Water-based exercise improves health-related aspects of fitness in older women

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Institute of Natural Sciences, Nagoya City University, Nagoya, JAPAN; Center for Physical Activity and Aging, Wichita State University, Wichita, KS; Graduate School of Sports Science, Chukyo University, Aichi, JAPAN; Department of Kinesiology, Indiana University, Bloomington, IN; Department of Health and Psychosocial Medicine, Aichi Medical University, Aichi, JAPAN; and 3rd Department of Internal Medicine, Nagoya City University Medical School, Nagoya, JAPAN

ABSTRACT

TAKESHIMA, N., M. E. ROGERS, E. WATANABE, W. F. BRECHUE, A. OKADA, T. YAMADA, M. M. ISLAM, and J. HAYANO. Water-based exercise improves health-related aspects of fitness in older women. *Med. Sci. Sports Exerc.*, Vol. 33, No. 3, pp. 544–551, 2002. **Purpose:** The purpose of this study was to determine the physiological responses of elderly women to a well-rounded exercise program performed in water (WEX). **Methods:** The participants (60–75 yr of age) were randomly divided into a training (TR) group ($N = 15$) and a control group ($N = 15$). The TR group participated in a 12-wk supervised WEX program, 70 $\text{min}\cdot\text{day}^{-1}$, 3 $\text{d}\cdot\text{wk}^{-1}$. The WEX consisted of 20 min of warm-up and stretching exercise, 10 min of resistance exercise, 30 min of endurance-type exercise (walking and dancing), and 10 min of cool-down exercise. **Results:** The WEX led to an increase ($P < 0.05$) in peak $\dot{V}O_2$ (12%) and $\dot{V}O_2$ at lactate threshold (20%). Muscular strength evaluated by a hydraulic resistance machine increased significantly at resistance dial setting 8 (slow) for knee extension (8%), knee flexion (13%), chest press (7%) and pull (11%), shoulder press (4%) and pull (6%), and back extension (6%). Vertical jump (9%), side-stepping agility (22%), trunk extension (11%), and $FEV_{1.0}$ (7%) also increased significantly. There was a significant decrease in skin-fold thickness (−8%), low-density lipoprotein (LDL) cholesterol (−17%), and total cholesterol (−11%). There were no significant changes in these variables in the control group. **Conclusion:** These results indicate that WEX elicits significant improvements in cardiorespiratory fitness, muscular strength, body fat, and total cholesterol in older adult women. Water-based exercise appears to be a very safe and beneficial mode of exercise that can be performed as part of a well-rounded exercise program. **Key Words:** HEAD-OUT WATER IMMERSION, WELL-ROUNDED EXERCISE, ELDERLY

Elderly individuals can benefit from a properly designed aerobic exercise program (4,18,26). Recently, the basic exercise guidelines recommended by the American College of Sports Medicine (ACSM) for healthy adults and the elderly place additional emphasis on resistance exercise (1,2). Given the specific nature of adaptation to exercise and the need for maintaining muscle mass, muscular strength, and flexibility throughout life, a well-rounded training program consisting of resistance, aerobic, and flexibility exercises is highly recommended by the ACSM.

Exercising in water has become increasingly popular, and it has been reported that water exercise (WEX) for older individuals is therapeutically beneficial (25,34). The WEX is also a viable form of conditioning for those who are afflicted with orthopedic disabilities (25). Furthermore, overweight persons find chest-deep water to be a motivating factor because their bodies are hidden from the view of others while performing the training (22). The dual effects of buoyancy and resistance create an environment that requires high levels of energy expenditure with relatively little movement or strain on low-joint extremities. The water is an equalizing medium; its gravity-minimizing nature reduces compressive joint forces, providing a better exercise environment for patients with arthritis, back pain, osteoporosis, or other medical conditions that may restrict training on land. It has been reported that the resistance provided by water increases the energy cost of certain types of work (10,11). For example, $\dot{V}O_2$ is higher while ambulating in waist-deep water compared with walking on a treadmill at the same speed (12).

It has been reported that walking in waist-deep to chest-deep water and participating in water aerobics provide sufficient load to develop cardiorespiratory fitness in young and middle-aged adults (28). Reports are also available on the acute physiological responses of WEX on cardiovascular regulation, as well as the renal-endocrine response during water immersion at rest and during water exercise in older adults (9,12,32). However, there are few reports available to describe the effect of long-term WEX in older adults. Thus, although it appears that WEX may be a suitable exercise modality for elderly individuals, little is known about the general physiological adaptations in older adults who regularly engage in WEX. Therefore, on the basis of

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the promising nature of WEX and the ACSM recommendations that advocate well-rounded exercise programs, this study was conducted to determine the physiological responses of older adult women to a well-rounded exercise program performed in the water.

METHODS

Participants. In response to a local newspaper advertisement, 45 elderly women volunteered to participate in the study. Before acceptance into the study, a medical examination was performed and questionnaires regarding medical history and physical activity were completed. Fifteen volunteers were excluded on the basis of the medical examination report or the questionnaires because they were taking medication prescribed for hypertension, hypercholesterolemia, or hormone replacement therapy; had diagnosed coronary heart disease (CHD); or were participating in regular physical activity beyond that required for normal daily living. The remaining 30 volunteers (60–75 yr of age) were sedentary but apparently healthy. The ethical committee of the Institute of Natural Sciences at Nagoya City University approved the study. All participants received written and oral instructions for the study and each gave their written informed consent before participation.

Testing protocol. Following baseline measurements of body composition, cardiorespiratory fitness, muscular strength, blood lipids, and flexibility, the participants were randomly divided into two groups: a training (TR) group ($N = 15$) and a nonexercise control group ($N = 15$). The TR group participated in a 12-wk WEX program. The control group was instructed to continue their normal physical activity patterns. All participants were asked to not change their nutrition practices during the duration of the study. After 12 wk, all measurements were repeated in both groups.

After lying supine for 5 min, resting HR and blood pressure were measured by an automated machine (Colin Stress BP monitor, STBP-680). Using a microspirometer (Microspiro HI-298, Chest; Colin Co., Komaki, Japan), pulmonary function was assessed by measuring the forced vital capacity (FVC) and forced expiratory volume in the first second ($FEV_{1.0}$).

Skin-fold and girth measurements were taken in triplicate on the right side of the body (8), and the median value was used for analysis. Triceps and subscapular skin folds were measured using a skin-fold caliper (Eiken MK-60; Meikosha Co., Tokyo, Japan). The sum of the two skin folds was used for analysis. Thigh girth was measured at the midpoint between the inguinal crease and the proximal border of the patella. Arm girth was measured at the midpoint between the acromion process and the olecranon process. Girths were measured using a nonelastic tape measure. An experienced tester who was blind to group assignment performed all skin-fold and girth measurements.

$\dot{V}O_{2max}$ was determined using an incremental cycle ergometer (model 81E, Monark, Stockholm, Sweden) exercise protocol (33). Following a warm-up, the load was increased by 0.25-kPa (12.5 W) increments every minute until volitional exhaustion. Pedal rate was maintained at 50 rpm with the assistance of an auditory-visual metronome. Where necessary, the ACSM-recommended criteria were followed to terminate an exercise test before volitional exhaustion. A $\dot{V}O_{2max}$ was accepted if oxygen uptake reached a plateau (increased $< 0.25\ L{\cdot}min^{-1}$ with an increase in workload), respiratory exchange ratio (RER) was greater than 1.1, or predicted maximal HR (220 − age) was achieved.

Measurements of $\dot{V}O_2$ and $\dot{V}CO_2$ were made via indirect calorimetry using the open-circuit spirometry method. Expired gas was passed through a mixing chamber and analyzed continuously (Anima Gas Analyzer Telemetry System, AT-1000; Anima Co., Tokyo, Japan). Gas analyzers were calibrated immediately before and after each test with a known concentration of oxygen and carbon dioxide. Ventilation was measured with the system's ventilation module. Heart rate was monitored (12-lead ECG; Lifescope 8, Nihon-Koden Co., Tokyo, Japan) continuously throughout the test. Blood pressure was measured by an automatic device (Colin Stress BP monitor, STBP-680) and ratings of perceived exertion (RPE) (Borg's 6- to 20-point scale) were scored during the last 15 s of each stage of exercise.

Lactate threshold (LT) was determined from a series of venous blood samples (1 mL each) drawn from an antecubital vein every minute during exercise. The blood samples were analyzed by an electrochemical enzymatic method (Toyobo Lactate Analyzer, HEK-30 L, Toyobo, Tokyo, Japan) immediately after collection. The $\dot{V}O_2$ at LT ($\dot{V}O_2$LT) was defined as the point at which the rate of production and diffusion of lactate exceeded the rate of removal, and was identified as the point at which lactate concentration ($[La^-]$) abruptly increased in a nonlinear fashion (5). For discerning the nonlinear point of $[La^-]$ increase, the log $[\dot{V}O_2]$-log $[La^-]$ transformation method was used (5).

Muscle strength (peak torque) was evaluated by a hydraulic-resistance machine (Hydra Omintron, Henley Healthcare Co., Sugarland, TX). The resistance produced by this hydraulic-resistance machine is regulated by selecting dial settings of 1 through 11 that control the diameter of the aperture through which the hydraulic fluid passes. The aperture openings range from 0.120 mm (setting 1, low resistance) to 0.025 mm (setting 11, high resistance). In this study, the machine was set at dial settings 2 (low intensity), 5 (moderate intensity), and 8 (high intensity). The participants were asked to move through their full range of motion as rapidly and forcefully as possible. Peak torque (Nm) was recorded for knee extension/flexion, shoulder press/pull, chest press/pull, and lumbar flexion/extension. These exercises simulated the strength training components that were practiced during WEX. Each exercise was performed three times and the highest value was used for analysis.

Muscle power was evaluated using vertical jump (21). Each participant stood with the feet 10–20 cm apart on a specially designed measuring scale (Jump Meter, T.K.K. 5106, Jump MD, Takei Scientific Instrument Co., Nigata, Japan) that consisted of a round-shaped, flat jumping board. A measuring tape was fastened to the abdomen of the participant and a string was tied from the measuring tape to the center of the jumping board. The participant then jumped as high as possible. Jumping performance was recorded as the distance between standing and jumping heights determined from the tape measure. To ensure measurement consistency, the same tester conducted all trials.

Agility was determined from a side-stepping test (21). Each participant stood astride a line with a line marked at 1 m to each side. On a signal, the participant started stepping to the left line and then returned to the starting position (one repetition). Without pausing, the participant performed the same task on the right side and continued moving from side to side as quickly as possible for 20 s. The number of repetitions completed in 20 s was recorded as the final score.

Flexibility was measured by 1) trunk flexion from a standing position and 2) trunk extension from a prone position (21). For the trunk flexion test, each participant was asked to stand in bare feet on a specially designed measuring bench, placing the toes even with the front edge of the bench. A measuring scale was attached vertically to the front of the bench. The zero mark of the scale was fixed at the level of the upper surface of the bench. The scale was graduated in centimeters in both the upward and downward directions. The upward distance from the zero mark was a negative score and the downward distance was a positive score. While standing on the bench, the participant was asked to bend over and reach down as far as possible without bouncing, while keeping the knees locked. Performance was scored as the distance reached by the middle fingers and held for at least 1 s. For the trunk extension test, each participant was asked to lie pronated with the hands clasped behind the back. An assistant held the feet to secure the legs to the floor surface. The participant was asked to extend the spine by lifting the shoulders and chin off the floor as far as possible. The distance between the floor and the chin as measured by a specially designed measuring scale (Trunk Extension Meter, T.K.K. 5104 Extension-D, Takei Kiki Co.) was recorded as maximal trunk extension. Each flexibility test was performed twice and the maximum values were used for analysis.

After an overnight fast of approximately 12–14 h, a blood sample (7–8 mL) was collected from an antecubital vein. Participants were instructed to not engage in physical activity beyond their basic daily activities 24 h before the blood draw. Following the separation of serum, concentrations of cholesterol (TC) and triglycerides (TG) were measured by an enzymatic procedure (Hitachi 7450 analyzer, Hitachi, Ltd., Tokyo, Japan). High-density lipoprotein cholesterol (HDLC) was measured using the tungstophosphlic acid-magnesium chloride precipitation method (Hitachi 7150 analyzer) and low-density lipoprotein cholesterol (LDLC) was calculated as TC − HDLC − TG/5 (16).

Exercise-training program. The TR group participated in a 12-wk WEX program, 3 sessions$\cdot$wk^{-1} and 70 min per session. Each session was led by trained fitness instructors and supervised by the researchers. Training was performed on three different days of the week with at least 1 day of rest between sessions. The water level was fixed at xiphoid or near xiphoid level with an average water temperature of 30°C. The daily exercise program consisted of stretching and warm-up exercise (20 min), endurance-type exercise (walking and dancing, 30 min), resistance exercise (10 min), and cool-down/relaxation exercise (10 min). The warm-up consisted of stretching exercises before entering the pool followed by slow-pace walking while changing the rhythm and direction in water. For the endurance-type activity, participants walked, danced, and performed a combination of both while in the water. The intensity of aerobic exercise was prescribed on the basis of the baseline peak $\dot{V}O_2$, and the HR corresponding to LT was used as an indicator of the prescribed intensity during exercise. The HR was monitored continuously for all participants during training sessions by a HR monitoring device (ECG, Accurex Plus, Polar Electro, Finland) to ensure that the training intensity was maintained as prescribed. The resistance exercises were performed using Finbell water-resistance products (Sanritsu Co., Nagoya, Japan) that included soft cushioned hand bars and leg pads that provided resistance when moved under the water. Dumbbell- and barbell-type devices were used to perform upper body resistance exercises (chest press, biceps curl, lumber rotation) and leg pads were used to perform lower body exercises (knee extension and flexion, leg extension and flexion, leg press and leg curl, calf press, leg abduction and adduction) during each exercise session. Because of the physical characteristics of water, the resistance increases with the velocity of movement. Thus, the participants were instructed to move through the full range of motion for each exercise as rapidly as possible while performing each repetition. Each exercise was performed for one set of 10–15 repetitions. The cool-down consisted of floor exercises and muscular relaxation.

TABLE 1. General characteristics of participants at baseline (mean ± SD).

	Exercise Group (TR) (N = 15)	Control (N = 15)
Age (yr)	69.3 ± 4.5	69.3 ± 3.3
Height (cm)	149.6 ± 4.2	154.2 ± 6.7*
HR rest (bpm)	77.7 ± 10.9	73.4 ± 8.5
SBP rest (mm Hg)	129.1 ± 6.8	131.3 ± 14.2
DBP rest (mm Hg)	76.7 ± 7.8	77 ± 9.9

* Significantly different ($P < 0.05$) between groups.

Statistical analysis. The data are presented by mean ± SD. Percent changes from before to after were calculated from the differences in the scores. Comparisons of means at baseline between the two groups were performed using a two-tailed, independent *t*-test. A *P* value, set *a priori*, of < 0.05 was considered statistically significant.

RESULTS

Pretraining data. No significant differences at baseline were present between the TR group and controls in age, resting HR, resting systolic blood pressure, and resting diastolic blood pressure (Table 1). Height was significantly less in the TR group compared with the controls (Table 1).

TABLE 2. Effects of water-based exercise on fitness and blood lipid parameters in older women.

	Before		After		Change (%)	ANOVA (Group × Time)
	Mean	SD	Mean	SD		
Body weight (kg)						
Exercise group	52.2	8.6	51.9	8.6	–0.6	$F(1,28) = 0.403$
Control group	52.7	6.4	52.5	6.4	–0.4	$P > 0.10$
Skin-fold thickness (mm)						
Exercise group	40.5	11.1	37.3	10.3	–7.9	$F(1,28) = 4.516$
Control group	47.5	12.5	49.4	12.7	4.0	$P < 0.05$
Arm girth (cm)						
Exercise group	27.7	2.8	28.0	2.9	1.1	$F(1,28) = 3.614$
Control group	28.4	1.8	28.3	2.0	–0.4	$P = 0.07$
Thigh girth (cm)						
Exercise group	45.0	3.7	45.5	4.6	1.1	$F(1,28) = 0.654$
Control group	46.8	2.8	47.0	2.8	0.4	$P > 0.10$
Vertical jump (cm)						
Exercise group	23.1	4.6	25.2	4.4	9.1	$F(1,28) = 10.48$
Control group	23.0	4.8	22.3	4.5	–3.0	$P < 0.05$
Side step (steps·20 s^{-1})						
Exercise group	23.3	5.2	28.4	4.4	21.9	$F(1,28) = 7.823$
Control group	22.9	5.2	23.9	5.7	4.4	$P < 0.05$
FEV$_{1.0}$ (L)						
Exercise group	1.67	0.41	1.78	0.37	6.6	$F(1,28) = 7.043$
Control group	1.68	0.32	1.58	0.35	–6.0	$P < 0.05$
Trunk extension (cm)						
Exercise group	32.6	11.1	36.1	8.0	10.7	$F(1,28) = 5.129$
Control group	29.7	9.6	29.2	9.9	–1.7	$P < 0.05$
Trunk flexion (cm)						
Exercise group	15.4	5.9	16.6	4.7	7.8	$F(1,28) = 1.348$
Control group	8.3	8.0	8.5	8.3	2.4	$P > 0.10$
TC (mg·dL^{-1})						
Exercise group	219.6	37.9	195.3	35.5	–11.1	$F(1,28) = 4.426$
Control group	227.2	25.0	214.9	21.0	–5.4	$P < 0.05$
HDLC (mg·dL^{-1})						
Exercise group	62.3	15.5	62.4	15.6	0.2	$F(1,28) = 0.378$
Control group	67.4	17.1	68.5	17.6	1.6	$P > 0.10$
LDLC (mg·dL^{-1})						
Exercise group	128.6	39.1	106.7	34.0	–17.0	$F(1,28) = 9.897$
Control group	121.8	2.1	116.1	16.3	–4.7	$P < 0.05$
TG (mg·dL^{-1})						
Exercise group	86.1	27.8	78.8	28.6	–8.5	$F(1,28) = 2.415$
Control group	113.9	47.8	90.9	34.6	–20.2	$P > 0.10$

However, body weight and skin-fold thickness were similar between groups at baseline (Table 2).

As some of the participants (TR group, $N = 7$; controls, $N = 8$) failed to achieve the criteria established for $\dot{V}O_{2max}$ during both precycle and postcycle ergometry testing, the peak value of $\dot{V}O_2$ (peak $\dot{V}O_2$) was used for analysis. There were no significant differences at baseline in $\dot{V}O_2$ LT or peak $\dot{V}O_2$ between the groups (Fig. 1). The [La$^-$] at LT and at peak $\dot{V}O_2$, peak RER, peak exercise systolic blood pressure, and RPE were also similar between groups at baseline.

Training data. All of the participants continued the WEX training through the full length of the study without any case of injury. Participants did not suffer any injuries as a result of the training program. The TR group trained at a moderate intensity as indicated by weekly averages of training HR during walking and dancing exercise. Participants were exercising at 67% of HR$_{max}$ while walking and 65% of HR$_{max}$ while dancing during week 1 and 78% of HR$_{max}$ while walking and 71% of HR$_{max}$ while dancing during week 12. The RPE averaged 11.8 ± 1.2 during the first week and 13.5 ± 1.4 during the final week.

No significant changes were noticed in resting HR, resting systolic blood pressure, and resting diastolic blood pressure in either group. Skin-fold thickness decreased significantly (−8%), but arm girth and thigh girth did not change in the TR group (Table 2). No changes in any of these variables were noticed in the control group. No significant change in body weight was noticed in either group (Table 2). Total cholesterol (−24.3 mg·dL^{-1}) and LDLC

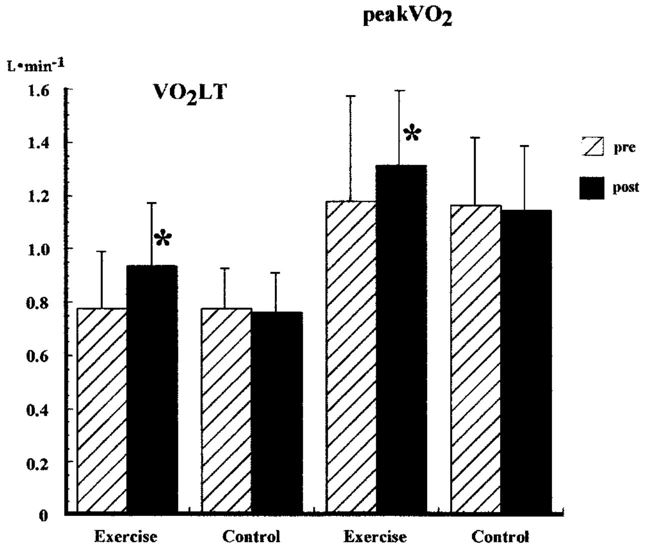

FIGURE 1—Effects of water-based exercise on cardiorespiratory fitness in older women.

TABLE 3. Effects of water-based exercise on muscular strength in older women: knee.[a]

	Resistance Dial	Before		After		Change (%)	ANOVA (Group × Time)
		Mean	SD	Mean	SD		
Extension, Nm							
Exercise group	2	5.6	1.1	7.1	2.1	26.8	$F(1,28) = 3.704$
Control group	2	6.1	1.3	6.7	1.6	9.8	$P = 0.09$
Exercise group	5	14.6	3.8	17.0	3.6	16.4	$F(1,28) = 7.023$
Control group	5	15.3	3.7	15.1	3.0	−1.3	$P < 0.05$
Exercise group	8	34.4	8.0	37.3	7.4	8.4	$F(1,28) = 7.564$
Control group	8	34.4	5.3	33.7	5.3	−2.0	$P < 0.05$
Flexion, Nm							
Exercise group	2	6.0	2.7	8.4	3.1	40.0	$F(1,28) = 12.225$
Control group	2	6.8	1.6	6.5	1.8	−4.4	$P < 0.05$
Exercise group	5	14.4	5.1	17.5	5.9	21.5	$F(1,28) = 11.592$
Control group	5	15.5	3.7	14.4	3.7	−7.1	$P < 0.05$
Exercise group	8	26.0	7.8	29.3	8.1	12.7	$F(1,28) = 12.780$
Control group	8	28.6	4.6	26.7	4.6	−6.6	$P < 0.05$

[a] Knee value is mean average between right and left knee extension and flexion.

(-21.9 mg·dL^{-1}), but not HDLC or TG, were significantly changed in the TR group following WEX training (Table 2). The FEV$_{1.0}$ increased by 7% in the TR group and declined by 6% in the control group (Table 2).

The vertical jump score increased by 2.1 cm (9%), side-stepping agility increased by five steps in 20 s (22%), and trunk extension increased by 3.5 cm (11%) in the TR group following WEX training, but were not changed in the control group (Table 2). The WEX increased $\dot{V}O_2$ at LT by 20% (before, 0.777 ± 0.214 L·min^{-1}; after, 0.934 ± 0.224 L·min^{-1}; $F(1,28) = 49.309$, $P < 0.05$) and peak $\dot{V}O_2$ by 12% (before, 1.178 ± 0.39 L·min^{-1}; after, 1.314 ± 0.341 L·min^{-1}, $F(1,28) = 5.262$, $P < 0.05$) in the TR group (Fig. 1). There was no significant change in [La$^-$] at peak $\dot{V}O_2$ (before, 2.3 ± 0.6 mM; after, 3.0 ± 1.5 mM) but a significant change was noticed in [La$^-$] at LT (before, 0.9 ± 0.3 mM; after, 0.7 ± 0.2 mM) in the TR group. Peak HR did not change significantly (before, 153.5 ± 15.1 bpm; after, 157.5 ± 15.0 bpm) but HR at LT (before, 95.8 ± 7.7 bpm; after, 113.9 ± 13.5 bpm) did increase significantly in the TR group. There were no significant changes in $\dot{V}O_2$ at LT or peak $\dot{V}O_2$ (Fig. 1), [La$^-$] at peak $\dot{V}O_2$ (before, 2.4 ± 1.1 mM; after, 2.0 ± 0.7 mM), [La$^-$] at LT (before, 0.9 ± 0.3 mM; after, 0.9 ± 0.2 mM), peak HR (before, 148 ± 10 bpm; after, 144 ± 16 bpm), and HR at LT (before, 101 ± 8 bpm; after, 109 ± 9 bpm) in the control group. No significant changes were noticed in peak RER (TR group: before, 1.03 ± 0.4; after, 1.04 ± 0.11; controls: before, 0.98 ± 0.12; after, 0.94 ± 0.01), peak exercise systolic blood pressure (TR group: before, 218 ± 22 mm Hg; after, 227 ± 27 mm Hg; controls: before, 213 ± 22 mm Hg; after, 210 ± 17 mm Hg), or RPE (TR group: before, 17 ± 2; after, 17 ± 2; controls: before, 16 ± 2; after, 16 ± 2) in either group.

In general, muscle strength increased in the TR group following WEX training. Knee extension strength at hydraulic setting 2 increased by 27% with training and knee flexion strength measured at this setting increased by 40% in the TR group. In addition, knee extension and flexion strength were increased at setting 5 (16% and 22%, respectively) and setting 8 (8% and 13%, respectively) following training (Table 3). Chest press strength increased at setting 2 (11%), whereas chest pull strength increased at setting 5 (7%) and setting 8 (11%) (Table 4). Lumbar flexion and extension strength increased at setting 5 (3% and 7%, respectively), and only lumber extension strength increased (6%) significantly at setting 8 (Table 5). Shoulder press and pull strength increased at setting 5 (5% and 15%, respectively) and setting 8 (4% and 6%, respectively) (Table 6). None of the muscular strength variables increased significantly in the control group.

DISCUSSION

In this study, WEX led to an increase in oxygen uptake at LT (20%) and at peak (12%). In addition to the improvements in cardiovascular fitness that may be expected with

TABLE 4. Effects of water-based exercise on muscular strength in older women: chest.

	Resistance Dial	Before		After		Change (%)	ANOVA (Group × Time)
		Mean	SD	Mean	SD		
Press, Nm							
Exercise group	2	47.3	10.7	52.3	11.5	10.6	$F(1,28) = 5.560$
Control group	2	55.5	9.0	51.5	13.9	−7.2	$P < 0.05$
Exercise group	5	124.8	47.9	133.4	46.8	6.9	$F(1,28) = 2.365$
Control group	5	133.7	45.0	111.3	23.3	−16.8	$P > 0.10$
Exercise group	8	216.6	41.4	231.1	40.7	6.7	$F(1,28) = 4.077$
Control group	8	221.4	46.1	213.9	49.1	−3.4	$P < 0.05$
Pull, Nm							
Exercise group	2	73.7	35.2	73.5	17.2	−0.3	$F(1,28) = 0.140$
Control group	2	70.9	12.1	66.5	28.0	−6.2	$P > 0.10$
Exercise group	5	142.6	31.1	153.1	36.5	7.4	$F(1,28) = 5.226$
Control group	5	151.0	31.5	141.0	33.4	−6.6	$P < 0.05$
Exercise group	8	224.1	45.2	248.2	53.2	10.8	$F(1,28) = 4.651$
Control group	8	234.2	45.1	229.3	46.1	−2.1	$P < 0.05$

TABLE 5. Effects of water-based exercise on muscular strength in older women: low back.

		Before		After		Change (%)	ANOVA (Group × Time)
	Resistance Dial	Mean	SD	Mean	SD		
Extension, Nm							
Exercise group	2	62.3	27.3	61.5	18.8	−1.3	$F(1,28) = 0.503$
Control group	2	54.9	20.4	50.2	25.4	−8.6	$P > 0.10$
Exercise group	5	123.6	62.6	131.6	48.2	6.5	$F(1,28) = 5.523$
Control group	5	130.8	49.2	104.8	46.5	−19.9	$P < 0.05$
Exercise group	8	216.4	78.1	230.0	51.8	6.3	$F(1,28) = 5.222$
Control group	8	231.1	57.4	197.9	74.6	−14.4	$P < 0.05$
Flexion, Nm							
Exercise group	2	32.3	12.5	29.3	12.0	−9.3	$F(1,28) = 0.055$
Control group	2	34.4	11.9	29.5	12.0	−14.2	$P > 0.10$
Exercise group	5	68.4	26.0	70.5	27.1	3.1	$F(1,28) = 6.784$
Control group	5	74.6	24.2	59.8	22.9	−19.8	$P < 0.05$
Exercise group	8	132.8	30.9	127.9	39.4	−3.7	$F(1,28) = 2.187$
Control group	8	142.6	41.7	117.5	49.9	−17.6	$P > 0.10$

any aerobic training program, the WEX improved several other health-related components of fitness including muscle strength and power, flexibility, agility, and subcutaneous fat. Furthermore, the TR group demonstrated an improvement in pulmonary function (increase in $FEV_{1.0}$) and blood lipids (reductions in TC and LDLC). This study indicates that WEX leads to the improvement of health and fitness. Therefore, WEX should be prescribed as part of a well-rounded exercise program for older women.

Although $\dot{V}O_2$ was not measured during WEX, the HR and RPE were determined during each exercise session. The mean values for HR and RPE during the aerobic component of the WEX indicate that the intensity was of light to moderate intensity. In this study, the baseline HR at LT was used to prescribe the target HR during WEX and the HR was monitored continuously as described in the Methods section. There are some limitations in selecting the intensity of WEX on the basis of HR, particularly in the case of head-out WEX in young adults (3,10). However, our previous work indicates that the HR response and RPE at a given $\dot{V}O_2$ during WEX is similar to walking on land in older adults (34).

Cardiorespiratory endurance is defined as the ability to perform dynamic, moderate- to high-intensity work using a large muscle mass for an extended period of time (7). The accepted single best measure of cardiorespiratory fitness is $\dot{V}O_{2max}$ in healthy subjects. However, in the present study, approximately half of the participants failed to reach $\dot{V}O_{2max}$ as defined by a plateau in O_2 consumption with a corresponding increase in workload, RER greater than 1.1, or predicted maximal HR. Therefore, peak $\dot{V}O_2$ was used as a measure of cardiorespiratory fitness, and this increased by 12% in TR. This result is similar to the increased $\dot{V}O_{2max}$ (10%) observed previously in our laboratory using a similar progressive testing protocol following 12 wk of land-based aerobic training in Japanese older adults (33).

Increases in $\dot{V}O_2$ at LT (20%) were even greater than those observed in peak $\dot{V}O_2$ following WEX. This is also similar to results from our previous land-based training study that indicated an 18% increase in $\dot{V}O_2$ at LT (33). The LT is a term that refers to the $\dot{V}O_2$ or exercise intensity above which the rate of La^- production exceeds the rate at which it can be catabolized, thus inhibiting the increase of $[La^-]$ in the blood (35). The LT is known to be affected by many factors including oxygen transport, activity of the oxidative enzymes in mitochondria of skeletal muscle, and composition of the muscle fibers. Therefore, the increase in LT observed with WEX in this study may have been associated with an increase in aerobic enzyme activity and/or an increase in the proportion of oxidative fibers recruited. The resulting increase in LT after WEX training may be of great consequence, as it could allow older adults to engage in sustained rigorous work for longer periods of time. However, information regarding LT in older adults is lacking, and much more research on this topic is required.

TABLE 6. Effects of water-based exercise on muscular strength in older women: shoulder.

		Before		After		Change (%)	ANOVA (Group × Time)
	Resistance Dial	Mean	SD	Mean	SD		
Press, Nm							
Exercise group	2	19.3	5.8	17.8	4.6	−7.8	$F(1,28) = 0.316$
Control group	2	21.7	5.6	20.9	5.4	−3.7	$P > 0.10$
Exercise group	5	44.6	14.2	46.6	14.2	4.5	$F(1,28) = 6.297$
Control group	5	54.3	10.2	49.2	12.2	−9.4	$P < 0.05$
Exercise group	8	88.2	28.1	92.0	25.4	4.3	$F(1,28) = 5.526$
Control group	8	106.6	22.8	96.7	22.9	−9.3	$P < 0.05$
Pull, Nm							
Exercise group	2	51.3	18.8	56.1	20.4	9.4	$F(1,28) = 2.387$
Control group	2	55.9	13.6	55.2	16.6	−1.3	$P > 0.10$
Exercise group	5	104.9	34.4	121.1	34.6	15.4	$F(1,28) = 6.191$
Control group	5	122.8	28.0	115.5	45.2	−5.9	$P < 0.05$
Exercise group	8	193.8	43.3	205.5	47.4	6.0	$F(1,28) = 7.852$
Control group	8	223.8	36.2	208.0	42.9	−7.1	$P < 0.05$

Significant improvements in skin-fold thickness were associated with WEX training. Results from our study indicate a decrease of 7.9% in the sum of these skin folds for the exercise group and an increase of 4.0% in the control group after 12 wk. Skin-fold thickness has been previously reported to be reduced by 7.0% and 17% at the subscapular site and 5.5% and 14.1% at the triceps site after 7 and 14 wk of endurance training, respectively (29). Although this method does not estimate body composition *per se*, it is an indicator of subcutaneous adiposity. The finding that skin-fold thickness decreased, yet arm and thigh girth did not change, suggests that the TR group may have gained lean mass. Many studies using weight training ranging from moderate to high intensity have reported increases of muscle strength and hypertrophy in elderly men and women (13,15,17). To our knowledge, no report is available describing changes in muscle mass by WEX in the elderly. Further study is needed to determine the effects of WEX on muscle mass, intermuscular and intramuscular fat depots, and bone density.

In the present study, TC and LDLC improved as a result of WEX. The TG and HDLC, however, did not change significantly. This is in agreement with our previous findings from a 12-wk endurance training program using cycle ergometers in older Japanese adults (33). Several investigators have reported alterations in lipid profiles including increases in HDLC (7). Stein et al. (30) described that a minimal exercise intensity of 75% of the maximum HR was required to improve HDLC in a group of healthy middle-aged men. This level of intensity is above that performed during the present study. However, the effects of exercise training on serum lipid concentrations are affected not only by exercise intensity, but also by the duration and type of exercise, as well as by other factors including food intake (20,23,24,27,31,33). Although participants were instructed to not change their dietary habits, no measure of nutritional intake was performed. Given that dietary intake is an important factor in determining body composition and blood lipid concentrations, further research is needed to determine how nutrition and WEX may interact to affect the blood lipid profiles of older adults.

Aging is associated with a gradual decrease in muscle mass, strength, and power (19,27). This contributes to decreased mobility, decreased functionality, and increased risk of falling in older individuals (6,14). Recently, the ACSM recognized the benefits that can result from adding strength training to the exercise programs of aerobically active people (1,2). In the present study, most muscle strength and power measures improved significantly as a result of moving the arms and legs against the resistance of the water. Back strength was not affected to such a large extent as the arms and legs. This might be a result of the specific exercises used during training, or that the buoyant force of the water supports the body and reduces the reliance on postural muscles usually used while standing on land. Future WEX training studies should emphasize the use of back muscles in the exercise movements. Future studies should also give attention to the effects of WEX training on the performance of common activities of daily living that allow older adults to maintain independent lifestyles such as performing housework, shopping, using public transportation, carrying groceries, and climbing stairs.

There was no significant improvement in trunk flexion, possibly because it is difficult to perform trunk flexion exercises in the water without submerging the head. However, as a result of WEX training, trunk extension and agility improved, which could have a positive impact on the performance of activities of daily living as well as in the avoidance of falls. Lower body strength, flexibility, and agility have been associated with deficits in balance (increased postural sway) and impairments in gait function such as slower velocity and decreased stride length (36). Further study is needed to explore the effect of WEX on these parameters in older adults.

CONCLUSION

Our results indicate that exercising in water can significantly improve cardiorespiratory fitness, muscular strength, body composition, blood lipids, agility, and flexibility in older adults. Moreover, it may provide additional benefits by reducing the incidence of falls and injuries that occur while performing exercise, or while performing activities of daily living. Therefore, water-based exercise is a beneficial mode of exercise for older adults and can be safely used as part of a well-rounded exercise program.

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