Effects of an Aquatic Exercise Program on Pulmonary Function, Muscle Strength, and Balance in Women Aged 50 and Older

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Purpose: This study examined the effects of an aquatic exercise program on pulmonary function, muscle strength, and balance in women aged 50 years and older. **Methods:** Thirty-two women over the age of 50 were assigned to either an aquatic exercise group(n=16) or a control group(n=16). The aquatic exercise group participated in a 6-week aquatic exercise program consisting of two 60-minute sessions per week, including aerobic, resistance, and balance training components. The control group received no structured exercise intervention during the study period and was instructed to maintain their usual daily activities. Outcome measures included grip strength, knee extensor strength, 10-second sit-to-stand test(10sSTS), timed up and go test(TUG), and pulmonary function parameters(FVC, FEV_1, FEV_1/FVC, and PEF). **Results:** Significant improvements were observed in the aquatic exercise group for knee extensor strength (p=.000), TUG (p=.000), and PEF(p=.002) following the intervention. Two-way mixed ANOVA revealed significant group × time interaction effects for knee extensor strength(F=50.349, p<.001, partial η^2=.627), TUG(F=5.649, p=.024, partial η^2=.158), and PEF(F=10.299, p=.003, partial η^2=.256), indicating greater improvements in the aquatic exercise group compared with the control group. No significant interaction or main effects were observed for grip strength, 10sSTS, FVC, FEV_1, or FEV_1/FVC(p>.05). **Conclusion:** The aquatic exercise program significantly improved lower limb strength, functional mobility, and peak expiratory flow in women aged 50 years and older. These findings suggest that aquatic exercise can be a safe and effective way to improve lower extremity function and respiratory performance in middle-aged and older women.

Keywords: Aquatic exercise, Pulmonary function, Muscle strength, Balance, Middle-aged women

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Ⅰ. Introduction

As life expectancy increases, the elderly population continues to expand. Consequently, natural aging phenomena such as sarcopenia, muscle weakness, and decreased balance are emerging as social problems. Muscle mass and strength are reported to decrease by 1-2% annually starting in midlife(Cruz-Jentoft et al., 2019), leading to decreased mobility, activity limitations, increased risk of falls, and a decline in quality of life(Delmonico et al., 2007; Goodpaster et al., 2006; Sousa-Victor et al., 2016; Santilli et al., 2014).

Middle-aged women are at increased risk of accelerated functional aging, as age-related declines in pulmonary function and skeletal muscle strength begin to emerge and progressively worsen during midlife. Lung function indices such as forced expiratory volume and peak expiratory flow show a continuous decline with advancing age, even in healthy adults, reflecting inherent physiological aging processes(Thomas et al., 2019). In parallel, reductions in muscle strength, particularly in the lower extremities, have been shown to play a critical role in functional decline and mobility limitations, often preceding overt disability (Goodpaster et al., 2006). Therefore, middle-aged women

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represent an important target population for early intervention strategies aimed at preventing functional deterioration and preserving physical performance into older age.

Physical activity is known to be a key intervention for preventing these functional declines(Sayer et al., 2013; Lopez et al., 2003). Exercise is important in delaying aging and preventing disease, as it positively affects immune function and obesity factors in middle-aged women, aids weight loss, and prevents metabolic diseases(Chun et al., 2008). To improve physical function and reduce the risk of falls, exercise programs should be safe for participants and aims to improve body balance, muscle strength, posture, and lower extremity mobility(Sadaqa et al., 2023; Di Lorito et al., 2021).

Resistance exercise, in particular, increases muscle strength and muscle mass and improves physical performance in middle-aged and older adults(Liu & Latham, 2009; Grgic et al., 2020). Although resistance exercise is effective in maintaining muscle strength and muscle mass, it has been pointed out that the compliance rate is low in older adults and that continuous performance is difficult due to problems such as fatigue, joint strain, and pain(Lin et al., 2025; Grosman & Kalichman, 2025). In addition, other forms of exercise, such as aerobic exercise, have been shown to improve mobility, disability, and cognitive function, thereby enhancing quality of life(Pahor et al., 2014; Hillman et al., 2008).

In contrast, aquatic exercise has the advantage of allowing strength, endurance, and balance training even in situations of reduced weight load, as it provides sufficient resistance while reducing joint load due to the viscosity, buoyancy, and hydrostatic properties of water(Katsura et al., 2010; Becker, 2009).

Aquatic exercise can improve lung function(Charususin et al., 2021), and functional benefits such as reduced fall risk, pain reduction, and improved walking ability have also been reported(Zhang et al., 2023; Moreira et al., 2020). Nikolai et al.(2009) suggested that aquatic aerobics sessions could be a viable alternative to land-based exercise, particularly in middle-aged and older adults. Recent studies on the effects of aquatic aerobic exercise on physiological and anthropometric changes have focused on circuit or resistance training performed in shallow water(Alberton et al., 2015; Bergamin et al., 2015). Furthermore, a study by Ochoa et al.(2014) suggested a positive effect of aquatic exercise on body composition in older women. For these reasons, aquatic exercise is considered a realistic and safe intervention for middle-aged and older women with reduced exercise capacity. However, most existing studies have focused on the elderly or assessed only single variables such as muscle strength, balance, and gait. No studies have simultaneously analyzed pulmonary function, muscle strength, and balance.

Therefore, this study aimed to multidimensionally analyze the effects of six weeks of aquatic exercise on pulmonary function, muscle strength, and balance in middle-aged women aged 50 years and older, and to determine its clinical applicability.

Ⅱ. Methods

1. Subjects

The subjects of this study were women aged 50 years or older living in City A. Participants were recruited through a public recruitment notice for a spa-based exercise program conducted in collaboration with a local hot spring facility in Asan City. The recruitment notice was posted on-site at the spa facility and informed potential participants about the purpose, procedures, duration, and voluntary nature of the study.

Individuals who expressed interest were provided with detailed explanations regarding the study procedures and ethical considerations. Those who met the inclusion criteria ―women aged 50 years or older, able to walk independently, and willing to participate voluntarily―were enrolled after providing written informed consent in accordance with the ethical principles of the Declaration of Helsinki.

2. Intervention Protocol

1) Aquatic Exercise Program

A six-week aquatic exercise program was conducted in the aquatic exercise group at the indoor bathe pool and outdoor lazy river at P Hot Springs in City A(Figure 1).

Figure 1 photograph included in this manuscript was

Figure 1. Aquatic exercise program
Note. This photograph was taken by the authors for this study.

taken by the authors during the intervention sessions. The indoor bathe pool had a depth of 1.4 m, a water temperature of 32.6°C, and 60% humidity, while the outdoor lazy river had a depth of 1.4 m, a water temperature of 32.4°C, and 36% humidity.

Upper and lower extremity strength training, balance training, and aerobic exercise were primarily performed in the indoor bathe pool, whereas walking exercises were conducted in the outdoor lazy river. The aquatic exercise program was developed based on previous studies demonstrating its safety and effectiveness(Kim & O'Sullivan, 2013; Alikhajeh et al., 2025). The program consisted of two 60-minute sessions per week for six weeks(Table 1). Exercise intensity was maintained at a moderate level, corresponding to a Borg rating of perceived exertion(RPE) of approximately 11-13, based on participants' self-reported exertion levels(5-6 on a 10-point scale).

Before each session, participants performed a warm-up consisting of walking movements in the pool. After completing the exercise session, a full-body stretching routine was conducted as a cool-down. Lifeguards supervised all exercise sessions to ensure participant safety and to prevent accidents or injuries.

Participants in the control group did not participate in any structured exercise intervention during the same six-week period and were instructed to maintain their usual daily activities. No additional exercise guidance or supervised training was provided. All participants in both groups underwent identical assessments before and after the intervention period.

3. Measurement Method

1) Pulmonary Function

Pulmonary function was assessed using a spirometer (PONY FX, COSMED, Italy). To ensure accurate measurements, a demonstration and sufficient explanation were provided prior to the test. Participants were seated with their hips flexed 90°. Forced vital capacity(FVC), forced expiratory volume in 1 second(FEV_1), the ratio of FEV_1 to FVC(FEV_1/FVC), and peak expiratory flow(PEF) were measured. Each index was measured twice, with high reproducibility and the highest value used(Graham BL et al., 2019).

2) Muscle Strength

Muscle strength was assessed using a grip dynamometer(Jamar Hydraulic Hand Dynamometer, Jamar, USA) and a portable dynamometer(Manual Muscle Testing System, Lafayette Instrument Company, USA). Grip strength was measured as a representative proxy indicator of overall muscle strength and general health status in older adults. Measurements were performed with participants seated upright, with the shoulder adducted and neutrally rotated, the elbow flexed at 90°, the forearm in a neutral position, and the wrist maintained between 0° and 30° of extension. Participants were instructed to squeeze the dynamometer with maximal effort for 3-5 seconds following a standardized verbal instruction. Grip strength was measured three times for the dominant hand, with a rest period of at least 60 seconds between trials to minimize fatigue, and the highest value was used for analysis, in accordance with established recommendations for ensuring measurement reliability and reproducibility(Bohannon, 2019; Roberts et al., 2011).

Knee extensor strength was assessed using a portable dynamometer with participants seated on a chair, hips flexed at approximately 90° and knees flexed at 60°. The dynamometer was positioned perpendicular to the anterior aspect of the distal lower leg, just proximal to the ankle joint. Participants were instructed to perform a maximal voluntary isometric contraction of the knee extensors for

Table 1. Aquatic exercise program components

Category			Detailed Content (To be selectively used during the exercise program operation)
Warm-up	Aquatic Walking		- Walking forward and backward (gradually increasing speed)
	Stretching		- Dynamic stretching for the neck, shoulders, wrists, hips, knees, and ankles. - Main muscles to stretch: Calf muscles, Trapezius, Rhomboid, Pectoralis major, Hamstring, Quadriceps, Iliopsoas.
Main Workout	Strength and Muscular Endurance Exercise	Upper body focus	- Torso rotation while holding the pool edge with both hands - Torso rotation while wearing aqua gloves - Torso flexion by bringing both arms towards the chest - Torso extension by spreading both arms out to the sides - Rowing while holding the pool edge with both hands - Large arm circles (rotating arms widely) - Diagonal movements using arms and torso together in the water
		Lower body focus	- Hip flexion/extension: Forward and backward leg swings (or kicks) - Standing on one leg, hip abduction/adduction: Leg lifts/swings side to side (while balancing on the other leg) - Toe raises and heel raises (on one or both legs) - Single and double leg jumping and hopping - Holding the pool edge with both hands and lifting the lower body using a floatation device (buoy) on the ankles - Holding the pool edge and performing a cycling motion with the legs - Squats
	Cardiovascular Exercise		- High-knee jogging in place - Jumping Jacks - Jogging - Side step & touch - Aqua skip (or Water Skipping) - Backward kicks - Walking forward with arm propulsion (swimming arms) - Aqua twist jump (or Water Twist Jump)
	Walking Exercises		- Walking in place (lifting feet high, with eyes closed, incorporating arm movements, etc.) - Walking with knees bent - Sideways walking (without crossing legs, while crossing legs, etc.) - Heel-to-toe walking (Tandem Gait) - Walking on one foot - Heel walking and toe walking - Walking with water up to the neck - Walking with long strides
Cool-down	Aquatic Walking		- Walking forward and backward at a preferred speed (water level: waist to shoulder)
	Stretching		- Static stretching for the neck, shoulders, wrists, hips, knees, and ankles. - Main muscles to stretch: Calf muscles, Trapezius, Rhomboid, Pectoralis major, Hamstring, Quadriceps, Iliopsoas.
	Spa and Hydrotherapy Pool Use		- Using the in-facility spa and hydrotherapy pool: Relaxation effect after exercise

Note. The aquatic exercise program was performed at a moderate intensity, corresponding to a Borg rating of perceived exertion (RPE) of approximately 11–13 (5–6 on a 10-point scale).

3-5 seconds against the dynamometer. Three trials were performed with sufficient rest between trials, and the highest value was used for analysis to ensure reproducibility (Katoh & Yamasaki, 2009).

Functional muscle strength of the lower extremities was additionally evaluated using the 10-second sit-to-stand test(10sSTS). Participants were seated on an armless chair with their feet placed flat on the floor and arms crossed over the chest. They were instructed to stand up and sit down as many times as possible within 10 seconds. The total number of completed repetitions was recorded as an indicator of lower extremity functional strength and performance(Bohannon et al., 2010).

3) Balance

The timed up-and-go test(TUG) was used to assess balance. The TUG involved standing from a seated position, walking to a cone placed 3 m in front of the subject, returning to the chair, and sitting down. The time required to do so was measured.

4. Statistical Analysis

Statistical analyses were performed using SPSS software version 22.0(IBM SPSS, Armonk, NY, USA). Normality of continuous variables was assessed using the Shapiro-Wilk test. For variables that met the assumption of normality, between-group differences were analyzed using independent t-tests, and within-group pre-post changes were analyzed using paired t-tests. Group × time interaction effects were examined using two-way mixed ANOVA.

For variables that did not meet the assumption of normality, nonparametric tests were applied. Specifically, between-group differences in TUG were analyzed using the Mann-Whitney U test, and within-group pre-post changes were examined using the Wilcoxon signed-rank test. The level of statistical significance was set at $p < 0.05$.

Ⅲ. Results

1. General Characteristics of the Subjects

A total of 32 women aged 50 years or older participated in this study. They were assigned to an aquatic exercise group(n=16) or a control group(n=16). General characteristics, including age, height, weight, and BMI, by group are presented in Table 2.

Table 2. General Characteristics (N=32)

Variable	Aquatic exercise	Control	*t*	*p*
Age(year)	64.68±6.47[a]	61.37±2.84	1.872	0.075
Height(cm)	157.71±4.57	159.62±2.80	-1.421	0.168
Weight(kg)	59.00±5.95	58.34±7.58	.272	0.787
BMI	23.74±2.58	22.89±2.89	.881	0.386

[a]Mean±standard deviation

Table 3 presents the results of two-way mixed ANOVA for outcome measures analyzed using parametric methods, including group × time interaction effects and subsequent post-hoc analyses.

No significant group × time interaction effects were observed for grip strength, and neither the main effect of time nor the between-group difference was significant (p>.05).

A significant group × time interaction effect was observed for knee extensor strength(F=50.349, p<.001, partial η^2=.627), indicating a large effect size. Post-hoc analyses revealed a significant improvement from pre- to post-intervention in the aquatic exercise group(p<.001), whereas no significant change was observed in the control group. In addition, a significant between-group difference was observed at post-intervention(p<.001).

For the 10sSTS, no significant group × time interaction effect was found(p>.05). Although a significant increase in repetitions was observed in the aquatic exercise group(p=.018), no significant change was found in the control group, and no significant between-group difference was detected.

No significant group × time interaction effects were observed for pulmonary function indices including FVC, FEV_1, and FEV_1/FVC, and neither the main effects of time nor the between-group differences were significant(p>.05). In contrast, PEF demonstrated a significant group × time interaction effect(F=10.299, p=.003, partial η^2=.256), representing a large effect size. Post-hoc analyses indicated a significant increase in PEF in the aquatic exercise group(p=.002), whereas no significant change was observed

Table 3. Effects of the Intervention on Outcome Measures in the Aquatic Exercise and Control Groups

		Aquatic exercise (n=16)	Control (n=16)	*P*	Group×time interaction effects		
					F	*P*	*Eta2*
Grip strength (Lbs)	Pre	44.11±9.78	43.82±9.26	0.578	0.320	0.576	0.011
	Post	42.31±8.30	43.53±10.14	0.933			
	P	0.835	0.602				
Knee Extensor strength (Nm)	Pre	19.40±4.02	21.58±2.88	0.087	50.349	0.000	0.627
	Post	38.39±11.51	23.37±2.74	0.000*			
	P	0.000*	0.069				
10sSTS (reps)	Pre	7.06±2.20	7.12±2.15	0.936	2.612	0.117	0.080
	Post	8.06±2.32	7.43±1.67	0.390			
	P	0.018*	0.136				
FVC (l)	Pre	2.73±0.36	2.81±0.26	0.485	0.699	0.410	0.023
	Post	2.75±0.46	2.77±0.24	0.888			
	P	0.768	0.391				
FEV_1 (l)	Pre	2.07±0.36	2.13±0.26	0.547	1.795	0.190	0.056
	Post	2.12±0.32	2.09±0.24	0.794			
	P	0.407	0.214				
FEV_1/FVC (%)	Pre	75.25±9.40	77.12±4.89	0.485	1.153	0.291	0.037
	Post	77.06±6.22	77.16±6.47	0.965			
	P	0.165	0.973				
PEF (l)	Pre	4.11±1.31	4.14±0.83	0.929	10.299	0.003	0.256
	Post	5.03±1.38	4.26±0.74	0.043*			
	P	0.002*	0.623				

Values are presented as mean ± standard deviation.
Within-group and between-group effects, as well as group × time interaction effects, were analyzed using two-way mixed ANOVA. partial η^2 indicates partial eta squared.
10sSTS: 10-second STS test, TUG: Timed up and go test, FVC: forced vital capacity, FEV_1: Forced Expiratory Volume in 1 sec, PEF: Peak Expiratory Flow, *p<0.05

Table 4. Changes in Timed Up and Go (TUG) Performance

	Pre	Post	Within-group p‡	Between-group p†	Group×time interaction effects		
					F	*P*	*Eta2*
Aquatic exercise (n=16)	7.49±1.05	5.79±0.83	0.000*	0.030*	5.649	0.024	0.158
Control (n=16)	7.52±1.05	6.66±1.24	0.013*				

Values are presented as mean ± standard deviation. *p<0.05
‡ Within-group changes were analyzed using Wilcoxon signed-rank test
† Between-group comparisons at post-intervention were performed using the Mann-Whitney U test

in the control group.

Changes in TUG performance are summarized in Table 4. There was no significant difference in TUG performance between the aquatic exercise and control groups at baseline(p = .748). In the aquatic exercise group, TUG performance significantly improved after the intervention(p = .000), and a significant improvement was also observed in the control group(p = .013). Post-intervention TUG values were significantly lower in the aquatic exercise group compared with the control group(p = .030). Furthermore, a significant group × time interaction effect was observed for TUG(F = 5.649, p = .024, partial η^2 = .158), indicating that the improvement in TUG was significantly greater in the aquatic exercise group than in the control group.

Ⅳ. Discussion

This study compared changes in pulmonary function, muscle strength, and balance after a 6-week aquatic exercise program in community-dwelling women aged 50 years or older. The results demonstrated significant improvements in PEF, knee extensor strength, and TUG, whereas no significant changes were observed in grip strength, 10-second sit-to-stand performance, or vital capacity indices(FVC, FEV_1, and FEV_1/FVC).

Regarding pulmonary function indices, only PEF showed improvement. PEF reflects expiratory rate and instantaneous expiratory muscle power and is highly responsive to relatively short-term exercise interventions. Consistent with the present findings, Yamashina et al.(2019) reported a significant increase in expiratory pressure following a 6-week aquatic walking program, suggesting that aquatic exercise can effectively stimulate expiratory muscle function.

Importantly, the improvement in PEF in the present study was accompanied by a large group×time interaction effect size(partial η^2=.256), indicating that the observed change was not only statistically significant but also of substantial practical magnitude. This finding suggests that even in the absence of direct respiratory muscle training, a short-term aquatic exercise program can induce clinically meaningful adaptations in expiratory function.

In an aquatic environment, hydrostatic pressure in combination with buoyancy continuously exerts external resistance on the rib cage and abdomen, increasing the mechanical load during both inspiration and expiration. This resistance makes thoracic expansion and forceful expiration more demanding, thereby promoting repeated activation of the expiratory muscles. Previous studies have also reported that aquatic exercise improves thoracic mobility, respiratory muscle strength, and functional capacity(Jung et al., 2014; Charususin et al., 2021; Hoshi et al., 2022). Therefore, the large effect size observed for PEF in this study supports the notion that aquatic exercise provides sufficient respiratory loading to elicit meaningful expiratory muscle adaptations.

The results of this study suggest that the significant improvement in knee extensor strength appears to be related to the continuous muscle load provided by the resistance and viscosity of the aquatic environment(Prado et al., 2022). Movement in water offers greater resistance than air, leading to repetitive overload of major lower extremity muscle groups, such as the quadriceps femoris(Waller et al., 2013). At the same time, buoyancy reduces body weight, helping to increase activity levels without joint pain or fatigue(Carayannopoulos, 2020; Kim, 2024). The results of this study are consistent with the muscle strength-enhancing effects of aquatic exercise reported in previous studies(Prado et al., 2022; Juesas Torres et al., 2025). In particular, the high interaction effect size identified in this study suggests that aquatic exercise has a clinically meaningful effect on improving lower extremity muscle strength in middle-aged women.

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However, although there was a significant improvement in 10sSTS after aquatic exercise intervention, there was no significant difference in grip strength and 10sSTS values between the two groups. Grip strength is mainly determined by the activity of the forearm flexors and digital flexors, and upper extremity resistive load or grip-focused training is necessary for improvement. Studies that included resistance exercise or hand and forearm-specific training reported significant increases in grip strength(Grgic et al., 2020). However, the aquatic exercise program applied in this study mainly consisted of lower extremity-centered aerobic, resistance, and balance training, and the upper extremity resistive load was insufficient, and task-specific loading necessary for strengthening grip strength was not included, which is why it is believed that it did not lead to improvements in grip strength.

In this study, knee extensor strength significantly increased after aquatic exercise, but 10sSTS performance did not show a significant difference between the two groups. This is interpreted as a result of the intervention period being insufficient to translate into improvements in functional endurance and fatigue resistance for performing repeated STS tasks, although aquatic exercise was sufficient to improve maximal strength. STS performance requires not only lower extremity strength but also repetitive performance capacity and metabolic adaptations(Bohannon, 2007), and endurance-based STS improvements are generally reported to be noticeable in longer training interventions lasting 8 weeks or more(Yanagawa et al., 2016). Therefore, this study suggests that a longer training period and repetitive load are necessary to induce changes in endurance and functional performance sufficient to show a significant difference from the control group.

In contrast, TUG performance significantly improved in both groups, and a significant group × time interaction effect was observed, indicating that the magnitude of improvement was significantly greater in the aquatic exercise group. This differential improvement can be attributed to the unique physical properties of the aquatic environment, including buoyancy, hydrostatic pressure, and water viscosity, which reduce fall risk while enabling continuous balance and gait-related stimulation. These conditions facilitate repetitive activation of postural control, lower extremity stabilizing muscles, and gait-related musculature, thereby enhancing dynamic balance and movement speed.

Consistent with our findings, a recent meta-analysis demonstrated that aquatic exercise significantly improves functional outcomes related to gait speed, balance, and fall risk(Melo et al., 2023). Furthermore, a systematic review comparing aquatic and land-based exercise reported that aquatic exercise tended to be equivalent or slightly superior in dynamic balance and gait-related indicators(Kim et al., 2020). Therefore, the superior improvement in TUG observed in the aquatic exercise group in the present study likely reflects not only gains in muscle strength but also the combined influence of aquatic resistance, buoyancy, and continuous postural challenge, supporting the effectiveness of aquatic exercise as a multimodal intervention for improving functional mobility and dynamic balance in middle-aged and older women.

This study has several limitations. Although the effects of a six-week aquatic exercise program were compared in thirty-two middle-aged women, the relatively small sample size and short intervention period of six weeks resulted in no significant response in pulmonary function indices, except for PEF, which has a high short-term response. The program focused on the lower extremities, lacking direct stimulation of the upper extremities and respiratory muscles, which may have contributed to the limited changes in grip strength and STS results. Therefore, future studies should investigate the effects of aquatic exercise program over a medium- to long-term period of 12 weeks or longer to confirm improvements in muscle strength and endurance. Furthermore, a standardized aquatic exercise protocol should be established through expanded validation across diverse age groups, genders, and disease groups.

From a clinical perspective, the findings of this study suggest that aquatic exercise can be effectively applied as a community-based intervention for middle-aged and older adults, particularly those who may have difficulty participating in land-based exercise due to joint pain, balance deficits, or reduced exercise tolerance. The observed improvements in knee extensor strength, functional mobility, and expiratory flow indicate that aquatic exercise may serve as a practical and safe training option to enhance lower extremity function and respiratory performance in clinical and preventive rehabilitation settings.

Ⅴ. Conclusion

This study confirmed that a six-week aquatic exercise program significantly improved knee extensor strength, functional mobility(TUG), and peak expiratory flow(PEF) in community-based women aged 50 years and older. These results suggest that aquatic exercise may be a safe and effective intervention for improving lower extremity function and expiratory capacity in middle-aged and older women.

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