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Effects of aerobic workout on the changes in the characteristics of dynamics of the center of gravity in different age categories

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Introduction: The quality and function of movements undergo deterioration due to weight gain. Aerobic training normalizes body weight, improves the health status, and in addition, it is expected to improve the dynamics of movements. The aims of this study were to prove the beneficial effects of recreational physical activities on the movements. *Methods:* Participants were divided into five different age categories: second childhood, adolescence, mature age I, mature age II, and aging. Squatting and vertical jumping of the participants were measured at the beginning and at the end of a 5-month training program. These movements simulated ordinary daily movements. Changes in the body were determined by InBody230. APAS 3D system was used for movement analysis. *Results:* The results showed significant improvements in body weight, fat mass, muscle mass, fat mass–body weight ratio, muscle mass–body weight ratio, body mass index, body fat percentage, and waist–hip ratio. During jumping, the lifting and sinking of the center of gravity's (CG) position and its velocity and acceleration were improved. In case of squatting, the results showed significant improvements in the velocity and acceleration of dynamical characteristics of the CG. Other correlations were observed between changes in body composition and the dynamics of movements. *Discussion:* The research proved that recreational training optimized body composition and improved the characteristics of CG's dynamics. The study suggests considerable connection between body composition and the characteristics of the movements' dynamics. From this point of view, our training program was the most effective in the working age groups.

Keywords: center of gravity, recreational physical activities, body composition, movement analysis, vertical jumping, squatting

Introduction

The data of the World Health Organization (WHO) demonstrate that the global incidence of overweight and obesity has nearly doubled since 1980. More than 1.4 billion adults were overweight and over 500 million people were obese all over the world in 2008 (21). The severity of obesity can be determined by the body mass index (BMI), the waist circumference

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(WC), and the body fat percentage (BF%) (9, 11). Obesity is a risk factor for many diseases, including diabetes mellitus (3), hypertension (15), heart diseases (26), dyslipidemia (5), cerebrovascular diseases (25), metabolic syndrome (6), and pulmonary (23) and gastrointestinal abnormalities (12).

Obese people often experience minor disabilities, such as low exercise capacity, which causes breathlessness. These cause physical inactivity, weight gain (19), and physical malfunctions (14, 19). Previous studies revealed that physical activity and energy restriction are the most important factors in the prevention or management of obesity (21). Aerobic training and an appropriate diet can optimize body composition (10, 16). Moreover, studies carried out by the American College of Sports Medicine and the American Heart Association suggest low-intensity aerobic physical activity (13).

Ross and Rissanen (20) applied 180 min of physical activity a week at 50%–85% of maximum heart rate (MHR) for 4 months and found that this method reduced body weight (BW) and WC in adults.

Davidson et al. (4) used a different training program for the 60–80 years old participants: 150 min a week at 60%–75% of the MHR for 6 months. This activity reduced BW, WC, and fat mass (FM).

Lee et al. (18) detected significant reduction of FM and increase of skeletal muscle mass (SMM) and muscle–fat ratio without weight loss among middle-aged obese people, who participated in a 13-week aerobic exercise intervention that consisted of leather walking or light jogging on a treadmill for 60 min, five times per week, at a moderate intensity (~60% of peak oxygen uptake).

Araya et al. (1) applied 180 min of physical activity a week for 3 months, which reduced abdomen circumference and waist–hip ratio (WHR) in women more than 60 years of age.

In a 6-year follow-up study, a notable 15% difference was revealed by Stenholm et al. (24) in the walking speed of obese and normal body-type participants with the age of ≥65 years. The lack of adequate muscle strength and power might be responsible for the difficulty in performing simple tasks such as walking and stair climbing in obese individuals (19). Since an increase in body fat makes the speed of movements slower, the dynamics of the daily movements can be improved by optimizing the body composition.

Human movements might be appropriately described by the movements of the center of gravity (CG). For example, during the swinging motion of a jump, the activity level of the muscles is low when the CG is sinking. When the CG starts to increase, the activity level of the muscles becomes high and the jump could be completed (2, 8). Araya et al. (1) reported after their training program that body composition was optimized and the height of the jump increased.

The aims of this study were to investigate the impact of recreational physical activities, a 5-month training program on body composition as well as on the dynamics of movements.

Based on the changes in body composition, the characteristics of the CG's dynamics were tested after application of recreational training in different age classes for 5 months. Simple movements were applied in our investigations, which were to simulate climbing stairs and sitting down or standing up from a chair. Similar muscles are used in performing these daily activities as in vertical jumping and squatting. An important factor in the selection of these movements was the fact that anthropometrical parameters like height and limb length were not influenced by the measurement. Squatting and vertical jumping were considered to be suitable movements to measure the effects of the recreational training program on the changes in the characteristics of dynamics of the CG. Moreover, we attempted to find an appropriate age limit to determine the correlation between body composition and the dynamics of movements.

Materials and Methods

Settings and participants

Ninety-two participants (56 females and 36 males) were chosen for this study; they were randomly selected untrained volunteers. The participants were 31.66 ± 19.27 years old. They were divided into five groups based on their ages (7): G1: second childhood ($n = 14$; female: 8–11 and male: 8–12 years old), G2: adolescence ($n = 20$; female: 12–15 and male: 13–16 years old), G3: mature age I ($n = 22$; female: 21–35 and male: 22–35 years old), G4: mature age II ($n = 23$; female: 36–55 and male: 36–60 years old), and G5: aging ($n = 13$; female: 56–74 and male: 61–74 years old). The human examinations were carried out under the license of the Regional Research Ethics and Science Committee of the University of Szeged (WHO 2658).

Exercise program

The training program was based on earlier studies (1, 4, 13, 18, 20) and included aerobics, spinning, table tennis, and swimming. Recreational training periods of 60 min were used, repeated three times a week for five months at 80.36% ± 0.51% of the MHR. During exercise, the heart rate was constantly controlled with polar heart rate monitors (Polar Team System, Finland) (17). Examinations on the body composition and the dynamics of movements were performed at the beginning and at the end of the training sessions, always under the same circumstances.

Measurement of body composition

Body composition was assessed using data obtained by bioelectrical impedance analysis (BIA; Biospace InBody230® Body Composition Analyzer, Seoul, Korea). Changes in BW, FM, SMM, BMI, BF%, and WHR were observed in the study (17). The FM/BW and SMM/BW were calculated from these body composition data. Losses in BW with constant SMM indicate an increase in the ratio of SMM/BW (18).

Measurement of dynamics of movements

The APAS 3D system was used for movement analysis (Ariel Dynamics Inc., Ariel Performance Analysis System, version 12.3.0.2®, USA). The measurements were taken in two dimensions with a 2 × 2 m reference frame and four reference points. Ten marker points were used on joints such as ankles, knees, hips, shoulders, elbows, and 1 marker point was used on the forehead. CG was calculated by the software based on the reference and marker points. The participants performed two different simple movements, squatting and vertical jumping, to test which can describe better the changes in the characteristics of the CG's dynamics after the training program. These movements were recorded at a speed of 30 frames/s with a camera (Casio EX-F1®, Tokyo, Japan). The participants were instructed to perform the moves as quickly as they could and in the widest possible movement range. The changes in position, velocity, and acceleration were analyzed regarding the CG of the moves.

Statistical analysis

Data are expressed as mean ± SEM. The percentages of delta (Δ%) within the first and the last examinations are highlighted for the statistical analysis. Initially, one-sample *t*-test was used to determine the significance of the changes separately in the groups. Later, analysis of variance (ANOVA) was used with the difference of delta (ΔD) of the groups to detect significant differences between the changes in the parameters of the groups. The possible connection in the body composition and the dynamics of movements were investigated with correlation. The significance level was $p \leq 0.05$ for all comparisons.

Results

Changes in body composition

The differences and changes in body composition were examined after participating for 5 months in the study (Fig. 1). After the training program, BW significantly changed in G1 (1.48% ± 0.45%), G3 (−2.36% ± 1.24%), G4 (−2.37% ± 1.03%), and G5 (−1.36% ± 0.36%). The FM significantly reduced in G3 (−8.64% ± 3.5%) and G4 (−6.08% ± 2.88%). Moreover, the SMM has also shown significant decline during the examination in G5 (−2.9% ± 1.02%). FM/BW showed reduction in G3 (−7.02% ± 3.12%), and SMM/BW upgraded in G3 (2.86% ± 1.27%) and G4 (1.96% ± 1.03%). The BMI was normalized in G3 (−2.16% ± 1.23%), G4 (−2.28% ± 1.04%), and G5 (−1.33% ± 0.37%). The results show that the BF% decreased in G3 (−6.6% ± 2.98%) and G4 (−4.05% ± 2.32%). The WHR improved in G2 (−1.77% ± 0.91%), G4 (−0.71% ± 0.35%), and G5 (−0.87% ± 0.46%).

The ANOVA revealed differences in the improvements of body composition parameters between the groups (Fig. 1). The data show significant differences in BW between G1 and G3 (−3.84%), G1 and G4 (−3.86%), G2 and G3 (−3.34%), G2 and G4 (−3.36%), and G2 and G5 (−2.34%). The changes in FM were significantly different between G1 and G2 (−5.51%), G1 and G3 (−12.07%), G1 and G4 (−9.51%), G2 and G3 (−6.57%), G3 and G5 (9.5%), and G4 and G5 (6.94%). There were significant differences in the changes in SMM between G1 and G5 (−3.63%), G2 and G4 (−4.63%), G2 and G5 (−6.93%), G3 and G5 (−3.35%), and G4 and G5 (−2.3%). We detected differences in the changes in FM/BW between G1 and G2 (−4.89%), G1 and G3 (−8.88%), G1 and G4 (−5.97%), G2 and G5 (5.25%), G3 and G5 (9.25%), and G4 and G5 (6.34%). We observed significant differences in changes in SMM/BW between G1 and G3 (3.57%), G1 and G4 (2.67%), G2 and G5 (−4.56%), G3 and G5 (−4.41%), and G4 and G5 (−3.5%). The statistical analysis revealed further remarkable differences in BMI between G1 and G3 (−3.63%), G1 and G4 (−3.75%), G2 and G3 (−3.21%), G2 and G4 (−3.33%), and G2 and G5 (−2.38%). We found significant differences in changes in BF% between G1 and G2 (−4.98%), G1 and G3 (−8.55%), G1 and G4 (−6.01%), G2 and G5 (5.21%), G3 and G5 (8.78%), and G4 and G5 (6.23%). There were significant differences in changes of WHR between G1 and G2 (−2.21%), G1 and G3 (−0.93%), G1 and G4 (−1.14%), and G1 and G5 (−1.31%).

Changes in the dynamics of movements

Figure 2 represents the changes in the dynamics of movements, which demonstrate that the 5-month recreational training program improved the lifting of the position of the CG in G3 (12.18% ± 5.61%), G5 (15.98% ± 6.98%), and the sinking of the position of the CG in the G2 (16.8% ± 9.16%), the G3 (40.08% ± 11.43%), G4 (61.29% ± 23.47%), and the G5 (34.73% ± 8.74%) during jumping. The measurement showed significant changes in the velocity of the CG in G2 (−9.97% ± 5.29%), G4 (16.49% ± 6.88%), and G5 (14.69% ± 5.37%); however, the changes could also be seen in the acceleration of the CG in G3 (313.71% ± 166.38%) and G5 (17.27% ± 5.22%) during jumping.

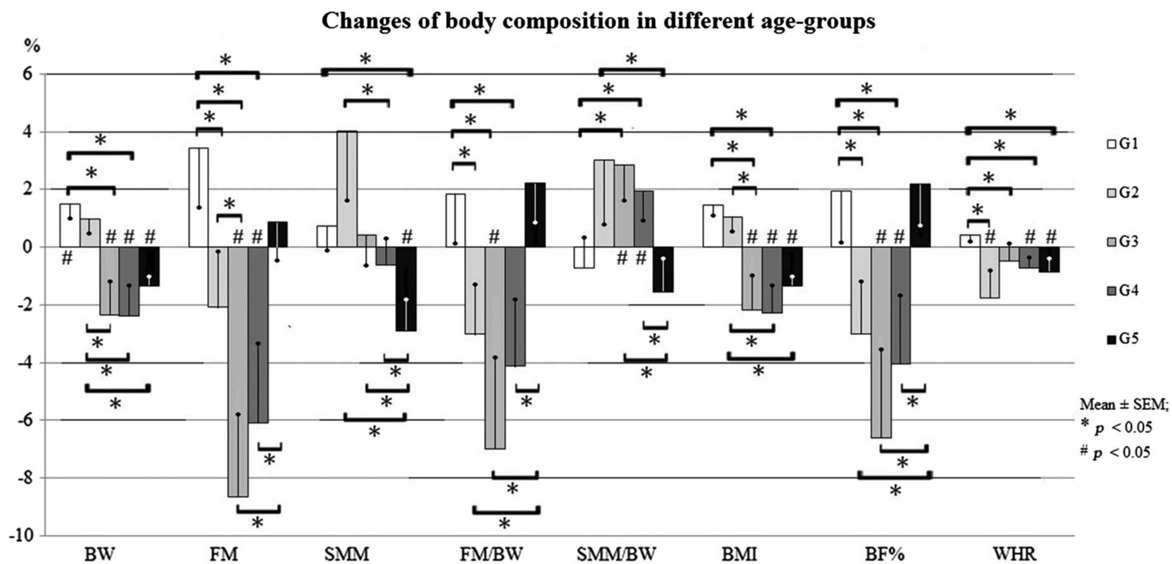

Fig. 1. Changes in body composition in different age-groups. Values are means ± SEM. G1: second childhood; G2: adolescence; G3: mature age I; G4: mature age II; G5: aging; BW: body weight; FM: fat mass; SMM: skeletal muscle mass; FM/BW: fat mass–body weight ratio; SMM/BW: muscle mass–body weight ratio; BMI: body mass index; BF%: body fat percentage; WHR: waist–hip ratio. *Significant differences between changes of groups; [#]Significant changes in groups; $p \leq 0.05$

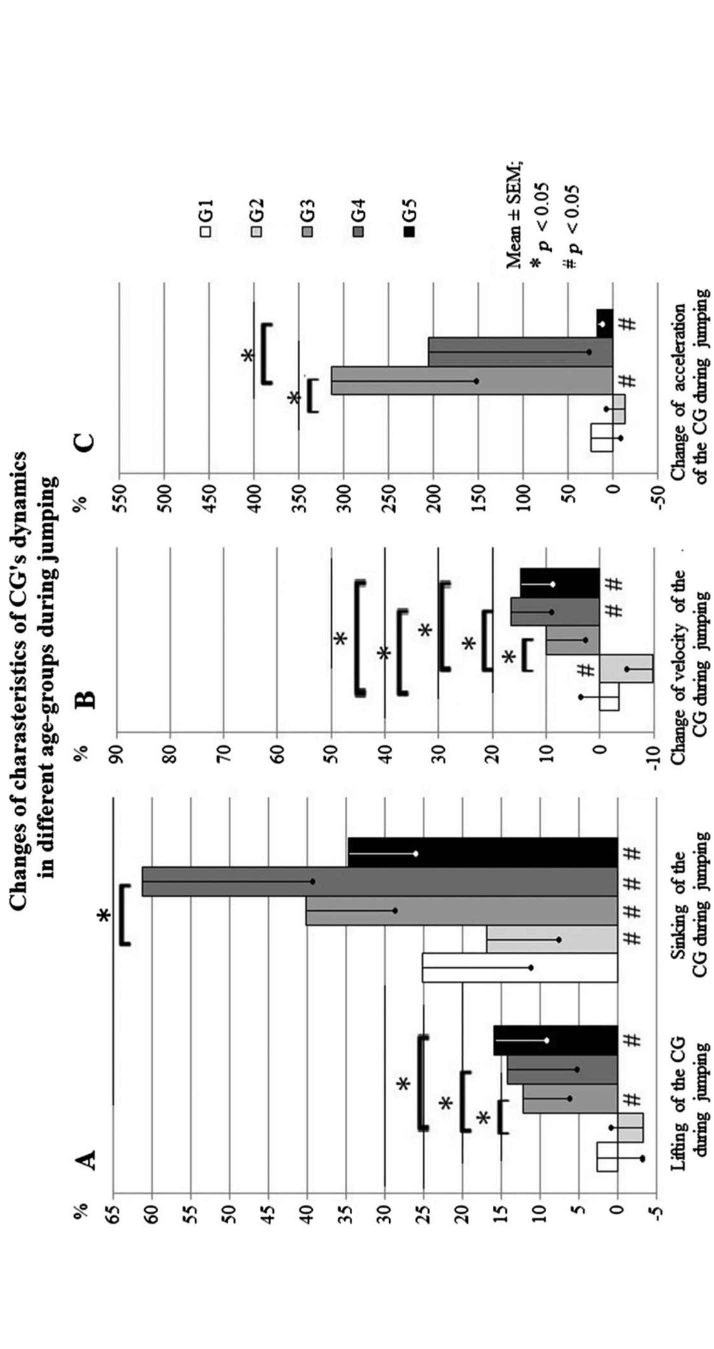

Fig. 2. Changes in characteristics of CG's dynamics in different age groups during jumping. (A) Differences between the groups in lifting and sinking of CG; (B) Differences between the groups in the velocity of CG; (C) Differences between the groups in the acceleration of CG. Values are means ± SEM; CG: center of gravity; G1: second childhood; G2: adolescence; G3: mature age I; G4: mature age II; G5: aging. *Significant differences between changes of groups; #Significant changes in groups; $p \leq 0.05$

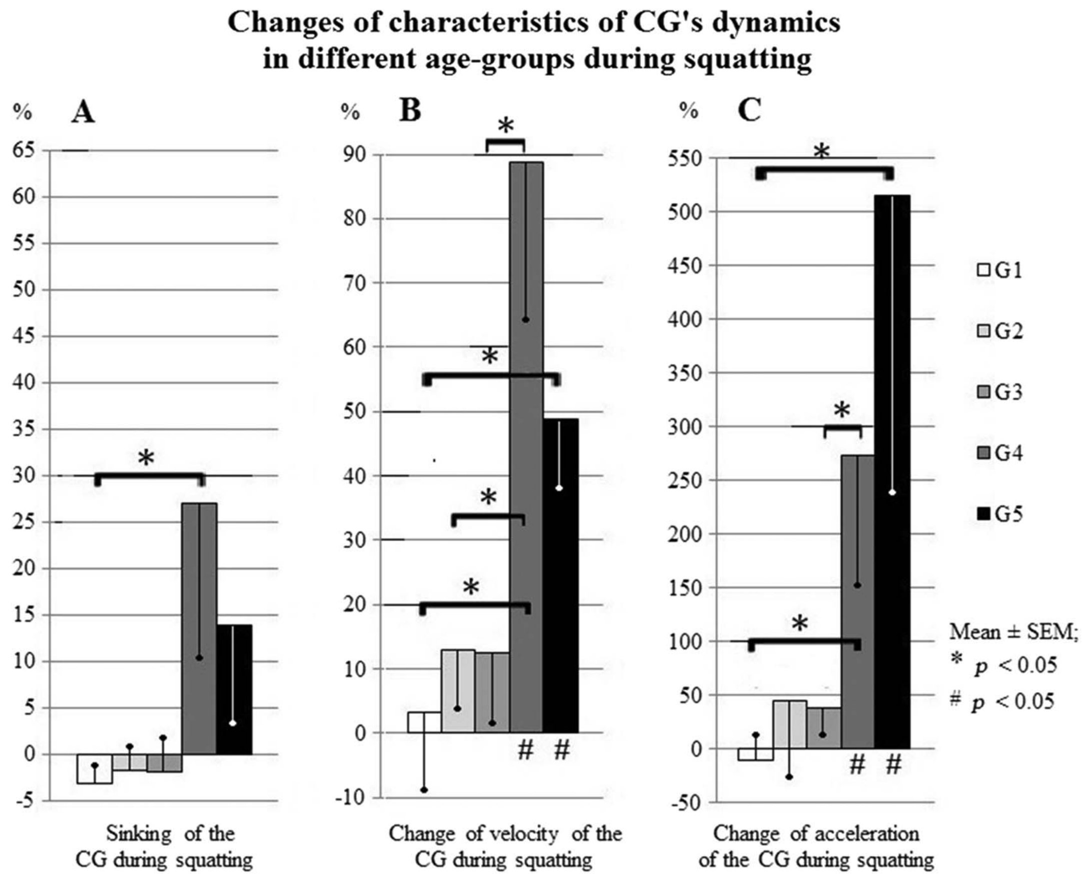

Fig. 3. Changes in characteristics of CG's dynamics in different age groups during squatting. (A) Differences between the groups in sinking of CG; (B) Differences between the groups in the velocity of CG; (C) Differences between the groups in the acceleration of CG. Values are means ± SEM; CG: center of gravity; G1: second childhood; G2: adolescence; G3: mature age I; G4: mature age II; G5: aging.
*Significant differences between changes of groups. #Significant changes in groups; $p \leq 0.05$

Changes in the characteristics of jumping showed significant differences considering the lifting of position between G2 and G3 (15.51%), G2 and G4 (17.45%), and G2 and G5 (19.31%); the sinking of position between G2 and G4 (44.49%) (Fig. 2A); the velocity of CG between G1 and G4 (20.13%), G1 and G5 (18.32%), G2 and G3 (19.86%), G2 and G4 (26.28%), G2 and G5 (24.47%) (Fig. 2B); and the acceleration of CG between G2 and G3 (327.3%) G3 and G5 (−330.98%) (Fig. 2C).

Changes in the characteristics of squatting also showed significant differences. The velocity of the CG in G4 (88.68% ± 25.12%) and G5 (48.92% ± 10.08%) and the acceleration of the CG in G4 (273.18% ± 123.22%) and G5 (514.93% ± 276.23%) increased during squatting (Fig. 3).

Furthermore, squatting data showed significant changes between G1 and G4 (30.28%) with regard to the sinking of the CG (Fig. 3A). The changes in squatting specify significant differences in the velocity between G1 and G4 (85.41%), G1 and G5 (45.66%), G2 and G4 (75.79%), and G3 and G4 (76.19%) (Fig. 3B), and the changes were also observed in the acceleration of CG between G1 and G4 (283.58%), G1 and G5 (525.34%), and G3 and G4 (234.74%) (Fig. 3C).

Correlation between the changes in body composition and the dynamics of movements

During the jumping exercise, the lifting of the CG demonstrated notable correlations with FM ($r = -0.52$), SMM ($r = 0.45$), FM/BW ($r = -0.5$), SMM/BW ($r = 0.5$), and BF% ($r = -0.49$) in G2 and BW ($r = -0.48$), FM ($r = -0.43$), SMM/BW ($r = 0.46$), and BMI ($r = -0.46$) in G3. Similar correlation was observed between the sinking of position during jumping and BW ($r = 0.7$), FM ($r = 0.51$), BMI ($r = 0.69$) in G1; BW ($r = 0.57$) in G2; SMM/BW ($r = 0.43$) in G4; and the BW ($r = -0.67$), FM ($r = -0.63$), FM/BW ($r = -0.56$), BMI ($r = -0.65$), BF% ($r = -0.55$), and WHR ($r = -0.7$) in G5. The velocity of CG during jumping did not show any correlation with the changes in body composition parameters. However, correlation was shown between the acceleration of CG and the decrease in BW ($r = -0.46$) or BMI ($r = -0.52$) in G2.

The statistical analysis proved significant correlation between the sinking of CG at squatting and FM ($r = 0.49$), SMM ($r = -0.47$), FM/BW ($r = 0.47$), SMM/BW ($r = -0.5$), BF% ($r = 0.46$), and WHR ($r = 0.65$) in G2; BW ($r = -0.76$), FM ($r = -0.74$), FM/BW ($r = -0.69$), SMM/BW ($r = 0.78$), BMI ($r = -0.76$), BF% ($r = -0.69$), and WHR ($r = -0.55$) in G4; and the SMM ($r = 0.55$) and WHR ($r = 0.73$) in G5. The velocity of CG during squatting also showed correlation with the BW ($r = -0.44$), FM ($r = 0.54$), SMM ($r = -0.75$), SMM/BW ($r = -0.68$), BMI ($r = -0.72$), BF% ($r = 0.65$) in G2 and the BW ($r = -0.55$), BMI ($r = -0.56$), and WHR ($r = -0.89$) in G5. The acceleration of CG data also presented remarkable correlation with BW ($r = -0.5$) and BMI ($r = -0.57$) in G2 and WHR ($r = -0.74$) in G5.

Discussion

Physical activity has beneficial effects on body composition. Moreover, regular exercise can improve body composition parameters, such as the BW, the FM, and the SMM. Ross and Rissanen (20) demonstrated that aerobic exercise and a suitable diet can optimize the body composition and the BW. Another study by Lee et al. (18) revealed a decrease in FM and an increase in SMM after aerobic exercising with weight observance. In addition, regular exercise prevents several diseases including diabetes mellitus, hypertension, heart diseases, dyslipidemia, cerebrovascular diseases, metabolic syndrome, and pulmonary and gastrointestinal abnormalities (3, 5, 6, 12, 15, 23, 25, 26). Regular physical activity also facilitates daily movements that develop physical capacity. The aim of this research was to verify that recreational training optimizes body composition and improves the dynamics of movements. Non-invasive methods were employed to find out the changes between the age groups before and after participation in the training program.

Based on this research, changes of body composition were observed most frequently in G3 (BW, FM, FM/BW, SMM/BW, BMI, and BF%) and G4 (BW, FM, SMM/BW, BMI, BF%, and WHR) after the training program. A previous study by Araya et al. (1) showed that physical activity optimized body composition and improved the height of jumping. Development of lifting during jumping was also observed. Our results are consistent and show similar increase in the characteristics of dynamics of CG during jumping in G3 (lifting, sinking, and acceleration), G4 (sinking and velocity), and G5 (lifting, sinking, velocity, and acceleration) groups. In addition, our data suggest that the training program can optimize the characteristics of the dynamics of CG. The data showed improvement in the characteristics of the dynamics of CG during squatting in G4 (velocity and acceleration) and G5 (velocity and acceleration) groups. Differences were also observed between the G1, G2 and G3, G4, G5 groups using ANOVA. When examining body composition, differences in changes were observed between primarily G1 and G3 and G1 and G4 (BW, FM, FM/BW, SMM/BW, BMI, BF%, and WHR) or G2 and G5 (BW, SMM, FM/BW, SMM/BW, BMI, and BF%). Based on the results of the dynamics of movements, differences were observed between G1 and G4 (velocity of CG during jump and sinking, velocity, and acceleration of CG during squat), G1 and G5 (velocity of CG during jump and velocity and acceleration of CG during squat), G2 and G3 (lifting, velocity, and acceleration of CG during jump), and G2 and G4 (lifting, sinking, velocity of CG during jump and velocity of CG during squat). Under the age of 21 years, participants did not show significant changes after completing the 5-month training program because of their routine physical activities at school as well as at home. If the training program had been longer, the results might have shown more significant differences in these age groups in comparison with a physically inactive control group. However, the training program had positive effects on the sedentary lifestyle of older adults.

The development in the characteristics of the dynamics of CG was shown in the present training program by the results of body composition measurements in G3 (BW, FM, SMM/BW, BMI – lifting of CG during jumping), G4 (SMM/BW – sinking of CG during jumping; BW, FM, FM/BW, SMM/BW, BMI, BF%, WHR – sinking of CG during squatting), and G5 (BW, FM, FM/BW, BMI, BF%, WHR – sinking of CG during jumping; SMM – sinking of CG during squatting; BW, BMI, WHR – velocity of CG during squatting; WHR – acceleration of CG during squatting). Many links were detected in G2, but there were several positive (FM, SMM, FM/BW, SMM/BW, BF% – lifting of CG during jumping; BW, BMI – acceleration of CG during jumping; BW, BMI – velocity of CG during squatting; BW, BMI – acceleration of CG during squatting) and negative (BW – sinking of CG during jumping; FM, SMM, FM/BW, SMM/BW, BF%, WHR – sinking of CG during squatting; FM, SMM, SMM/BW, BF% – velocity of CG during squatting) connections in this group. These differences can be explained by the adolescents' peak velocity in growth when their movements need recoordination. In comparison, older adult participants have compulsive motor coordination.

Another aim of this study was to test two movements to confirm the effects of the changes in body composition on the characteristics of dynamics of CG. Our results showed similarities with previous studies in the field of recreational physical activity (1, 10, 20). The characteristics of the dynamics of CG during jumping were optimized in G2, G3, G4, and G5 just like during squatting in G4 and G5 due to the improved body composition.

These results endorsed the conclusion that vertical jumping is more suitable than squatting to measure the correlation between the changes in body composition and the characteristics of the dynamics of movement in all age groups. In case of squatting, this correlation can be observed mostly in the older age categories. This study reflects the interaction between the improvement in the parameters of body composition and the dynamics of daily movements. Hence, the risk factors of the mental, internal, and musculoskeletal diseases can be decreased by these trainings (22). Our training program was the most effective in the working-age classes (G3, G4, and G5). This is most important because physical activity can improve the health status and the working ability in this age group. However, at the age of a pensioners', the SMM is degraded, but the overall effects of the recreational training can increase the quality of life. Mobility has significant effects on the way of living. If people have this ability, they can be self-supporting. The coordinating and conditioning skills are formed at a basic level at school age, and should be also generated in older age classes by systematic physical activities.

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Conflict of interest

The authors report no conflict of interest.

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