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Assessment of respiratory function and aerobic capacity in postmenopausal women participating in water aerobics classes

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Abstract
Introduction. Respiratory function is subject to the aging process, similarly to that of multiple other systems. Regular aquatic exercise favors physical development, and improves circulation and respiration, as well as overall health. Aim of Study. The purpose of the study was to assess the impact of a 12-week training program involving water aerobics on respiratory system function and aerobic capacity in post-menopausal women. Material and Methods. The study included 30 women (21 in the study group, 9 controls). Women in the study group participated in supervised water aerobics classes, twice a week for 3 months. At the beginning and end of the study, all the women underwent a spirometry test and an exercise test by an ergometer. Results. An analysis of changes after the training program demonstrated a significant increase of the maximal aerobic capacity in the study group ($p < 0.05$). No significant changes were found in spirometry indicators (VC) or airflow parameters in the large and small airways (MEF_{75}, MEF_{50}) following a 12-week water aerobics program. Conclusions. The implemented training program for healthy postmenopausal women did not improve the spirometry indicators studied, and the observed aerobic capacity increase likely resulted from improved circulatory and metabolic performance that determines an individual's exercise tolerance and health.

KEYWORDS: spirometry, postmenopausal women, maximum oxygen uptake.

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Introduction

Health is a major component of the quality of life (QoL), especially in older individuals. In an aging society poor health and deteriorating QoL are major problems that interfere with an individual's functioning in the society. Maintenance of good health and QoL is the primary consideration for elderly individuals who undertake exercise [10].

Respiratory function, which is required for supplying oxygen to the muscles, is subject to the aging process, similar to that of multiple other systems. This process may have individually varying dynamics and health consequences and it is affected by multiple factors that may be beyond an individual's control. Lung aging results from physiological changes that occur in the body with age, the history of disease and environmental factors associated with lifestyle [22]. While total lung capacity (TLC) remains largely unchanged, residual volume (RV) increases, whereas vital capacity (VC) decreases with age. RV increases, while expiratory reserve volume (ERV) decreases in elderly patients. In (non-smoking) women older than 45 years peak expiratory flow (PEF) drops by approx. 2.5 mL/year. Forced expiratory volume in one second (FEV_1) decreases by 17.7 ± 1.4 mL/year on average in individuals aged 40-49, and by 37.1 ± ± 2.1 mL/year in those aged 60-79 [18].

In older age the metabolic cost of respiration increases both at rest and during exercise. This increases oxygen use, while its supply is restricted by lung aging, which in many cases leads to quick onset of dyspnea even with low-intensity exercise. In physically fit individuals this point moves towards greater exercise intensity [18].

Physical fitness is a product of multiple factors, including physiological, biochemical and psychological ones. Contributors to better fitness include good respiratory, circulatory and metabolic functions associated with muscular effort. Physical fitness changes as a result of training and is affected by an individual's sex and age. As women typically have a greater body fat percentage, smaller heart and lungs, as well as lower hemoglobin levels, their VO_2max is approximately 10-12% lower than that of men. Greater physical fitness allows one to perform the same work with the same load at a lower energy expense. One parameter used in the assessment of the body's aerobic capacity is the maximum oxygen uptake (VO_2max). VO_2max is largely determined by genetic factors and its most intensive development occurs by the age of 16 in girls and by the age of 20 in boys. The parameter then stabilizes until the age of 30, followed by a decrease by approx. 0.75% annually due to aging processes in the body. A rapid decrease, exceeding 20% per decade, is observed in individuals older than 70 years. The rate of this decrease depends on one's exercise levels and the VO_2max value achieved by the age of 25-30. The parameter increases with endurance training, by up to 10-30%. Regardless of age, the greatest gain is observed in individuals with a low physical fitness level who are then subjected to guided physical training. In individuals with a high aerobic capacity, the VO_2max increase with training may only reach several percent [1, 25].

Literature provides evidence for the positive impact of aquatic exercise on circulatory function [11, 12, 21]. If the chest is completely immersed in water during exercise, the work of respiratory muscles increases to overcome the resistance of water resulting from its density and hydrostatic pressure. Therefore, the impact of water aerobics training on the static and dynamic respiratory parameters occurs constantly, with the relevant spirometry parameters expected to change accordingly. Regular aquatic exercise favors physical development, improves circulation and respiration [4], as well as overall health [3, 26].

Aim of Study

The purpose of the present study was to determine the effectiveness of a 3-month training program involving water aerobics in terms of improvement of respiratory function and aerobic capacity in post-menopausal women participating in the program as compared to controls.

Material and Methods

Participants

Subjects were recruited by advertisements in local media and at educational events and were qualified to participate in the project based on medical history and cardiology tests. The following exclusion criteria were applied (presence of at least one of the factors listed below): diseases of the locomotor system preventing independent movement, giant obesity, active or post cancerous disease (ongoing radiation or chemotherapy treatment), liver diseases (ALT > 3 × borderline) except for liver disease, chronic kidney disease (eGFR < 30 mL/1.73 m^2/min), acute inflammation (CRP > 5 mg/dL), unstable ischaemic heart disease, after an ischaemic or haemorrhagic stroke (<6 months), post-STEMI (ST-elevation myocardial infarction) women with a drug-eluting stent implantation, NSTEMI (non-ST-elevation myocardial infarction) (<12 months), inherited metabolic disorders (phenylketonuria and galactosaemia), autoimmune diseases (an acute thyroiditis, celiac disease, systemic connective tissue disease, haemolytic anaemia, vitiligo, Addison's disease, hyperbilirubinaemia), non-specific enteritis (Crohn's disease and ulcerative colitis), psychological disorders, antibiotic therapy, steroid therapy (ongoing), drug and alcohol addiction (a daily consumption of more than 1 portion of alcohol).

The study included 52 women randomly assigned to the study group (n = 26) or the control group (n = 26). Randomization was performed by simple random allocation; all subjects' identifiers were sent to a person with no further relationship to the study, who performed the randomization blindly using a computer list. All subjects were Caucasian and specifically, belonged to the native Polish population from the Greater Poland region. The subjects were asked for the entire study period not to change their dietary habits and not to engage in any new physical activity beside that provided for in the study protocol. Individuals with chronic illnesses restricting their ability to engage in aquatic exercise or constituting a contraindication to spirometry were excluded from the study. Five women (study group) dropped out from the project due to non-completion of the minimum required number of training sessions. Seventeen women (control) withdrew during the study. Ultimately, the

Table 1. Participants' anthropometric characteristics

Group	Age (years)	Height (cm)	Weight – pre (kg)	Weight – post (kg)	Z	BMI – pre (kg/m²)	BMI – post (kg/m²)	Z
Study group (n = 21)	63.20 ± 4.72	158.05 ± 4.81	73.20 ± 22.11	72.01 ± 20.42	2.34*	28.93 ± 7.50	28.67 ± 7.22	1.73
Control group (n = 9)	64.07 ± 3.66	161.39 ± 6.58	74.81 ± 12.28	73.20 ± 12.01	1.96*	28.63 ± 3.83	28.12 ± 3.62	1.77

Data are presented as means ± standard deviations
* $p < 0.05$

analyses included 30 subjects (study group n = 21, control group n = 9). The groups were heterogeneous in terms of anthropometric characteristics, such as body weight, height and age (Table 1). All participants consented to participate in the study and were informed about its voluntary nature, objectives, benefits and course. The study was conducted in accordance with the Declaration of Helsinki and the National Statement and Human Research Ethics Guidelines, and approved by the IRB (Institute for Research in Biomedicine) at the Poznań University of Medical Sciences (2017-12-17; Ethics Approval Number 1224/17). The study was performed between April and October 2017 in an accredited endurance test laboratory of the Poznan University of Physical Education.

Anthropometric measurements, respiratory function and aerobic capacity testing

Anthropometric measurements and spirometry tests were performed twice, at the same time of day. The first tests were performed in January and the second – in June of the same year. Body weight and height was measured using a certified Radwag device (Radom, Poland), accurate to 0.01 kg for weight and 0.5 cm for height.

Pulmonary function test

Pulmonary function was evaluated by conventional spirometry using a spirometer (PDD-301/s, Piston, Budapest, Hungary). Direct evaluation was performed for lung volumes, capacities and flows through the procedures of Slow Vital Capacity (SVC) and Forced Vital Capacity (FVC) performed in this order at least three times each, in accordance with the standards of the American Thoracic Society (ATS) and the European Respiratory Society (ERS), with the patient in a seated position. Results were expressed as absolute values and as percentages of the reference predicted values from Pereira [16]. The SVC procedure was used to obtain vital capacity (VC). The FVC procedure allowed to determine forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, MEF_{75}, and MEF_{50} [16].

Aerobic capacity evaluation

Aerobic capacity was assessed with the modified Astrand–Ryhming protocol to predict VO_2max using a Kettler DX1 Pro ergometer (Ense-Parsit, Germany), while heart rate (HR) was monitored using a Polar A-5 pulse meter (Polar Electro Oy, Kernpele, Finland) [5]. The predicted VO_2max was read from the nomogram [1, 2] or accompanying tables [2] and multiplied by both the Astrand and the von Dobeln age correction factors. These two predictions in L/min were then converted to mL/kg/min [2, 5].

Training program

The project lasted for 3 months, with training sessions twice a week. Exercises were performed in deep water and participants wore flotation belts, with no contact with the bottom of the pool. The trainer was in the pool as well, clearly demonstrating each exercise. Various types of resistance equipment were used [27].

A single unit of training was 45 minutes long. It included in sequence: warm up exercises, cardio warm up, the main aerobic and strengthening portion, and cool down (Table 2). The training program comprising 24 units was developed based on water aerobics method guidelines and adjusted to the participants' level of ability. Heart rate was measured using the Polar A-5 pulse meter (Polar Electro Oy, Kernpele, Finland) [17, 19, 28].

Statistical analysis

Descriptive data were expressed as mean values and SD. Distribution normality was tested using the Shapiro–Wilk test. In order to calculate the significance of changes in the parameters studied, the nonparametric test of pairs by Wilcoxon was performed. The significance of differences between the study and control groups was calculated using the Mann–Whitney U-test. Spearman's rank analysis was applied to calculate correlation coefficients. Findings were considered statistically significant at $p < 0.05$. The obtained results were analyzed statistically using the Dell Inc. (2016) Dell Statistica 13 software (Tulsa, Oklahoma, USA).

Table 2. Water aerobics program

Week / equipment	Part of the class	Exercises	Intensity	Frequency
	warm up (5 min)	• walking in place • arm exercises in multiple planes		2 times per week
	cardio warm up (5 min)	• running in place • running in multiple directions • arm exercises with multiple hand positions • movement exercises in multiple directions		
(1) no equipment (2) long pool noodle (3) short pool noodle (4) BEtomic (5) aquadisc (6) gloves (7) cuffs (8) happy flower (9) big wave bells (10) punches	main portion aerobic/ strengthening (30 min) cool down (5 min)	• arm exercises in multiple directions and within different ranges (pushing, pulling) • leg exercises (single and double leg raises, jumps, jumping jacks, scissors, grounded, elevated) • coordination exercises • lying front and lying back exercises • position change exercises • stretching and relaxing exercises	40-50% HRR 40-50% HRR 50-60% HRR 50-60% HRR 50-60% HRR 60-65% HRR 60-65% HRR 60-65% HRR 65-70% HRR 65-70% HRR 65-70% HRR	

Results

The descriptive characteristics of the participants (study and control groups) are shown in Table 2. The circulatory and respiratory function and capacity parameters studied are given in Table 3. All the parameters studied were measured at the start of the training program and immediately after its completion, in line with measurement standards.

Table 3 shows changes in the parameters studied after the training program in the study group and in controls, as well as differences in the change rates between the two groups.

In both groups there was a decrease of body weight between the two tests ($p < 0.05$), without a significant change in BMI (Table 1). An intra-group analysis of changes after the training program demonstrated a significant increase of the maximal aerobic capacity in the study group ($p < 0.05$). No significant changes were found in spirometry indicators (VC) or airflow parameters in the large and small airways (MEF_{75}, MEF_{50}) following the 12-week water aerobics program (Table 3).

Spearman's R correlation analysis demonstrated a negative correlation between the post-training change in body

Table 3. Results of two exercise and spirometry tests for the study group and controls

Variable		Pre	Post	Z-value	Change
VO_2 max (mL/kg/min)	study group	30.69 ± 7.66	32.37 ± 7.81	2.80*	1.68 ± 2.56
	control group	27.31 ± 0.79	30.04 ± 5.80	1.48	2.73 ± 5.67
VC (L/min)	study group	2.88 ± 0.34	2.89 ± 0.38	1.50	0.22 ± 0.63
	control group	2.52 ± 0.44	2.52 ± 0.50	0.40	0.04 ± 0.21
FVC (L/min)	study group	2.82 ± 0.43	2.86 ± 0.42	0.23	0.05 ± 0.28
	control group	2.55 ± 0.42	2.72 ± 0.52	1.78	0.07 ± 0.08
FEV_1 (L/min)	study group	2.45 ± 0.34	2.41 ± 0.34	0.45	0.00 ± 0.18
	control group	2.21 ± 0.30	2.31 ± 0.42	0.31	0.02 ± 0.12
FVC/VC (L/min)	study group	85.74 ± 7.58	83.71 ± 4.82	0.68	–0.59 ± 7.71
	control group	86.70 ± 5.62	85.53 ± 8.11	0.94	–0.65 ± 7.87
MEF_{75} (L)	study group	5.50 ± 1.18	5.18 ± 1.02	1.48	0.16 ± 1.79
	control group	4.75 ± 0.59	5.36 ± 0.92	0.94	0.34 ± 0.95
MEF_{50} (L)	study group	3.63 ± 0.98	3.15 ± 0.72	1.48	–0.31 ± 0.72
	control group	3.60 ± 0.69	3.59 ± 0.88	0.94	–0.02 ± 0.44

Data are presented as means ± standard deviations
* $p < 0.05$

Table 4. Spearman's rank correlation coefficient for changes in selected anthropometric and spirometric parameters and changes in aerobic capacity in both groups

	ΔVO_2max study group	ΔVO_2max control group
Δ body weight	r = –5.5411 p = 0.0113*	r = 0.1000 p = 0.7980
Δ VC	r = –0.1000 p = 0.7227	r = –1.000
Δ VT	r = 0.0529 p = 0.8456	r = 0.3143 p = 0.5441
Δ FVC	r = –0.3029 p = 0.2541	r = –0.1429 p = 0.7872
Δ FEV_1	r = –0.1912 p = 0.4781	r = –0.3714 p = 0.4685
Δ FVC/VC	r = –0.0265 p = 0.9225	r = 0.4857 p = 0.3287
Δ MEF_{75}	r = –0.2265 p = 0.3990	r = –0.6000 p = 0.2080
Δ MEF_{50}	r = –0.0486 p = 0.8582	r = 0.4286 p = 0.3965

weight and the aerobic capacity in the study group only (Table 4).

Discussion

The purpose of the study was to evaluate the effectiveness of water aerobics training in terms of circulatory and respiratory function and aerobic capacity in healthy post-menopausal women. Endurance training improves respiratory system function by increasing chest mobility, respiratory muscle strength and the diffusing capacity of the lungs. This is associated with an increased ventilation to perfusion ratio and increased blood flow to the upper lungs. The strengthening of chest musculature with endurance training additionally contributes to better posture, as postural muscles are also strengthened. The respiration mechanism also becomes more economic, as the respiratory volumes increase while the respiratory rate decreases. In the present study no improvement of respiratory function was observed following a 12-week training program. The lack of effectiveness of aquatic training programs with a similar duration was already described by Janyacharoen et al., who found no change in the basic spirometry parameters (VC and FEV_1/VC) in their subjects [6].

The lack of statistically significant improvement in respiratory function is likely due to participants' good respiratory health. Out of the 30 women included in the project only 2 had moderate signs of restrictive disease. Spectacular improvements of VC and FEV_1/VC following aquatic exercise were described in patients with obstructive and restrictive lung disease. Literature includes a number of cases where respiratory function did improve with aquatic endurance training. In Jung et al. there was a significant improvement of spirometry parameters in patients with spinal cord injury [7]. Lung function in patients with cervical spinal cord injury is mainly impaired due to respiratory muscle weakness, while in patients with chronic obstructive pulmonary disease — due to airway obstruction. In their study Nolasco et al. demonstrated that vitamin D supplementation was associated with improved spirometry parameters in post-menopausal women, irrespectively of participation in a water aerobics training program [14]. Song and Kim also observed an improvement in spirometry parameters in a group of patients with a history of stroke, participating in aquatic exercise as part of their physical therapy [23].

The benefits of aquatic exercise are evidenced by multiple studies, including that by Nuttamonwarakul. The study showed that aquatic exercise resulted in improved blood glucose and lipid levels and reduced cardiovascular risk in older patients with type 2 diabetes [15]. Neiva demonstrated that training of the same duration as that applied in the present study leads to increased muscular strength, especially with regard to upper extremity muscles. It also reduced body fat content and systolic blood pressure [13]. In their study Sarojini et al. reported that this type of training improved muscle flexibility and overall physical fitness [20]. In literature, there are also reports on the effectiveness of such training in terms of changing participants' lean body mass, muscle mass, and body fat weight [9].

Findings by multiple authors warrant the conclusion that aquatic exercise does contribute to better physical fitness and function in participants of various ages [8, 24]. In most cases fitness levels were evaluated indirectly, through aerobic capacity measurement, simple walking tests or the Senior Fitness Test.

In the present study the participants' aerobic capacity values increased independently of any changes in body weight. Both in the study group and in controls there was a statistically significant decrease in body weight. Therefore, it is likely that neither body weight nor respiratory function was the main contributor to the observed significant increase in aerobic capacity among the women studied. These findings warrant the conclusion that the circulatory and respiratory fitness of healthy older women engaging in water aerobics is modified by circulatory and metabolic changes in the muscles.

Conclusions

Exercise contributes to better health and physical fitness in individuals of various ages and various fitness levels. The aging process undoubtedly contributes to a decrease of the body's functional reserve and affects exercise tolerance. Aquatic exercise is safer than other proposed forms of exercise that are performed on land, as the aquatic environment is load-reducing, which prevents injuries.The implemented training program for healthy post-menopausal women did not improve the spirometry indicators studied, while the observed aerobic capacity increase likely resulted from improved circulatory and metabolic performance that determines an individual's exercise tolerance and health. Presumably, greater benefits in terms of spirometry parameters could be expected after water aerobics training in individuals with reduced respiratory function. Therefore, further research should concentrate on the analysis of the impact of this form of training on the respiratory functions of people with respiratory failure caused of the aging process, COPD, emphysema or changes caused by SARS-CoV-2 virus infection.

The limitation of the study is a small sample size, especially in the control group. The duration of the project between April and October resulted in exclusions from the study, because women participated in additional physical activity beyond the one carried out in the research project.

Conflict of Interests

The authors declare no conflict of interest.

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