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Changes in Body Composition of Senior Females Induced by Strength-Endurance Motor Program

Abstract

The aim of work was to determine the effects of 8-week strength-endurance training program on somatic indicators in senior females. Applying bioelectrical impedance analysis method (InBODY 230 device) we evaluated the following parameters: body weight, BMI, body fat, total skeletal muscle mass, body fat percentage, skeletal muscle mass in left and right upper and lower extremities, trunk muscle mass, and the mineral mass in the body. To assess regularity of physical activities, variability of lifestyle and quality of life, we used a standardized survey questionnaire. The study was carried out on 29 senior citizens, of the average 70.28 years of age and BMI 26.47 kg/m^2. A group of active elderly women underwent an 8-week strength-endurance program, including exercises focused primarily on the development of strength abilities of the upper limbs, and secondarily on developing strength abilities of lower extremities and developing general aerobic abilities. The influence of the aerobic program induced statistically significant increase in the total skeletal muscle mass from the initial value of 22.966 kg to 23.552 kg, an increase by 0.552kg ($p \leq 0.01$) of the monitored parameter. On the contrary, the parameter of body fat percentage of the studied group showed significant decrease of the input value of 36.207%, to the output value of 35.062%, representing a change at the level of 1.145% ($p \leq 0.01$). By assessment of changes in the muscle mass of upper limbs and the trunk, we found a statistically significant increase, which reflects a change in the total quantity of the skeletal muscle ($p \leq 0.005$). The mineral mass in the probands increased by only 0.091 kg. However, this increase was confirmed at 0.1% level of statistical significance ($p \leq 0.001$). The above results indicate that regular performance of physical activities in groups of the elderly proves to be efficient in preventing sarcopenia, obesity and maintaining a balance of the particular tissues making up the total body composition.

Keywords: senior females, strength-endurance program, muscle mass, body fat percentage.

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Introduction

According to the National Program for Active Ageing for the years 2014–2020, the Statistical Office of the Slovak Republic concludes that in Slovakia the ratio between the number of working age citizens, i.e. aged 15–64 years (71.5% in 2012), pre-productive age citizens (15.4% in 2012) and post-productive age people (13.1% in 2012) is favorable [26]. The average age of the population in 2009, compared to 2001 increased from 36.2 years to 38.49 years. By 2025 the average age is expected to increase to 42 years. Medium age life expectancy among men as well as women is rising. In 2008, the value of this demographic parameter in the group of men rose to 70.85 years and in the group of women it reached 78.73 years [26]. The basic principles of the national program for the protection of the elderly [27] include the principle of self-realization, based on the rights of the elderly to have the conditions and opportunities to achieve physical, social and mental well-being. The principle of life-cycle is based on the fact that the elderly do not form a homogenous group and that interindividual differences increase with age [10]. Ageing is an irreversible process, although it is now a generally accepted statement that we can purposefully influence a number of factors that have an impact on the ageing process, and thereby encourage its slowdown. The speed of this process can be retarded by proper mental and physical activity. We distinguish between primary ageing, characterized by physiological ageing accompanied by individual symptoms, and secondary ageing, involving pathological changes due to diseases [25].

With age, there is an increased risk of cardiovascular disease, obesity, diabetes mellitus type 2 and decreased function of the respiratory and motor systems [31]. Common diseases in people older than 65 years of age are cardiovascular diseases, the most common cause of premature death in this group. As a reason behind this condition, it is possible to find several changes in the body closely related to ageing. Vascular walls in the elderly lose their elasticity, peripheral resistance increases and hence blood pressure, too. It increases the content of blood lipids. Insulin sensitivity is reduced, metabolism of energy reserves of the body changes, followed by a higher frequency of the incidence of diabetes mellitus type 2 [24].

With increasing age the mineral loss and bone loss occur in the elderly. The result of this process is an increased incidence of osteoporosis. This is due to the decreasing bone mineral density (bone density) and decreasing physical activity by the elderly [3], [24]. In women leaching of minerals takes place more rapidly than in men. The intense loss of calcium supplements occurs due to endocrine changes, especially in the period up to five years from the start of the menopause [30]. The loss is reflected more in spine bone than the extremities. The density of the compact bone of the spine is reduced during the first 50 years of life in women by up to 30%. The density of the sponge-like bone in women decreases by up to 65%. With age, the natural bone remodelling slows down, resulting in the accumulation of micro-fractures negatively influencing bones integrity [29]. As a frequent consequence, fractures in different areas of the body structure occur, together with negative functional changes in the motor system (spine, proximal femur, forearm, humerus) [31].

It is reported that by the age of 50 the size of the cross section of major muscle groups is reduced by approximately 10%. In the sixth and seventh decennium muscle strength decreases by 15–20% compared to the period of maturity, and in subsequent decades it is further reduced by about 30% [24]. In the later years reduction of height follows due to muscle atrophy and the gradual increase of imbalance between different muscle groups, that in later stages contributes significantly to hyperkyphosis and scoliosis [19].

For these and other reasons, physical activity of the seniors is becoming the center of interest of health professionals, social workers, economists and politicians. Independence and the quality of life of seniors is closely linked to their motor functions. To maintain their motor functionality, they have to carry out optimal and regular physical activity. Physical activity designed for seniors should meet a number of conditions. The primary factor influencing the choice of their physical activities should be health risk prevention, not neglecting the consideration of therapeutic needs concerning the social and psychological aspects of their life though. Among other things, it should be appropriate from the aspect of economy and should be applicable under a number of variable and diverse conditions of social interactions [4]. Currently, opinions concerning the character, intensity, frequency and duration of the physical activity in elderly people vary significantly. However, aerobic exercise needed to maintain functional fitness, which gradually decreases with age, is still considered to be fundamental. Among the recommended are particularly cyclical endurance activities (walking, cycling, swimming, basketball, tennis and other sports at recreational level) and gymnastics for health and fitness to maintain the performance of the musculoskeletal system, such as joint mobility exercises, stretching and balancing exercises and rhythmic dynamic exercises of reasonable intensity [12], [14]. Medium intensity exercise during ageing helps to maintain a sufficient level of strength abilities needed to maintain the vitality of muscle in carrying out routine daily activities. Disproportionately high physical activity brings along a significantly increased risk of falls and injuries at a period when trauma and consequences of the injuries may significantly exceed the benefits of the physical activity undertaken [21]. On the contrary, a properly designed training program may in a group of elderly women and men reduce the risk of falls by up to 75% [8], [34].

The further the more focus is currently given to strength training of moderate intensity, aimed at strengthening the major muscle groups, sufficient to maintain and develop ATH and bone integrity, at a minimum frequency of 2-times a week [4], [17].

To achieve the synergy effect of benefits arising from various types of physical activities, many authors recommend combining the elements of strength and endurance training, while carrying out physical activity regularly and systematically [17]. Yet, from the available conclusions of the authors, the impact of long-term implementation of physical activity on body composition in the elderly is not known exactly. The differences in the conclusions of other authors made us prepare and implement our research, in which we monitor changes in body composition of elderly females during the implementation of the training program which included components of endurance and power loading.

The aim of the study was to analyse the changes in body composition during the eight-week training program in the group of senior females. The primary parameters monitored were BMI values, the amount of skeletal muscle and the percentage of body fat.

The aim of our research was to determine the efficacy of our 8-week strength-endurance motor program on the body composition of elderly women. We expect that the implementation of regular physical activity among seniors during the monitored period will affect the somatic indicators measured by us as follows:

1) a slight increase in body weight, BMI and the amount of skeletal muscles, muscle mass of right and left upper and lower limb, muscle tissue in the trunk, the amount of minerals in the body measured by the method of multifrequency bioelectrical impedance.
2) decrease of body fat percentage.

Methods

The research involved women actively participating in group exercises organized by the physical educational associations for seniors. The condition to meet for the inclusion in the program was the age of participants – over 58 years of age, their consent to participate in the study and willingness to undergo the initial and final measurements. Out of all the available subjects, 29 physically active elderly women fulfilled the selection criteria, such as residing in the Košice region at the time of research, with an average age of 70.28 years and an average height of 159.84 cm. Before the start of the training intervention, each subject completed a questionnaire focused on their health condition and performance of physical activities.

When creating the 8-week strength-endurance motor program for seniors, we followed the standards and recommendations of several authors [28], [35], [39], [32]. We have created a program incorporating a variety of toning, aerobic, stretching and relaxation exercises. We adjusted the volume, intensity of load and speed to the age and health condition of the probands.

The subjects performed the selected physical activity on a regular basis 2--times a week for the entire length of the eight-week training program. The trainings were conducted under the professional supervision of a sports training specialist. The training included exercises primarily focused on the development of strength abilities of the upper limbs, in addition to to the development of strength abilities of the lower limbs and the development of general aerobic abilities (general aerobic base). Exercises to develop flexibility were included in the warm-up and in the final stages. Each study subject was under medical supervision during the period of the training program.

The training units were carried out during morning hours and lasted 60 minutes each. They consisted of a 10-minute warm-up section of basic aerobic steps (speed of music 120 b.p.m.), followed by a 5-minute active stretching and a 20-minute aerobic part with the essential elements of aerobics and dance (120–130 b.p.m.). The after-aerobic part comprised a 15-minute section focused on "CORE" toning exercises with a 6 kg bar.

In the first week the participants carried out one set of 8 repetitions of CORE exercises, in the second week 2 sets of 8 reps, the third week 3 sets of 8 reps. In the subsequent weeks the subjects maintained the achieved peak load, thus performing 3 sets of 8 reps of CORE exercises. In case the subjects had a problem in maintaining the scheduled sets and reps within any training unit, those could be interrupted or omitted at any time.

A detailed description of the various CORE exercise techniques used in the training program:

— standing up with legs astride, bars overgripped wide, upper limbs close to the lower body. Vertical pull up with arms bent, followed by gradual return of arms to the starting position (activated muscles – primarily – m. deltoideus – acromial part and m. trapezius – superior fibers, secondarily m. deltoideus – clavicular part, m. supraspinatus) and m. infraspinatus.
— standing up with legs astride, bar undergripped at shoulder width – bend arms close to the body with forearms flexed in the front, "biceps curl" (activated muscles – primarily m. biceps brachii – caput longum et caput breve; secondarily – m. deltoideus and muscles of the forearm).
— lying down on the back, arms flexed lateral raise, bars gripped wider than shoulder width – raise arms to the front, legs flexed, feet against ground "benchpress" (activated muscles – primarily – m. pectoralis major – sternocostal part; secondarily – m. deltoideus clavicular part and triceps brachii.
— lying down on the back, arms flexed raised to the front, bars gripped narrower than shoulder width – arms forward raise "pull-over", legs flexed, feet against ground (activated muscles – primarily – m. pectoralis major, m. triceps brachii; secondarily deltoideus – clavicular part, pectoralis major and minor, and muscles of the forearm);

— standing up with legs astride, half squat, arms "biceps curl" – bars undergripped shoulder-width. Upper limbs as in exercise 2. Activated muscles – primarily quadriceps femoris, m. tensor fasciae latae, m. gluteus medius and maximus; secondarily – hamstrings (biceps femoris, semimembranosus, semitendinosus), thigh adductors, erector spinae and m. abdominis [9].

The final 10-minute section of the training unit was devoted to the development of flexibility, predominantly of the loaded muscle groups.

Prior to testing, the subjects completed a standardized questionnaire focused on detection of health variances and the divergence in performing physical activities [16].

Filling in the questionnaires and measurements took place in the gym of the Institute of Physical Education and Sports at P.J. Safarik University in Kosice. Testing was carried out in the morning hours, before the start of training unit. Subsequently, within the analysis of body composition, the subjects were measured for body height and waistline. Measurements continued by assessment of body composition using the method of bioelectrical multifrequency impedance (BIA; InBody 230, Biospace, Seoul, Korea) [15]. The device provides reliable and valid estimates of body composition. It is a quick, non-invasive method, suitable also for use outside the laboratory. BIA is a method used in healthy subjects as well as in patients with various diseases. With this method we are able not only to determine a body composition, but also to follow the development and changes in body composition of the monitored individuals. In our research, we focused on the following somatic indicators: BW – body weight, body mass index (BMI), LBM – lean body mass, BFM – body fat mass, BFP – body fat percentage, RMM; LMM – right/left segment of muscle mass, TMM – trunk muscle mass and the quantity of minerals in the overall body composition (MRL).

To keep a high degree of validity and reliability of BIA testing, we tried to comply with the recommended principles to achieve results as accurate as possible:

— avoid eating excess amounts of food 4–5 hours prior to measurement,
— avoid alcohol consumption the day before measurement,
— avoid major physical exertion on the day of analysis,
— stop taking diuretics 7 days prior to the test,
— do not take a shower shortly before examination,
— for more accurate measurement, it is advisable to wipe off sweat and dirt from the contact areas (palms and feet) [5], [6], [7].

Validity and reliability, as well as the diagnostic value of the results of anthropometric analysis using the method of bioelectrical impedance (BIA) are disputed even today. It is well known that the accuracy of results is greatly influenced by the level of compliance with the protocol of measurement, and instructions for maintaining the validity of measurements using BIA [11]. However, the further the more scientific studies draw conclusions which recommend the use of BIA methods in applied research. The authors are reporting high correlation of the results of body fat analysis (r = 0.82–0.99) [20], [22], [1], [13] and the proportion of lean body mass (r = 0.85–0.94) [38], [20] in the total body composition. When evaluating the reliability of results of BIA measurement values, the test-retest ICC value reported was 0.999 [18], [1]. Based on the conclusions of these authors, we are bound to consider the BIA method a reliable diagnostics of the proportion of body fat and lean body mass in overall body composition, especially in middle-aged and elderly women.

For processing and evaluation of the empirical data, basic statistical characteristics were applied (arithmetic mean, median, standard deviation, maximum and minimum values). The degrees of statistical significance of changes in all evaluated parameters were estimated using the paired t-test parametric statistical method. We assessed the significance of changes at the 5%, 1%, 0.5% and 0.1% levels of significance. Processing and evaluation of the obtained data were carried out using the statistical program Statistica version 12. All the basic statistical characteristics are shown in the tables and figures below. The results have undergone logical-substantive analysis.

Results

The aim of the study was to analyze changes in body composition in a group of elderly women during an eight-week training program.

When comparing the initial and final values of body weight in the subjects after completion of the 8-week motor program, a modest increase was reported. Nevertheless, the increase did not prove to be significant at any level of statistical significance (THpre: 67.08 kg; THpost: 67.57 kg; p = n.s.). Similarly, BMI showed a slight increase, although statistically insignificant (BMIpre: 26.47 kg / m2; BMIpost: 26.50 kg / m2, p = n. s.).

More importantly though, after implementation of the training program, the group of seniors reported a statistically significant increase in the average amount of skeletal muscle (LBMpre: 22.966 kg; LBMpost: 23.552 kg; $p \leq 0{,}01$; Fig. 1). Obviously, while maintaining the average body weight, together with the increase of the average amount of the skeletal muscle there must have been a change in the proportion of fatty tissue in the total body composition. In the study, after implementation of the training program, we reported a statistically significant reduction in the average percentage expressing the share of fat deposits in the total body mass (BFMpre: 36.207%; BFMpost: 35.06%; $p \leq 0{,}01$; Fig. 1).

Segmental analysis of muscle mass in the upper limbs also pointed to changes in the volume of skeletal muscle. On both the right and the left upper limb, a statistically significant increase in the amount of skeletal muscle appeared (RHpre: 2.189 kg; RHpost: 2.265 kg; LHPR: 2.160 kg; LHpost: 2.232 kg; $p \leq 0{,}005$; Fig. 2).

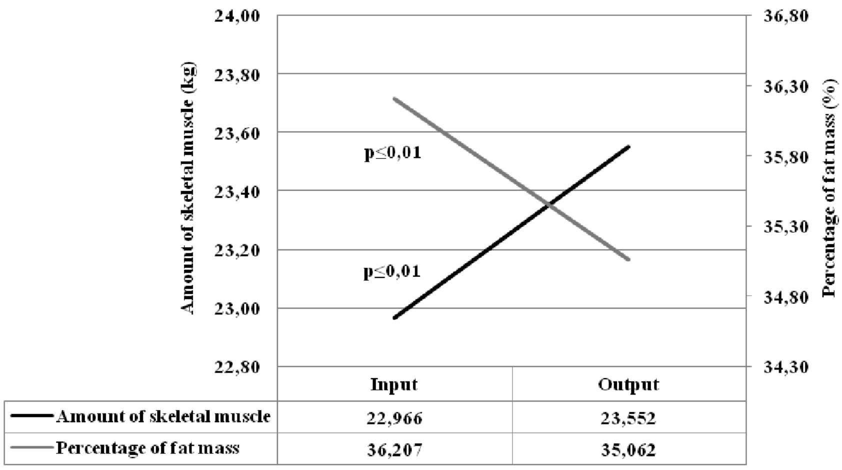

Figure 1. Changes of lean body mass (kg) and percentage of fat mass (%)

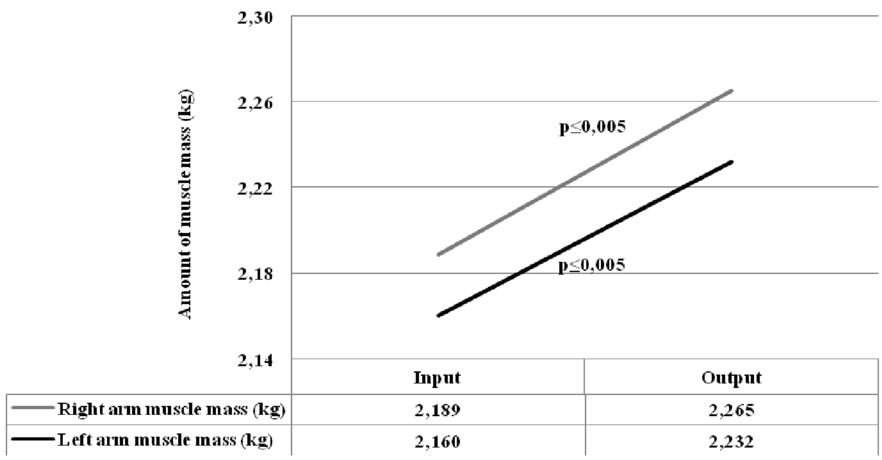

Figure 2. Changes in segmental analysis of lean body mass (kg) in left and right arm

When comparing the input and output values of the amount of muscle in the trunk, we found a statistically significant increase from the initial 19.172 kg to the output value of 19.599 kg ($p \leq 0{,}005$; Fig. 3).

After completing the 8-week training program, we reported significant changes in the amount of minerals in the body composition of the study group. While at the initial measurement, the average value of the parameter was 3.001 kg, the final values showed statistically significant increase of 0.091 kg to the value of 3.092 kg ($p \leq 0{,}001$; Fig. 4).

A summary of average values of the measured parameter, input to output changes, and the statistical significance of changes are presented in Table 1.

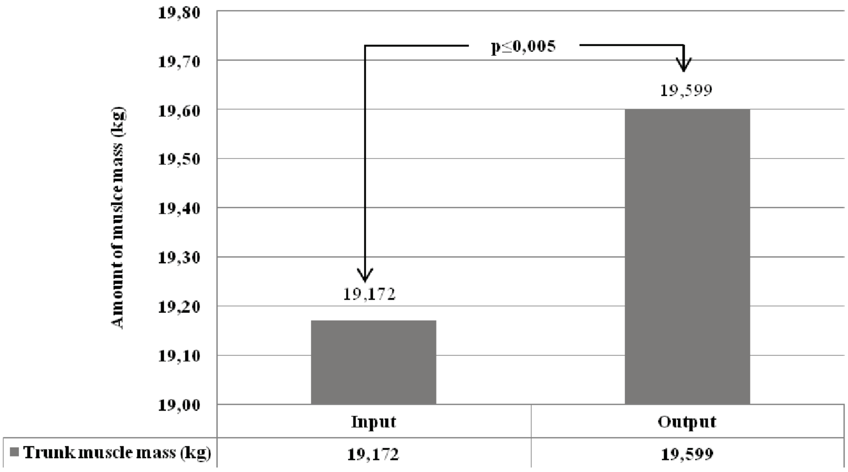

Figure 3. Changes of lean body mass (kg) in trunk

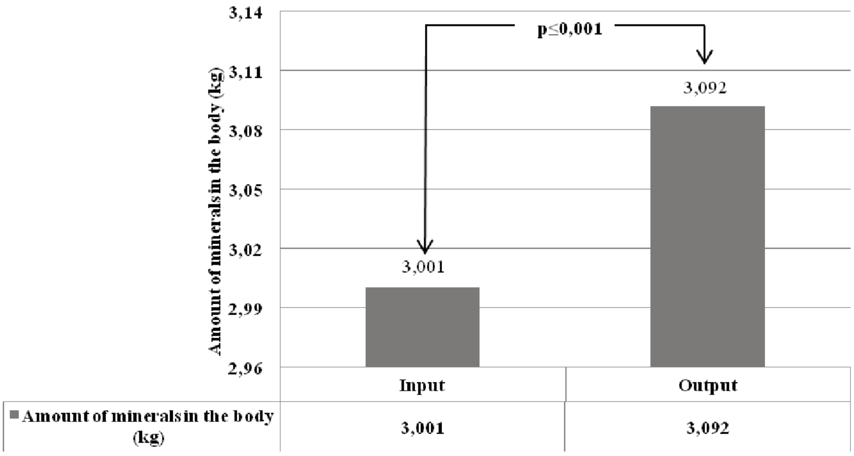

Figure 4. Changes in total body mineral content (kg)

Table 1. Resume of results and statistical significances of parameters monitored in research

Summary	Input	Output	Change	Statistical significance
LBM	22.966	23.552	+0.586	$p \leq 0.01$
BFP	36.207	35.062	−1.145	$p \leq 0.01$
RMM	2.189	2.265	+0.077	$p \leq 0.005$
LMM	2.160	2.232	+0.072	$p \leq 0.005$
TMM	19.172	19.599	+0.427	$p \leq 0.005$
MRL	3.001	3.092	+0.091	$p \leq 0.001$

Legend: LBM – lean body mass; BFP – body fat percentage; RMM, LMM – right/left segment muscle mass; TMM – trunk muscle mass; MRL – amount of minerals in overall body composition.

From the questionnaire, analyzing health variability in the group of elderly women, it follows that 50% of the subjects consider their health to be good, 33% very good, 3% describe it as excellent; On the contrary, only 6% consider their health being poor. The results of the questionnaire evaluation of the implementation of variable physical activities suggest that all the subjects of our group carried out regular physical activity at least twice a week. A significant part of the study group (36.7%) stated that they carried out physical activity three times a week, and 10% of the elderly even four times a week. In addition to the dominant (53.4%) strength-endurance character of activities, the subjects also reported some aerobic activity of low intensity, with elements of walking (walking, Nordic walking) and water sports (swimming), at a duration of 30 to 180 minutes per week.

Subjective ratings of the quality of life in the observed group demonstrated superiority in the range of the mean (60%). Nearly one third (26%) indicated a high level of life quality, while a tenth reported a very high level of the quality of life. Low level of the quality of life was reported by 3% of the subjects.

Discussion

The results of the study show changes in the physique and in representation of the various tissues among the group of the elderly after 8 weeks of strength-endurance training intervention. Following the completion of the training program, there have been no significant changes in body weight or BMI. Obviously, the duration of the intervention was not sufficient to provide long-term benefits in terms of remarkable reduction of visceral fat in all the participants [4]. In addition, ageing leads to significant changes in the energy metabolism, resulting in pro-adiposity of deposits in the body, and a higher degree of saving important energy sources during load [23], [37]. These factors greatly retard the efficiency of regular physical loading focused on reducing body weight, compared with the efficacy of similar activity in the group of adults.

The influence of regular physical activity on body composition in senior females is reflected in the comparison of input and output values of the analysed parameters. The contrariness of changes in body composition, represented by increasing the amount of skeletal muscle and a reduction in the percentage of fat reserves, are typical adaptive changes following the period of regular, controlled training program designed for the elderly.

The benefits are represented by changes in lean body mass in different body segments and the trunk. A higher statistical significance of increase in the the amount of skeletal muscle of the two upper limbs and the trunk, compared to the overall changes in skeletal muscle in the body composition, confirm the high significance of segmental analysis. We assume that significant changes in the skeletal muscle mass will be apparently transferred to higher levels of physical strength, which in the case of the elderly is a major determinant of both the quality of life as well as of longevity or premature deaths respectively.

Following the initial measurements in the study group (n = 29), we found normal BMI values (BMI ≤ 25 kg/m^2) in only 13 probands. After accomplishing the training program, the number of the elderly with parameters of body composition falling within the normal range increased to 15. Obesity is a major health risk factor in both the young as well as the elderly. The marginal value of BMI supporting the risk of mortality is considered to be 27.0 [19]. It was pointed out by a few authors, who were investigating the relationship between BMI and early death of people over 65 years [36]. It was concluded that people with the lowest risk reported BMI values at 27.5. Seniors with BMI values at between 22 and 23 (defined as normal level BMI) proved a statistically higher probability of premature death.

Conclusions of research papers indicate that over 50 years of age there is an intense loss of muscle and bone mass, which increases the risk of physical weakness and even disability [28], [2]. Physical activity loading the skeleton under one's own weight (eg. brisk walking, dancing, gymnastics, etc.), is an effective form of saving muscle mass and bone mineral density [33]. Our study pointed indirectly to improved mineralization of the body. After implementation of the training program, there was a statistically significant increase in the quantity of minerals in the body, despite the relatively short duration of the training intervention.

Conclusions

The study confirmed significantly positive impact of the 8-week strength-endurance exercise program on selected body composition parameters in the group of senior females. To sum up, we can conclude a statistically significant increase in the amount of skeletal muscle, the muscle mass of right and left arm and the trunk, and in the amount of body minerals. A statistically significant reduction was observed in body fat percentage in the overall body composition.

Based on our findings and experience gained by implementing the exercise program for elderly women, we have formulated the following recommendations for the practice:

1. Implementation of active strength-endurance program with a frequency of twice a week is considered sufficient in order to improve body composition parameters in groups of senior women.
2. We recommend to increase the total amount of physical activity, not raising exercise intensity, but rather increasing the duration of physical activity in a single training unit.

3. We recommend to incorporate into the content of the motor program for senior females also strength exercises with additional 6 kg weights while engaging muscle groups primarily of the upper and secondarily of the lower extremities.
4. Strength-endurance program is recommended to be used more often in women over 59 years of age for improving the muscle mass.
5. With training programs for seniors including strength-endurance elements, we recommend a thorough inspection and fulfillment of the following conditions for rational implementation of the exercises: proper breathing, correct starting position, precise implementation of movement techniques, cooperation of abdominal and pelvic floor muscles during exercise.
6. Ensure frequent measurement of body composition in groups of seniors.
7. Elderly people are not recommended to carry out sudden changes in body position during exercise, no coordination-intensive exercises or jumps either.

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Zmiany w składzie ciała seniorek podczas programu siłowo-wytrzymałościowego

Streszczenie

Celem artykułu było określenie wpływu 8-tygodniowego programu siłowo-wytrzymałościowego na wskaźniki somatyczne seniorek. **Metody.** Przy pomocy metody bioelektrycznej impedancji (InBody 230) oceniano parametry: masa ciała, BMI, ilość tkanki tłuszczowej, ilość mięśni szkieletowych, procenty tkanki tłuszczowej, ilość masy mięśniowej prawej i lewej górnej i dolnej kończyny, ilość masy mięśniowej w tułowiu i ilość minerałów. Aby ocenić prawidłowość aktywności fizycznej, styl i jakość życia, użyliśmy standaryzowanego kwestionariusza. W badaniach wzięło udział 29 seniorek, których średnia wieku wynosiła 70,28 lat, a BMI 26,47 kg/m2. Grupa aktywnych starszych kobiet wykonywała 8-tygodniowy program siłowo-wytrzymałościowy, który obejmował pierwotnie ćwiczenia na rozwój zdolności siłowo-wytrzymałościowych kończyn górnych, wtórnie na rozwój zdolności wytrzymałościowych kończyn dolnych oraz rozwój ogólnych zdolności aerobowych. **Wyniki.** Wpływ programu wywołał znaczny wzrost ilości mięśni szkieletowych – od wartości wejściowej 22.966 kg do 23.552 kg wartości wyjściowej, co oznacza zwiększenie wartości monitorowanego parametru o 0,552 kg ($p \leq 0{,}01$). Z drugiej strony, parametr procent tkanki tłuszczowej badanej grupy wykazuje znaczny spadek wartości wejściowej 36.207% z wartością wyjściową 35.062%, co oznacza zmianę w poziomie o 1,145% ($p \leq 0{,}01$). W celu oceny zmian masy mięśniowej górnych kończyn i tułowia, wykazano statystycznie istotny wzrost, który odzwierciedla zmiany w całkowitej ilości mięśni szkieletowych ($p \leq 0{,}005$). Ilość minerałów w badanej grupie wzrosła tylko o 0,091 kg, jednak wzrost ten potwierdzono na poziomie 0,1% istotności statystycznej ($p \leq 0{,}001$). **Podsumowanie.** Wyniki te wskazują, że regularne wykonywanie ćwiczeń fizycznych w grupach starszych kobiet skutecznie zapobiega sarkopenii, otyłości oraz utrzymuje równowagę w udziale poszczególnych tkanek w stosunku do całkowitej masy ciała.

Słowa kluczowe: starsze kobiety, program silowo-wytrzymałościowy, masa mięśniowa, procent tkanki tłuszczowej.