019; 18(4): 772-9.

11. Spendlove J, Mitchell L, Gifford J, Hackett D, Slater G, Cobley S, et al. Dietary intake of competitive bodybuilders. Sports Med. 2015;45:1041-63. doi: 10.1007/s40279-015-0329-4.

12. Makiel K, Suder A, Kasza S, Kubasiak K. Body composition and dietary patterns in professional and amateur bodybuilders. Anthrop Rev. 2020; 83(2): 225-38. doi: 10.2478/anre-2020-0016.

13. American College of Sports Medicine. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc. 2009; 41(3): 687-708. doi: 10.1249/MSS.0b013e3181915670.

14. Bamman MM, Hunter GR, Newton LE, Roney RK, Kaled MA. Changes in body composition, diet, and strength of bodybuilders during the 12 weeks prior to competition. J Sports Med Phys Fitness. 1993; 33(4): 383-91.

15. Katch VL, Katch FI, Moffatt R, Gittleson M. Muscular development and lean body weight in bodybuilders and weight lifters. Med Sci Sports Exerc. 1980; 12: 340-4.

16. Chappell AJ, Simper T, Helms E. Nutritional strategies of British professional and amateur natural bodybuilders during competition preparation. J Int Soc Sports Nutr. 2019; 16(1): 35. doi: 10.1186/s12970-019-0302-y.

17. De Souza DC, dos Santos JAB, de Jesus DM, Gentil P. Biochemical profile and body composition alteration of amateur bodybuilders during the pre-contest period. J Funct Morphol Kinesiol. 2018; 3(2): 26. doi: 10.3390/JFMK3020026.

18. Viana R, Gentil P, Brasileiro E, Pimentel G, Vancini R, Andrade M, de Lira C. High resistance training volume and low caloric and protein intake are associated with detrimental alterations in body composition of an amateur bodybuilder using anabolic steroids: a case report. J Funct Morphol Kinesiol. 2017; 2(4): 37. doi: 103390/jfmk2040037.

19. Sandoval WM, Heyward VH, Lyons TI. Comparison of body composition, exercise and nutritional profiles of female and male bodybuilders at competition. J Sports Med Phys Fitness. 1989; 29(1): 63-70.

20. Heyward VH, Sandoval WM, Colville BC. Anthropometric, body composition and nutritional profiles of bodybuilders during training. J Appl Sci Res. 1989: 3(2): 22-9.

21. Devrim A, Bilgic P, Hongu N. Is there a relationship between body image perception, eating disorders, and muscle dysmorphic disorders in male bodybuilders? Am J Men's Health. 2018; 12(5): 1746-58. doi: 10.1177/1557988318786868.

22. Beji RS, Ksouri WM, Ali RB, Saidi O, Ksouri R, Jameleddine S. Evaluation of nutritional status and body composition of young Tunisian weightlifters. Tunis Med. 2016; 94(2): 112-7.

23. Rossow LM, Fukuda DH, Fahs CA, Loenneke JP, Stout JR.Natural bodybuilding competition preparation and recovery: a 12-month case study. Int J Sport Physiol Perform. 2013; 8(5): 582–92. doi: 10.1123/ijspp.8.5.582.

24. Robinson SL, Lambeth-Mansell A, Gilibrand G, Smith-Ryan BL. A nutrition and condition intervention for natural bodybuilding contestant preparation: case study. JISSN. 2015; 12:20. doi: 10.1186/s12970-015-0083-x.

25. Alwan N, Moss SL, Elliot-Sale KJ, Davies IG. A narrative review on female physique athletes: The physiological and psychological implications of weight management practices. Int J Sport Nutr Exerc Met. 2019; 29(6): 682-9. doi: 10.1123/ijsnem.2019-0037.

26. Van der Ploeg GE, Brooks AG, Withers RT, Dollman J, Leaney F, Chatterton BE. Body composition changes in female bodybuilders during preparation for competition. Eur J Clin Nutr. 2001; 55(4): 268-77. doi: 10.1038/sj.ejcn.1601154.

Correspondence to/Autor za korespondenciju
Adam Gligoroski
Doctoral student at Faculty of Physical Education, Sport and Health,
Ss. Cyril and Methodius University, Skopje, Republic of N. Macedonia
email: adamatleta@hotmail.com
mobile phone: 0038975435530
ORCID: 0009-0000-0628-1235

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