10.2478/mbs-2013-0034

Medical and Biological Sciences, 2013, 27/4, 39-45

ORIGINAL ARTICLE / PRACA ORYGINALNA

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MORPHOLOGICAL AND FUNCTIONAL EFFECTS OF THE RESISTANCE TRAINING AND HIGH PHYSICAL ACTIVITY OF RECREATIONAL TYPE IN YOUNG MEN

MORFOLOGICZNE I FUNKCJONALNE EFEKTY TRENINGU OPOROWEGO I WYSOKIEJ AKTYWNOŚCI FIZYCZNEJ O CHARAKTERZE REKREACYJNYM U MŁODYCH MĘŻCZYZN

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Summary

The influence of different types of physical activity on body composition, muscle function, bones and joints is indisputable. It also shapes physical efficiency in different periods of ontogenesis. The aim of this research was to evaluate the morphological and functional effects of the resistance training used by amateur bodybuilders, with reference to subjects declaring high physical activity of different type performed as recreation. Research data was taken from the measurement of 31 amateur bodybuilders and 33 students attending the University School of Physical Education, who declared high physical activity of recreational type. The age of the subjects ranged from 21 to 24 years old. The anthropometric features were examined. Fat mass was assessed on the basis on the skinfolds thickness. The level of three body build components: endomorphy, mesomorphy and ectomorphy were determined with used of Sheldon method. In order to compute static strength in forearm muscles, researchers measured the handgrip of right and left hands. The examined group of students and bodybuilders did not reveal any statistically significant differences in mean body height and components, e.g. length of trunk and lower limbs. However, observable differences were recorded in reference to body mass, which was higher for the group of bodybuilders. The bodybuilders were characterised by significantly wider shoulders and chest. Also, the values of wrist and knee bone breadth were higher in comparison to the group of students. The two groups differed distinctly in muscle development within the upper trunk area, shoulder girdle and upper limbs. Endomorphy and mesomorphy obtained higher values in bodybuilders, while in students they were characterised by greater body slenderness. Handgrip strength was significantly higher for bodybuilders. The research confirmed that both recreational physical activities (jogging, swimming, cycling) and resistance training have a positive influence on the correct body composition and improvement of respiratory and strength capabilities.

Streszczenie

Różnorodne ćwiczenia fizyczne mają znaczący wpływ na skład ciała, funkcjonowanie mięśni, kości i stawów oraz kształtowanie wydolności fizycznej człowieka w różnych okresach ontogenezy. Celem podjętych badań była ocena efektów morfologicznych i funkcjonalnych treningu oporowego stosowanego przez kulturystów amatorów na tle osób deklarujących wysoką aktywność fizyczną o charakterze rekreacyjnym. Materiał badawczy stanowią wyniki pomiarów 31 kulturystów amatorów oraz 33 studentów Akademii Wychowania Fizycznego, którzy deklarowali wysoką aktywność fizyczną o charakterze rekreacyjnym. Wiek badanych mieści się w przedziale 21-24 lata. Do badań uwzględniono cechy antropometryczne (wysokości, szerokości, obwody i fałdy skórno-tłuszczowe).

Zawartość tłuszczu określono metodą antropometryczną. Określono poziom rozwoju trzech komponentów budowy: endomorfii, mezomorfii i ektomorfii. Zmierzono także siłę ścisku ręki prawej i lewej, która określa siłę statyczną mięśni przedramienia. Średnia wysokość ciała ani jej składowe, tzn. długość korpusu ciała i kończyn dolnych nie różnią istotnie badanych kulturystów i studentów. Wyraźne różnice występują natomiast w przypadku masy ciała, która kształtuje się na korzyść kulturystów. Kulturyści dominują istotnie nad grupą studentów pod względem szerokości barków, klatki piersiowej oraz szerokości międzyrylcowej i kolanowej. Bardzo wyraźnie różnią obie grupy także cechy opisujące rozwój umięśnienia w obrębie górnej części tułowia, obręczy barkowej i kończyn górnych. Endomorfia i mezomorfia osiągają wyższe wartości u kulturystów. Natomiast studenci charakteryzują się większą smukłością ciała. Siła ścisku ręki prawej i lewej jest istotnie wyższa u kulturystów. Badania dowiodły, że zarówno systematyczne ćwiczenia fizyczne o charakterze rekreacyjnym (biegi, pływanie, jazda na rowerze), jak i trening oporowy wpływają pozytywnie na kształtowanie się prawidłowych stosunków tkankowych, poprawę sprawności oddechowej oraz możliwości siłowych człowieka.

Key words: amateur bodybuilders, students, anthropometric measurements, functional features
Słowa kluczowe: kulturyści amatorzy, studenci, pomiary antropometryczne, cechy funkcjonalne

INTRODUCTION

The proper physical development of young people is determined by the systematic performance of physical activities. Exercises performed by the elderly help to improve and sustain their health. The influence of different types of physical activity on body composition, muscle function, bones and joints is indisputable. It also shapes physical efficiency in different periods of ontogenesis. Much research has proven that appropriately selected physical activity decreases the risk of premature death and also helps prevent coronary artery diseases, high blood pressure, cancers and diabetes. Resistance training of inspiratory muscles can constitute one of the additional means supporting the circulatory-respiratory system of an athlete. Resistance exercise improves muscle mass, strength, endurance and physical fitness [1]. What is more, it increases strength in reference to mass [2]. This type of exercise dominates the practice of bodybuilding. The essence of bodybuilding is to shape the body through the hypertrophy of skeletal muscles, results being obtained through the performance of physical exercise with a load. Competitors shape their bodies through the increase of mass and development of mesomorphy [3]. Simultaneously, these contestants aim to reduce subscapular fat to maximum level in order to present the muscles. However, during off-season and at the season's beginning, morphological results may differ. Out of off-season the main purpose of the strength training is the muscle hypertrophy. During that period, contestants are likely to put on greater amounts of fat tissue. However, preparations before the season's beginning force them to decrease fat tissue while simultaneously retaining as much large muscle mass as possible. These changes are the result of certain diet modifications, as well as training [4]. Better access to fitness clubs and gyms has increased the popularity of training and become a common type of recreation. Even though the majority of people practicing recreational sports focus mainly on the improvement of their figure, there are those who treat strength training as a way to improve their health and physical condition.

Therefore, the aim of this research was to evaluate the morphological and functional effects of the resistance training used by bodybuilders, with reference to subjects declaring high physical activity of different type performed as recreation.

MATERIAL AND METHODS

Research data was taken from the measurement of 31 amateur bodybuilders and 33 students attending the University School of Physical Education, who declared high physical activity of recreational type. The age of the subjects ranged from 21 to 24 years old (bodybuilders: 22.2± 2.39 years; students: 21.8±2.14 years)). The bodybuilders' training period was diversified and ranged from 3 to 8 years (4.9±1.6 years). Each exercises at least 1.5 hours, four times per week. The students were physically active for at least 1.5 hours, 3 times per week. They practiced running, swimming, cycling, team games and occasionally trained at the gym. Diet of the subjects participating in the research was balanced and they did not use any dietary supplements.

The measurements were taken Martin's technique. An anthropometer was used to determine body height (B-v), sitting height (B-vs) and the length of lower limbs (B-sy). A spreading calliper was applied to measure the width of: biacromial (a-a), bideltoideum (dl-dl), biiliocristal (ic-ic) and chest depth (xi-ths) and width (thl-thl). Moreover, the breadths of epiphysis of

the following bones were measured: elbow (cl-cm), knee (epl-epm), interstyloid (spr-spu). Digital scales were used to measure body mass and anthropometric tape was used to determine the circumference of the following body parts: neck, shoulder girdle, chest, waist, arm in tension and at rest, minimum and maximum circumference of forearm, hips, maximum of a thigh and maximum and minimum of a calf. A Harpenden skinfold calliper, with a constant spring pressure of $10g/mm^2$, was used to measure the following skinfolds: subscapular, triceps, forearm, suprailiac, calf and stomach. Based on this, the sum of trunk and limb skinfolds was computed. Furthermore, an index describing subcutaneous fat distribution was applied (sum of limb skinfolds / sum of trunk skinfolds). Fat content (FM) was determined through the use of an anthropometric method. The sum of three skinfolds (3SF: triceps + subscapular + abdominal) was used to estimate body density [5]:

$$\mathbf{D= 1.0982 - 0.000815\ (3SF)- 0.000000(3SF)^2}$$ (Equation 1)

The percentage of fat in body mass was calculated on the basis of the fallowing Keys and Brożek equation [6]:

$$\%F = 100*(\frac{4.201}{D} - 3.813)$$ (Equation 2)

BMI was employed to evaluate the weight-height correlation. The development level of endomorphy, mesomorphy and ectomorphy was determined according to W.H Sheldon's typology in the Heath-Carter modification [7]. The saturation of somatotype with a selected component was expressed on a graded scale, ranging from 1-7 points. Fatness was expressed by endomorphy. Mesomorphy is related to the level of muscle development and the massiveness of bones. Ectomorphy describes body slenderness.

In order to compute static strength in forearm muscles, researchers measured the handgrip of right and left hands. To conduct the measurements, they employed the Hand Grip Dynamometer (Takei) with a measuring range: 0-100 kg, precision of 0.5 kg, and adjustable handle.

Basic statistical methods were employed to evaluate the measured data (*STATISTICA 9,0*). Before the calculations, researchers examined the distribution of analysed variables Kolmogorov-Smirnov test and did not observe any significant deviations. On this basis, they applied methods based on normal distribution. T- Student test was used to describe intergroup diversification. The correlations of handgrip strength and morphological features were analysed with the Pearson`s linear correlation coefficient.

RESULTS

The examined group of students and bodybuilders did not reveal any statistically significant differences in mean body height and components, e.g. length of trunk and lower limbs (Table I).

Table I. *Statistical characteristics of body mass, body height and width of the examined men (mean ± SD) and correlation of the handgrip strength with these features*

Tabela I. *Charakterystyka statystyczna masy ciała, wysokości i szerokości u badanych(średnia± SD) oraz korelacje siły ścisku z badanymi cechami*

Variable Zmienna	Bodybuilders Kulturyści	Students Studenci	Pearson`s r r Pearsona
Body mass (kg) Masa ciała (kg)	81,33 ± 9,27*	75,11 ± 7,45	0,352
Body height (cm) Wysokość ciała (cm)	179,75 ± 6,66	178,70 ± 5,25	0,187
Legs length (cm) Długość kończyn dolnych (cm)	93,30 ± 4,91	93,98 ± 4,00	0,180
Sitting height (cm) Wysokość siedzeniowa (cm)	94,26 ± 3,07	93,7 ± 3,09	0,127
Biacromial diameter (cm) Szerokośc barków (cm)	42,09 ± 2,02*	40,76 ± 2,22	0,336
Bideltoideum diameter (cm) Szerokośc deltoidem (cm)	48,68 ± 2,28*	46,13 ± 2,70	0,184
Chest diameter (cm) Szerokośc klatki piersiowej (cm)	30,08 ± 1,75*	28,41 ± 2,11	0,174
Chest depth (cm) Głębokośc klatki piersiowej (cm)	20,00 ± 1,72	19,71 ± 1,78	0,044
Biiliocristal diameter (cm) Szerokość bioder (cm)	28,36 ± 1,83	28,24 ± 1,71	0,172
Elbow breadth (cm) Szerokośc łokcia (cm)	7,23 ± 0,51	7,00 ± 0,49	0,298
Interstyloid breadth (cm) Szerokość międzyrylcowa (cm)	5,92 ± 0,36*	5,66 ± 0,32	0,433
Knee breadth (cm) Szerokość kolana (cm)	10,04 ± 0,50*	9,70 ± 0,64	0,078

*Statistically significant difference versus Students` group (*p < 0.01)

* Różnice istotne statystycznie w porównaniu z grupą studentów (*p<0,01)

However, observable differences were recorded in reference to body mass, which was higher for the group of bodybuilders (difference 6.2 kg). The bodybuilders were characterised by significantly wider shoulders (difference 1.3 cm), bideltoideum (difference 2.5 cm) and chest (difference 1.6 cm). Also the values of wrist and knee bone breadth were higher in

comparison to the group of students (difference 0.3 cm). There were no differences observed in the chest depth, biiliocristal diameter and elbow breadth. The two groups differed distinctly in muscle development within the upper trunk area, shoulder girdle and upper limbs (Table II).

Table II. *Statistical characteristics of circumference of the examined men (mean ± SD) and correlation of the handgrip strength with these features*

Tabela II. *Charakterystyka statystyczna obwodów ciała u badanych (średnia± SD) oraz korelacje siły ścisku z tymi cechami*

Variable Zmienna	Bodybuilders Kulturyści	Students Studenci	Pearson`s r r Pearsona
Neck circumference (cm) Obwód szyi (cm)	39,84 ± 2,24*	38,36 ± 1,56	0,457
Shoulder girdle circumference (cm) Obwód obręczy barkowej (cm)	121,64 ±7,10*	113,40 ± 6,07	0,568
Chest circumference in rest (cm) Obwód kl. piers. w spoczynku (cm)	91,10 ± 4,53*	87,20 ± 4,15	0,455
Chest circumference (inspiration) (cm) Obwód kl. piers w max. wdechu (cm)	97,49 ± 4,68*	93,31 ± 4,21	0,431
Chest circumference (expiration) (cm) Obwód kl. piers w max. wydechu (cm)	88,63 ± 5,16*	84,65 ± 4,64	0,349
Wrist circumference (cm) Obwód pasa (cm0	81,60 ± 5,75	81,92 ± 5,12	0,243
Arm circumference (in rest) (cm) Obwód ramienia w spocz, (cm)	33,67 ± 3,03*	29,07 ± 1,86	0,452
Arm circumference (in tension) (cm) Obwód ramienia w napięciu (cm)	37,63 ± 3,38*	32,73 ± 1,95	0,403
Forearm circumference (max.) (cm) Obwód przedramienia (max) (cm)	29,31 ± 2,20*	27,43 ± 1,35	0,601
Forearm circumference (min.) (cm) Obwód przedramienia (min) (cm)	18,40 ± 1,99*	17,12 ± 0,97	0,401
Hip circumference (cm) Obwód bioder (cm)	99,30 ± 4,56	97,89 ± 4,35	0,055
High circumference (cm) Obwód uda (cm)	59,08 ± 3,60	57,89 ± 3,57	0,287
Calf circumference (max.) (cm) Obwód podudzia (max) (cm)	38,58 ± 2,03	37,89 ± 2,41	0,308
Calf circumference (min.) (cm) Obwód podudzia (min) (cm)	24,11 ± 1,44	23,70 ± 1,53	0,204

*Statistically significant difference versus Students` group (*p < 0.01)

* Różnice istotne statystycznie w porównaniu z grupą studentów (*p<0,01)

The values of shoulder girdle (difference 8.2 cm), chest circumference (difference over 4 cm), arm circumference in tension, arm circumference at rest (difference approx. 5 cm) and forearm circumference (difference 1.9 cm) were higher for bodybuilders. The bodybuilders also obtained higher values for the remaining body measurements (biiliocristal diameters, thigh and calf circumference); however, these figures were statistically insignificant. Skinfold thickness was greater among the bodybuilders; however, for the majority of skinfolds the researchers did not observe any significant intergroup diversification (Table III).

Table III. *Statistical characteristics of skinfolds of the examined handgrip strength in the examined men (mean ± SD) and correlation of the handgrip strength with the examined skinfolds*

Tabela III. *Charakterystyka statystyczna fałdów skórno-tłuszczowych u badanych (średnia± SD) oraz korelacje siły ścisku z tymi cechami*

Variable Zmienna	Bodybuilders Kulturyści	Students Studenci	Pearson`s r r Pearsona
Subscapular skinfold (mm) Fałd tł. pod łopatką (mm)	9,68 ± 1,63*	9,04 ± 2,03	0,162
Triceps skinfold (mm) Fałd tł. nad tricepsem (mm)	5,91 ± 2,28	4,94 ± 2,60	0,111
Forearm skinfold (mm) Fałd tł. na przedramieniu (mm)	4,05 ± 1,14	3,62 ± 0,96	0,106
Suprailiac skinfold (mm) Fałd tł. nad grzebieniem biodr. (mm)	9,89 ± 2,75	8,76 ± 3,81	0,170
Stomach skinfold (mm) Fałd tł. na brzuchu (mm)	9,32 ± 2,89	9,63 ± 4,51	0,739
Calf skinfold (mm) Fałd tł. na podudziu (mm)	5,65 ± 1,71*	4,90 ± 2,08	0,111
Sum of skinfolds on the trunk (mm) Suma fałdów tułowia (mm)	25,23 ± 5,02	22,70 ± 6,28	
Sum of skinfolds of the limbs (mm) Suma fałdów kończyn (mm)	15,22 ± 3,14	13,46 ± 5,15	
Sum of skinfolds of the limbs / Sum of skinfolds on the trunk Suma f. kończyn /suma f. tułowia	0,61 ± 0,11	0,60 ± 0,17	

*Statistically significant difference versus Students` group (*p < 0.01)

* Różnice istotne statystycznie w porównaniu z grupą studentów (*p<0,01)

Only subscapular and calf skinfolds were significantly thicker in subjects exercising at the gym (0.64 mm and 0.75 mm respectively). Such correlation was also observed in the similar values of skinfold

sums for limbs, trunk and in the amount of fat in the subjects of both groups. The fat distribution index was almost identical in both groups. A difference was observed in the development of body components. Endomorphy and mesomorphy obtained higher values in bodybuilders, while in students they were characterised by greater body slenderness. The numbers describing somatotype of bodybuilders were: 2.78-6.27-1.91, while those of students: 2.23-5.05-2.47. BMI indicated greater massiveness of the bodybuilders (Table IV). The mobility of the chest is similar in both groups and indicates good respiratory fitness of the examined subjects.

Table IV. *Statistical characteristics of the body build components, body density and percentage amount of fat, BMI and handgrip strength in the examined men (mean ± SD)*

Tabela IV. *Charakterystyka statystyczna komponentów budowy, gęstości ciała, udziału tłuszczu, BMI i siły ścisku u badanych (średnia± SD)*

Variable Zmienna	Bodybuilders Kulturyści	Students Studenci
Endomorphy Endomorfia	2,78 ± 0,83*	2,23 ± 0,78
Mesomorphy Mezomorfia	6,27 ± 1,21*	5,05 ± 1,04
Ectomorphy Ektomorfia	1,91 ± 0,83*	2,47 ± 0,77
Body density (g ·cm^{-3}) Gęstośc ciała (g ·cm^{-3})	1,0736 ± 0,0049	1,0737 ±0,0102
Fat (%) Tłuszcz (%)	9,992 ± 1,77	9,986 ± 3,76
BMI (kg ·m^{-2})	24,9 ± 2,07*	23,5 ± 1,69
HSR (kG)	55,09 ± 6,79*	49,00 ± 8,64
HSL (kG)	52,47 ± 5,89*	45,32 ± 7,47
HSR+HSL (kG)	107,56 ± 12,05*	94,32 ± 15,50
(HSR+HSL)/body mass (kG/kg) (HSR+HSL) /masa ciała (kG/kg)	1,33 ± 0,18	1,26 ± 0,21

BMI – Body mass index, HSR- Handgrip strength (right), HSL- Handgrip strength (left), HSR+HSL – sum of right and left handgrip strength

BMI – wskaźnik masy ciała, HSR- siła ścisku ręki prawej, HSL- siła ścisku ręki lewej, HSR+HSL – suma siły ścisku ręki prawej i lewej

*Statistically significant difference versus Students` group (*p < 0.01)

* Różnice istotne statystycznie w porównaniu z grupą studentów (*p<0,01)

Handgrip strength was significantly higher for bodybuilders. The difference between the handgrip of a bodybuilder and a student for the right hand was 6 kG while for the left hand 7 kG. Nevertheless, the relative strength index in reference to body mass did not reveal any statistically significant differences. Researchers did not determine any statistically significant correlations between the handgrip strength of both hands and the somatic features examined. The highest values the correlation indices were observed between handgrip strength and forearm circumference, shoulder girdle circumference, chest circumference and arm circumference.

DISCUSSION

Research on the significance of selected types of physical activities, such as endurance exercises, has revealed their beneficial influence on body tissue composition and the proper functioning of cardiovascular and respiratory systems [8]. These types of exercises can be performed by people at different ages. Activities such as long distance running, cross-country skiing, swimming and cycling are especially recommended. Different types of exercises are very beneficial, especially when adjusted to the season of the year or the place of stay. Such types of exercises were performed by the examined students. Only until recently were strength exercises performed with great resistance perceived as not beneficial. Strength training was said to be an excellent way to develop and maintain body mass and muscles strength. However, research currently being conducted has proven these types of exercises to have a good influence on health and the course of some diseases [9, 10, 11]. Resistance training may be effective in creating suitable tissue relations and some of the functional features. It was confirmed by this study. These results confirmed the thesis that this type of training as a part of a complex strategy aimed at maintaining a healthy lifestyle among the young [12].

Bodybuilding requires intensive strength training, leading to different structural and functional body changes [13]. It is also essential to the development of muscles needed to increase handgrip strength. The results of strength training depend on the technique and loads applied to selected body parts, hence they can be quite diverse [14,15]. Therefore, morphological features are related to the proportions between length and width of the chest and waist, as well as body tissue composition. These features frequently determine the final success of a contestant in competition [16]. Bodybuilders examined in this research did not represent the highest sports level which, in reference to the top class contestants, was reflected in the lower values of the selected somatic parameters [17]. The results obtained reveal that bodybuilders display higher values of upper trunk and limb width in contrast to the students. Ogita [4] describes these features as significant during competitor assessment in

competitions. Hence, the obtained results can be the effect of strength training of selected body parts. Also, researchers did not observe any statistically significant differences in body fatness among the subjects. Skinfold thickness observed in both groups indicated fat distribution typical for men. The thickest were subscapular and suprailiac skinfolds. Previously conducted research has indicated that fat accumulation in the abdominal area is particularly dangerous. Such fat distribution increases the occurrence of ischemic heart disease, hypertension, cardiac failure and some cancers [18, 19]. The examined subjects did not reveal any alarming fat distribution in this area. The percentage of fat was computed on the basis of density calculated from the thickness of three skinfolds. It is claimed by many researchers that the estimation of body composition requires certain anthropometric measurements of skinfolds since they are more precise than other methods applied to evaluate fat content [13].

The level of each component's development (endomorphy, mesomorphy and ectomorphy) described typical correlations which occur in strength sports and martial arts [13,15,16,20,21]. Bodybuilders revealed distinct mesomorphy domination in comparison to students, which described strong muscle development related to the muscle hypertrophy and greater massiveness of bones. This resulted in the increase of force, examined by the use of a dynamometer. The values obtained by the bodybuilders were high and exceeded the values obtained not only by the examined students, but also those of judokas examined by Franchini et al. [22]. It can be presumed that increased force may result from applied resistance training [1,23]. Large muscle strength has an influence on shaping bone mass [24]. This was reflected in the greater width of epiphysis of bones in bodybuilders, especially within the upper limb area. Relative force showed interesting values. There is a regularity which says that body mass is a function of its volume while strength is proportional to the cross-sectional area of a muscle [25, 26]. In relation to greater circumferences within the upper limb area, the absolute handgrip of bodybuilders is greater. However, the reference of these values to body mass in the examined subjects indicated similar values of the index. Similar muscle fitness was shown in the representatives of both groups.

The conducted research enabled the researchers to indirectly evaluate the respiratory performance of the examined subjects. The measured circumference was used to compute the chest expansion (the circumferential difference between full inspiration and expiration). Amplitude determined on the basis of the obtained results was similar for both groups (approx. 9 cm). Its value indicated good respiratory fitness of both bodybuilders and students. Such fitness might result from an increased physical activity of those subjects.

CONCLUSIONS

1. On the basis of the results obtained during anthropometric measurements (trunk and limbs breadth and circumference) it can be stated that resistance training of amateur bodybuilders resulted in muscles hypertrophy and increased their bone massiveness.
2. The analysis of skinfolds thickness showed that both resistance training and recreational physical activity (swimming, jogging, cycling) resulted in the lower level of fatness in the examined subjects.
3. The results describing chest mobility indicated good respiratory fitness of the examined subjects regardless the type of physical activity.

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Received: 22.07.2013
Accepted for publication: 14.10.2013