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Original scientific paper

The Influence of a 7-month-long Intensive Aquatic Exercise Program on Changes in Physical Fitness, Bone Density and Lung Function Parameters in Postmenopausal Women

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A B S T R A C T

The aim of this study was to evaluate changes in the physical fitness, bone density and lung function parameters in older women who underwent a 7-month-long aquatic exercise program (AEP). 25 women took part in weekly 60-minute systematic AEP. Before and after the AEP participants and the control group subjects underwent the Fullerton Functional Fitness Test, bone mineral density and respiratory system assessment. A significant improvement in the results of hand grip strength, 30-second chair stand, 6-minute trial walking and chair sit and reach tests were reached in the AEP women. Additionally, in the AEP group, the forced expiratory volume in 1 sec (FEV1) significantly increased.

Key words*: older women, physical fitness, respiratory system, bone density, involutional changes*

Introduction

For many years, European societies have been experiencing a continuous increase in the number of people over the age of 60 years. The European Commission's[1] data show that this process will be continuing in the future, thus making the problems of ageing and old age the subjects of interdisciplinary and multi-center studies[2–4]. The average life expectancy has increased due to intensive economic development, the significant improvement of living conditions, better diet, the development of medicine and better access to health care[5]. The issue of senior citizens and their quality of life as well as their role in society is often highlighted in these studies. A higher level of education and further gerontological education result in greater knowledge regarding factors that condition a more active approach to their own health and healthy lifestyle[6–9]. Although involutional processes and certain chronic illnesses and dysfunctions cannot be avoided, the processes can be limited or retarded by a healthy lifestyle, so that people in this last period of ontogenesis could enjoy relatively high physical and psychical functionality[10–12].

One of the most important factors of health is physical activity. Researchers agree that suitable forms of physical activity for older people not only retard the ageing process, but also positively influence the motor system and other systems such as: the respiratory system, the vascular system and the nervous system[13–20]. The researchers mentioned above point out that unsuitable and excessive physical effort in older people may result in negative consequences for their health. Thus, many studies focus on the health effects of different physical activities, their frequency and the scope of structural-functional changes, including the sense of balance in older people[7,20–22]. Physical activities and exercises should be carefully selected for a particular older person in order to achieve positive health effects.

The most often recommended and employed exercises and activities are: gymnastic exercises, walking (e. g. Nordic walking), ballroom dance and rehabilitation (e. g. sanatorium)[3,23,24,]. One of the forms of physical activity could be aquatic exercises. Aquatic exercises are characterized by a high level of safety. The body in water is weightless and joints are relieved of the weight they carry,

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so the health effects are very beneficial. Organized aquatic physical activities are excellent for the prevention of illnesses and promotion of health, and not only in older people. We can therefore ask how often aquatic exercises should be performed in order to achieve positive changes in the body of an older person.

The aim of this study is to evaluate the basic somatic parameters, functional physical fitness, mineral bone density and efficiency of air flow in the respiratory system in older women with varied levels of physical activity. The test group consisted of women who underwent a 7-month-long aquatic training program. The control group consisted of women who led a sedentary lifestyle. In our work, we assumed that training should take place at least once a week for a bigger part of the year, so as to condition the body and to achieve improved functioning.

Material and Methods

The study group included 52 women, being inhabitants of the city of Jelenia Góra, attendants of the University of the Third Age at the Karkonosze College in Jelenia Góra. All of the subjects underwent a medical examination and functional tests of physical fitness in October 2013. The women were voluntarily divided into two groups. 25 women agreed to take part in weekly, 60-minute systematic aquatic exercises during November 2013 to May 2014 (7 months) and constituted the Aquatic Exercise Group (AEG). The rest (27 women) constituted the Control Group (CG) and did not take part in any organized exercise at the same time declaring a period of no-practice of any systematic physical exercise. After finishing the aquatic exercise program all the women from both groups underwent medical examinations and functional tests once again, which were conducted in the Biokinetics Laboratory at the Department of Biostructure of the University of Physical Education in Wroclaw.

Each aquatic exercise session was divided into three parts: a warm-up in the water based on games aimed to familiarize oneself with the aquatic environment; the main part (about 30 minutes) consisted of learning and the improvement of swimming abilities and breathing in water with moderate intensity so as not to exceeded 130 heart beats a minute, and concluding with a cool- down (about 5 min) aimed to calm the body.

During both examinations the height, weight, waist and hip circumferences were measured by trained staff using standard methods. Based on anthropometry, the BMI [kg/m^2] and waist-to-hip ratio (WHR) were calculated. Bone mineral density (BMD) was assessed using Dual Energy X-ray Absorptiometry (DEXA) with the EXA-3000 apparatus and was first analyzed using special software included in the apparatus. Four BMD characteristics were recorded: the value and % of BMD of the peak value calculated for young adults (20–25, USA reference population) T-score and %T-score. The value and % of BMD of the value for the reference population at a particular age, Z-score and %Z-score. The standard errors of measurement were estimated between 2% and 3%. The functional parameters of the respiratory system were assessed using the Flowscreen apparatus (780, 578, ver. 1.3, Jäger) and the following parameters were recorded: forced vital capacity (FVC) [ml], forced expiratory volume in 1 sec (FEV_1) [ml], peak expiratory flow (PEF) [l/s], ratio of forced expiratory volume in 1 second to forced vital capacity (called Tiffenau's index – FEV_1/FVC). The Fullerton Functional Fitness Test, also labeled the Senior Fitness Test[25–27], was used. The test evaluates six functional capacities.

Upper body strength was measured as the number of arm curls while holding a hand weight (5 pounds [2.27 kg] for females, 8 pounds [3.63 kg] for males) completed in 30 seconds. Lower body strength was measured as the number of unassisted full »chair stands« from a seated position and with the arms folded, performed in 30 seconds.

Aerobic endurance was measured as the distance (meters) walked in 6 minutes. A flat rectangular area of 50 m in length (20 m by 5 m) was marked at 5 m segments. A metric tape measure, marked off at each meter, was affixed to the floor along the walking course. The subjects were instructed to walk as fast as possible for six minutes. Two or three participants performed the test at the same time. On the starting signal, subjects began walking around the course, covering as much distance as possible in 6 minutes. To keep track of the distance walked, testers noted each completed lap on the record sheet, encouraged the subjects and called out the time remaining when subjects were about half-way through the test and when 2 minutes and 1 minute remained. If necessary, participants were permitted to rest on chairs provided along the walking course, but the clock continued to run. When the 6 minutes elapsed, the subjects stopped but were instructed to slowly step in place for a 5-minute cool down. The distance walked in 6 minutes was recorded to the nearest one meter.

Agility/dynamic balance (»8-ft up and go«) was measured as the time (0.01 second, Casio HS-80TW-1EF stopwatch) required to rise from a seated position, walk for 2.44 meters, and return to the seated position.

Upper body flexibility was measured as the »back scratch«. The test required the subject to reach over the shoulder with one hand and to reach up the middle back with the other hand. The overlap or distance separating the extended middle finger of each hand was measured to the nearest cm (+ middle fingers of each hand overlap; – middle fingers do not overlap). Lower body flexibility was measured as the »chair sit and reach«. With the subject in a sitting position at the front edge of a chair and the legs fully extended, he/she was instructed to extend the hands as far as possible towards the toes. The distance from the extended middle fingers to the tip of the toe (+ or –) was measured to the nearest cm.

The tests were administered in a circuit fashion after a 10-minute warm-up period, which included primarily stretching activities. The order of testing was as follows: chair stand-up, arm curl, chair sit and reach, back scratch, eight-foot up and go, and distance walk. A 3 to 5-minute rest period was provided between tests. Two trials were given for the flexibility tests and for the agility test. The better of the two scores was retained for analysis. One trial was given for the two strength tests and the six-minute walk. Subjects were tested in groups of 2 or 3 individuals.

Descriptive statistics of anthropometric, BMD, respiratory and functional parameters, and comparisons between AEG and CG groups were calculated and presented in the Tables 1–3. Differences between the groups were assessed by the t-Student test for independent samples. The effect of the aquatic training was tested using a two-way ANOVA with repeated measurements, where all parameters were dependent variables, with the group and particular examinations being factors. The Duncan test was used for post hoc comparisons and means within each group between the two examinations. All calculations were done using Statistica 12.5[28].

Results

Table 1 presents the descriptive statistics of all analyzed parameters at the first examination, i.e. before starting the aquatic exercise program. None of the parameters showed significant differences between the two groups. After the 7-month training period, both groups were examined again and the descriptive statistics of all parameters are shown in Table 2. There are significant differences between the two groups in three functional parameters and two lung function parameters. The AEG had better results in the following tests: 30-second chair stand, 6-minute trial walk, and chair sit and reach. Additionally, members of this group reached, on average, better results in FEV_1 and FEV/FVC.

The results of the two-way analysis of variance with repeated measurements are presented in Table 3. For the four functional parameters, II-order interaction was highly significant. This means that significant changes in the

TABLE 1
DESCRIPTIVE STATISTICS OF ANALYSED PARAMETERS IN THE AQUATIC EXERCISE GROUP (AEG) AND CONTROL GROUP (CG) BEFORE STARTING THE EXERCISE PROGRAM.

	AEG N=25		CG N=27			
	Mean	SD	Mean	SD	t	p
Age [years]	64.80	4.88	64.74	4.67	0.04	0.9682
Height [cm]	159.86	4.19	158.92	6.10	0.64	0.5226
Weight [kg]	72.52	11.73	69.56	12.79	0.87	0.3884
BMI [kg/m^2]	28.44	4.90	27.50	4.54	0.72	0.4776
Functional parameters						
Hand grip strength [kG]	26.16	6.56	27.22	5.55	–0.63	0.5301
30-second chair stand [n]	17.24	3.81	16.70	3.36	0.54	0.5922
30-second arm curl [n]	20.56	3.39	20.56	4.07	0.00	0.9966
6-minute trial walk [m]	584.28	95.35	547.11	54.95	1.74	0.0883
Chair sit and reach [cm]	6.60	6.85	8.29	5.64	–0.98	0.3337
Back scratch [cm]	–0.62	5.53	–3.06	5.93	1.53	0.1326
Stand and go [s]	6.93	1.14	6.88	0.85	0.16	0.8743
Bone density parameters						
BMD [g/cm^2]	0.32	0.08	0.33	0.09	–0.60	0.5502
T-score	–2.85	1.37	–2.59	1.40	–0.67	0.5047
T-score %	65.07	16.80	68.22	17.25	–0.67	0.5081
Z-score	–0.99	1.25	–0.73	1.34	–0.72	0.4744
Z-score %	83.00	21.40	87.61	22.93	–0.75	0.4579
Lung function parameters						
FVC [ml]	2.93	0.49	2.83	0.51	0.73	0.4694
FEV_1 [ml]	2.30	0.43	2.20	0.46	0.84	0.4072
PEF [l/s]	4.33	0.90	3.96	1.06	1.33	0.1909
FEV/FVC	78.66	5.34	77.43	6.21	0.77	0.4475

BMD – Bone mineral density
FVC – forced vital capacity
FEV_1 – forced expiratory volume in 1 sec
PEF – peak expiratory flow

TABLE 2
DESCRIPTIVE STATISTICS OF ANALYSED PARAMETERS IN THE AQUATIC EXERCISE GROUP (AEG) AND CONTROL GROUP (CG) BEFORE FINISHING THE EXERCISE PROGRAM.

	AEG N=25		CG N=27			
	Mean	SD	Mean	SD	T	p
Age [years]	65.39	4.89	65.33	4.67	0.05	0.9637
Height [cm]	159.85	3.98	158.90	6.13	0.66	0.5136
Weight [kg]	72.56	11.88	69.49	13.10	0.88	0.3826
BMI [kg/m^2]	28.44	4.81	27.48	4.68	0.73	0.4674
Functional parameters						
Hand grip strength [kG]	28.96	5.04	26.96	4.78	1.47	0.1488
30-second chair stand [n]	20.76	5.32	16.85	4.19	2.95	0.0048
30-second arm curl [n]	22.76	4.02	21.67	3.92	0.99	0.3260
6-minute trial walk [m]	624.36	75.10	524.93	77.64	4.69	<0.0001
Chair sit and reach [cm]	11.44	7.91	6.59	5.84	2.53	0.0147
Back scratch [cm]	–1.24	6.30	–2.15	6.05	0.53	0.5983
Stand and go [s]	5.99	0.76	6.14	0.81	–0.69	0.4909
Bone density parameters						
BMD [g/cm^2]	0.33	0.08	0.33	0.10	0.01	0.9889
T-score	–2.64	1.38	–2.63	1.57	–0.02	0.9867
T-score %	67.63	16.90	67.76	19.17	–0.03	0.9791
Z-Score	–0.79	1.24	–0.75	1.47	–0.10	0.9235
Z-score %	86.37	21.36	87.21	25.43	–0.13	0.8982
Lung function parameters						
FVC [ml]	3.07	0.57	2.86	0.59	1.30	0.2000
FEV_1 [ml]	2.40	0.49	2.11	0.52	2.08	0.0423
PEF [l/s]	4.31	0.95	4.11	1.11	0.69	0.4961
FEV/FVC	78.05	4.57	72.99	8.51	2.64	0.0109

average results before and after the aquatic exercise program occurred only in the AEG group. After the aquatic exercise program, a significant improvement in the average results of the following tests was reached in AEG women: hand grip strength, 30-second chair stand, 6-minute trial walking, chair sit and reach. These effects are shown graphically in Figures 1–4. In Figure 1 the average hand grip strength increased in the AEG women, whereas the means of the CG group did not change at all. Also, the average results of the 30-second chair stand showed significant changes in AEG women (Figure 2). Similarly, the average results of the 6-minute trial walk in the AEG group increased, whereas in the CG group it slightly decreased (Figure 3). The same pattern is repeated in Figure 4, presenting results of the chair sit- and -reach test. All the parameters of the post hoc tests showed significant differences in the average before and after aquatic exercise program in the AEG women, but not in the CG group.

Besides the functional parameters, the aquatic exercise program had the significant effect of improvement in the lung function parameters (Table 3). In the AEG group post aquatic training, the average value of the FEV_1 signifi-

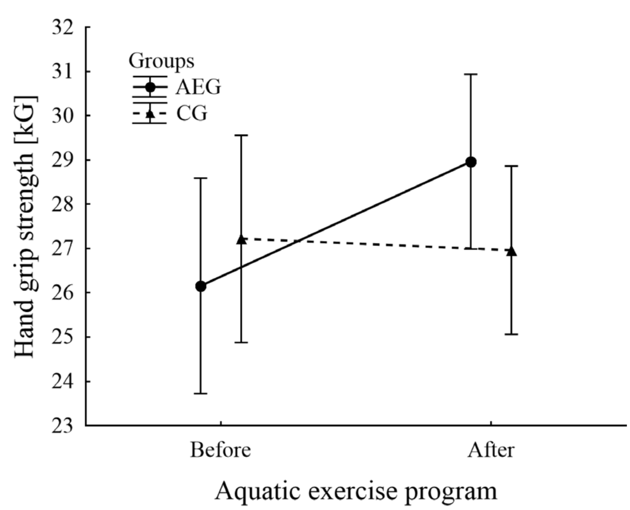

Fig. 1. Means (95% CI) of hand grip strength before and after aquatic exercise program in training group (AEG) and control group (CG) of older women.

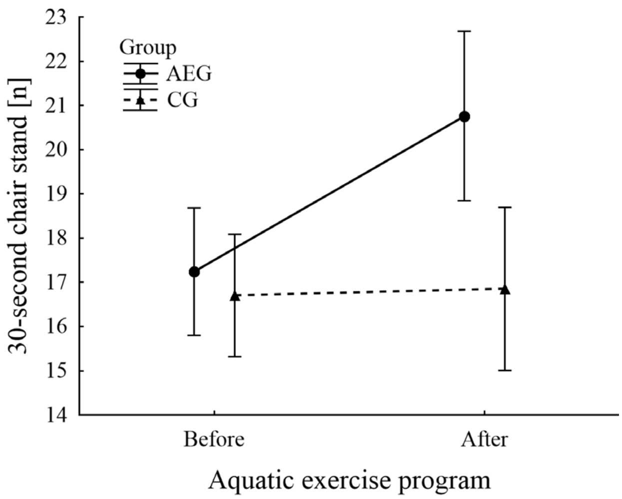

Fig. 2. Means (95% CI) of 30-second chair stand before and after aquatic exercise program in training group (AEG) and control group (CG) of older women.

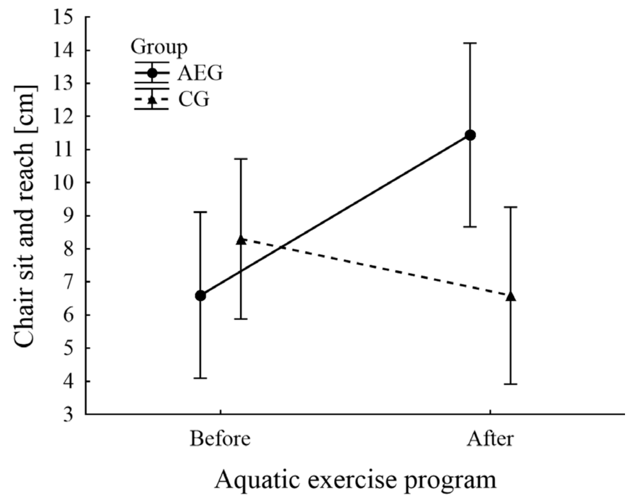

Fig. 4. Means (95% CI) of chair sit and reach before and after aquatic exercise program in training group (AEG) and control group (CG) of older women.

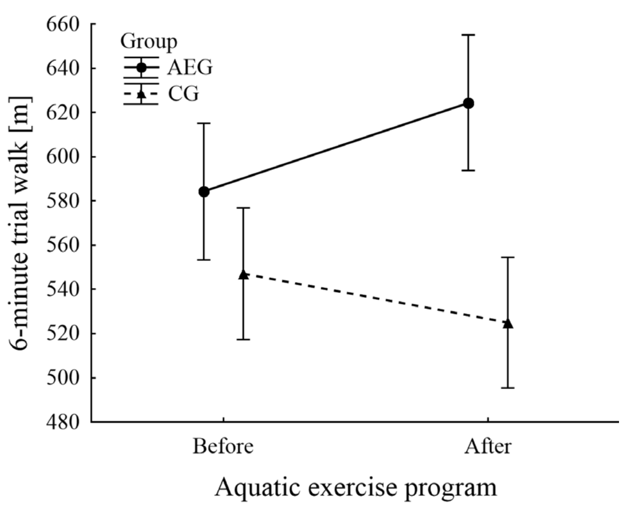

Fig. 3. Means (95% CI) of 6-minute trial walk before and after aquatic exercise program in training group (AEG) and control group (CG) of older women.

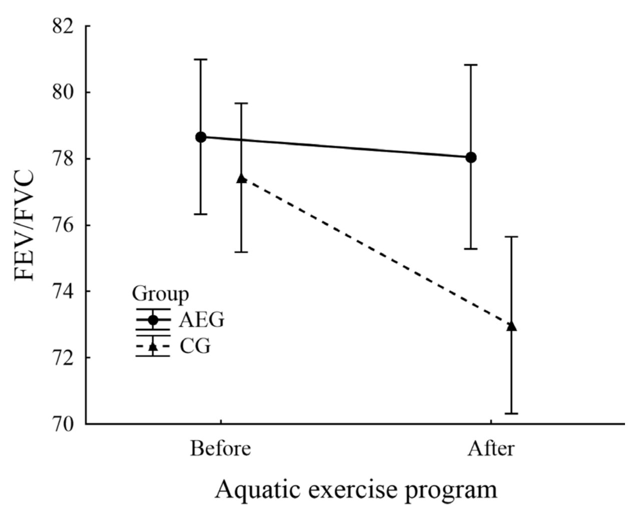

Fig. 5. Means (95% CI) of ratio FEV/FVC before and after aquatic exercise program in training group (AEG) and control group (CG) of older women.

cantly increased (Figure 5).The ratio FEV/FVC showed no changes in the AEG women, whereas a significant decrease in the CG group was found (Figure 6). No significant changes were noticed in bone mineral density parameters in both groups of women.

Discussion and Conclusion

Multi-faceted medical, social and economic problems caused by the growing percentage of older people living in societies, have resulted in a high interest in researching these issues. The results of the studies show that it is necessary to take action to retard involutional processes, to maintain health and functional independence of seniors on an optimal level, so as to maintain the quality of their lives[2,3,10,16,19]. Authors of many studies agree that physical activity prevents and treats many pathological states, therefore making it an important factor in promoting physical and psychical health. However, it is open to debate on what the right level of the stimulus is, as well as the frequency and the form of physical activity, in order to achieve the optimal functional state of the body of an older person.

During the examination before starting the aquatic exercises, no major differences were noticed between the

TABLE 3
RESULTS OF THE TWO-WAY ANALISIS OF VARIANCE WITH REPEATED MEASUREMENTS FOR ALL PARAMETERS

Variables	Group		Repeated		Interaction		Post hoc Duncan test	
	F	P	F	p	F	p	P*	p†
Age [years]	0.01	0.9660	75200.11	0.0000	3.02	0.0887	0.0001	0.0001
Height [cm]	0.43	0.5167	0.02	0.8843	0.00	0.9653	0.9426	0.8938
Weight [kg]	0.78	0.3824	0.00	0.9687	0.02	0.9041	0.9543	0.9102
BMI [kg/m²]	0.53	0.4690	0.01	0.9314	0.01	0.9358	0.9969	0.9063
Functional parameters								
Hand grip strength [kG]	0.11	0.7414	4.54	0.0381	6.58	0.0134	0.0030	0.7599
30-second chair stand [n]	4.69	0.0352	10.66	0.0020	9.00	0.0042	0.0002	0.8530
30-second arm curl [n]	0.36	0.5532	8.93	0.0043	0.97	0.3304	0.0096	0.1872
6-minute trial walk [m]	13.46	0.0006	0.75	0.3913	9.05	0.0041	0.0086	0.1359
Chair sit and reach [cm]	0.96	0.3316	3.27	0.0768	14.17	0.0004	0.0004	0.1982
Back scratch [cm]	1.20	0.2786	0.05	0.8225	1.44	0.2365	0.4949	0.3190
Stand and go [s]	0.06	0.8072	49.13	0.0000	0.67	0.4187	0.0001	0.0002
Bone density parameters								
BMD [g/cm²]	0.08	0.7731	1.20	0.2787	2.43	0.1252	0.0813	0.7601
T-score	0.76	0.3867	1.14	0.2904	2.68	0.1076	0.0615	0.6889
T-score %	0.12	0.7332	1.24	0.2711	2.56	0.1161	0.0610	0.7326
Z-Score	0.19	0.6638	1.57	0.2164	2.51	0.1196	0.0505	0.8157
Z-score %	0.19	0.6638	1.45	0.2348	2.35	0.1315	0.0588	0.8161
Lung function parameters								
FVC [ml]	1.18	0.2829	3.15	0.0821	1.35	0.2500	0.0430	0.6678
FEV_1 [ml]	2.39	0.1283	0.02	0.9031	7.52	0.0085	0.0483	0.0700
PEF [l/s]	1.19	0.2800	0.32	0.5731	0.52	0.4742	0.9139	0.3668
FEV/FVC	4.02	0.0503	9.57	0.0032	5.50	0.0230	0.5989	0.0005

* p level of post hoc test assessing differences between parameters before and after aquatic training for AEG.
† p level of post hoc test assessing differences between parameters before and after 7-month aquatic training for CG.

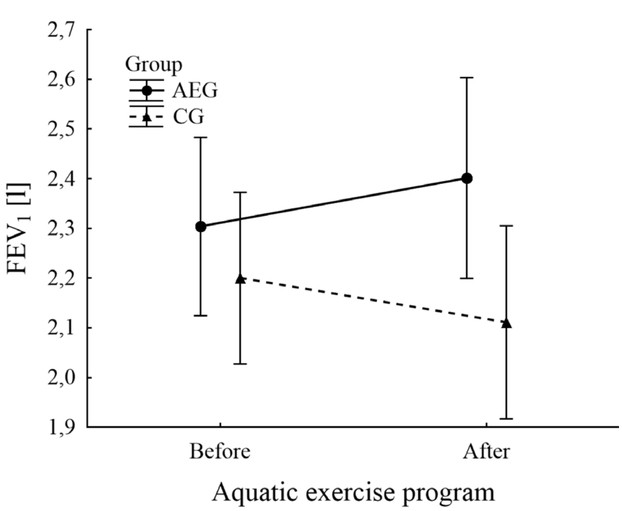

Fig. 6. Means (95% CI) of forced expiratory volume in 1 second (FEV1) before and after aquatic exercise program in training group (AEG) and control group (CG) of older women.

study group and the control group, regarding structural and functional parameters, which is of great importance for our study. The subjects of the study were on a similar level of selected biological condition factors. After the 7-month-long period of aquatic exercises, the functional physical fitness in the study group increased significantly. Strength of muscles, oxygen efficiency, agility/dynamic balance and flexibility of the lower body improved. The tests included simple exercises connected with everyday activities and self-service. Similar effects of exercise programs, both aquatic and on land, were achieved in the study carried out by Taunton et al.[29]. A longer program of exercise was found to be more effective[30]. The research shows that the level of functional fitness in older people may improve significantly due to systematic physical exercise. Poliszczuk[31] claims that the horizontal position of the body in water has a positive effect on the functioning of internal organs, lowering nervous excitability, strengthening the motor system and improving circulatory-respiratory parameters.

In the control group, all functional physical fitness parameters, except the agility/dynamic balance parameter, remained on the same level as during the preliminary tests or worsened slightly, which suggests progressing involutional processes. As we can see, the physical exercise program induced positive physical fitness changes in the subjects of this study. There were also positive and significant differences in the vital lung capacity and forced expiratory volume in 1 second, in the women in the study group. The results of the airflow in the respiratory tract tests in the women in the control group did not show any significant changes, or were slightly worse and the Tiffenau indicator worsened distinctly.

Aquatic exercises are also connected with improved hygiene habits and building up resistance, which greatly lowers the risk of infection. The aquatic exercise program took place in the period of autumn-winter-spring. The women taking part in the study attended training sessions regularly, which seems to confirm the effect of building up the resistance of the body. It may be assumed that this kind of exercise is especially beneficial for functional physical fitness, the respiratory system and especially for general health, as it helps to prevent infections and illnesses typical for this part of the year.

In both the study and control groups, the bone mineral density did not show any significant changes between the preliminary and the final tests. Some studies have shown bone mass improvements due to physical exercise[32,33], whereas others failed to confirm such effects[34,35]. There are doubts whether aquatic exercise could have any benefits for bone, for once in water the mechanical load on the skeleton is reduced[36]**.** Hootman[37] claims the mineral density of bone in people who swim is on a similar level to people leading a sedentary lifestyle. The results of our study confirm this thesis. Although, in the second test the parameters of bone mineral density were slightly better in the women from the study group, it is well-known that processes in the osseous tissue are very slow and a period of 7 months may be too short to cause clear changes in the mineral structure of bones. It also suggests that it would be of greater benefit for the osseous tissue to combine two kinds of exercise, not only aquatic exercise but, for instance, simple gymnastic exercises performed at home.

Our observations confirm that a lack of physical activity is connected with progressing involutional processes in functional physical fitness and the physiological efficiency in women from the control group, in comparison to the women from the study group. It could be concluded that during the preliminary test both groups of older women showed similar levels of selected parameters of their biological condition. After completing a 7-month-long training program, the women who did the aquatic exercises demonstrated a clear improvement of functional physical fitness and better test results of airflow in the respiratory system, in comparison to the women from the control group, which shows that there is a real possibility to retard ageing processes. The analyzed parameters of the biological condition in the women from the control group show progressing involutional processes. Aquatic exercise did not influence bone mineral density. In both groups the results of the preliminary and final tests are on similar levels.

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UTJECAJ INTENZIVNOG SEDMOMJESEČNOG PROGRAMA VODENOG VJEŽBANJA NA PROMJENE U FIZIČKOJ AKTIVNOSTI, GUSTOĆI KOSTIJU I PARAMETRIMA FUNKCIJE PLUĆA KOD ŽENA U POSTMENOPAUZI

S A Ž E T A K

Cilj ovog istraživanja bio je procijeniti promjene u parametrima fizičke spremnosti, gustoće kostiju i plućne funkcije kod starijih žena koje su pretrpjele 7-mjesečni vodeni program vježbanja (AEP). 25 žena sudjelovalo je tjedno 60 minuta sustavno AEP. Prije i nakon, sudionici AEP i Grupa ispitanika kontrolne prošao Fullerton Funkcionalni fitness test, mineralnu gustoću kostiju i procjene dišnog sustava. Značajno poboljšanje u rezultatima rukohvat snage, 30 sekundi stolica stoje, 6 minuta ispitivanje šetnju i stolice sjediti i doći do ispitivanja su donesene u AEP žena. Osim toga, u AEP skupine, prisilno izdisajni volumen u 1. sekundi (FEV1) se značajno povećao.