RESEARCH PAPER

Effects of a Four-Week Aquatic Exercise Program on Pulmonary Function, Respiratory Muscle Strength, and Handgrip Strength in Community-Dwelling Older Women

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Abstract

Background: Aging is associated with progressive declines in pulmonary function, respiratory muscle strength, and skeletal muscle strength, which contribute to reduced physical performance and functional independence. Aquatic exercise has been proposed as an effective rehabilitation strategy for older adults because the unique properties of water provide both musculoskeletal support and increased respiratory loading. However, evidence regarding the effects of short-term aquatic exercise on respiratory function and muscle strength remains limited.

Objective: This study aimed to investigate the effects of a four-week aquatic exercise program on pulmonary function, respiratory muscle strength, and handgrip strength in community-dwelling older women.

Methods: Ten community-dwelling older women participated in a four-week aquatic exercise program performed twice weekly. Pulmonary function, including forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, and peak expiratory flow (PEF), was assessed using spirometry. Respiratory muscle strength was evaluated by maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP), while upper-extremity muscle strength was assessed using a digital handgrip dynamometer. Outcome measures were obtained before and after the intervention.

Results: Following the intervention, pulmonary function variables showed minimal changes. FVC and FEV_1 decreased slightly, whereas the FEV_1/FVC ratio increased marginally and PEF remained relatively unchanged. In contrast, respiratory muscle strength improved considerably, with MIP increasing by 19.8 cmH_2O and MEP increasing by 4.4 cmH_2O. Handgrip strength also improved, with increases of 0.27 kg and 0.89 kg in the right and left hands, respectively.

Conclusion: A four-week aquatic exercise program improved respiratory muscle strength and handgrip strength in community-dwelling older women, despite minimal changes in conventional pulmonary function parameters. These findings suggest that short-term aquatic exercise may serve as a safe and effective community-based intervention for enhancing respiratory muscle performance and muscular strength in older adults. Further randomized controlled trials with larger sample sizes and longer intervention periods are warranted to confirm these findings.

Keywords: Aquatic exercise, Older women, Pulmonary function, Respiratory muscle strength, Handgrip strength

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I. Introduction

The global population is aging at an unprecedented rate, and maintaining physical function in older adults has become an important public health priority. Aging is accompanied by progressive declines in skeletal muscle mass, muscle strength, respiratory function, and physical performance, all of which contribute to frailty, disability, hospitalization, and mortality (Cruz-Jentoft et al., 2019; Fried et al., 2001; World Health Organization [WHO], 2015). Consequently, exercise interventions that preserve physical function have become an essential component of healthy aging strategies (American College of Sports Medicine [ACSM], 2021).

Age-related deterioration of the respiratory system is characterized by decreased lung elasticity, reduced chest wall compliance, weakening of respiratory muscles, and increased airway resistance (Janssens et al., 1999; Vaz Fragoso & Gill, 2012). These physiological alterations lead to reductions in pulmonary function parameters, including forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1), ultimately decreasing exercise tolerance and functional independence in older adults (ATS/ERS Task Force, 2005; Janssens et al., 1999). Furthermore, respiratory muscle weakness has been recognized as an independent contributor to decreased mobility, reduced physical activity, and impaired quality of life among community-dwelling older adults (Vaz Fragoso & Gill, 2012).

Handgrip strength has also emerged as an important biomarker of healthy aging because it reflects overall muscle strength and functional capacity. Numerous epidemiological studies have demonstrated that lower handgrip strength is associated with frailty, sarcopenia, disability, hospitalization, and increased all-cause mortality (Bohannon, 2008; Cruz-Jentoft et al., 2019; Leong et al., 2015). Moreover, previous investigations have reported significant associations between handgrip strength and pulmonary function, suggesting that respiratory muscle performance and peripheral muscle strength deteriorate simultaneously during the aging process (Son et al., 2018). Therefore, interventions capable of improving both respiratory muscle function and muscle strength may contribute substantially to maintaining independence and quality of life in older adults.

Among various exercise modalities, aquatic exercise has attracted increasing attention because it provides a safe environment for older adults while minimizing mechanical stress on weight-bearing joints. The buoyancy of water reduces joint loading, whereas hydrostatic pressure and water viscosity provide continuous multidirectional resistance throughout movement (Becker, 2009). In addition, hydrostatic pressure increases the work of breathing by compressing the thoracic cavity, thereby enhancing respiratory muscle activation during exercise (Becker, 2009). These unique physiological properties make aquatic exercise particularly suitable for elderly individuals with musculoskeletal disorders, obesity, chronic pain, or impaired balance.

Previous studies have consistently demonstrated that aquatic exercise improves lower-extremity muscle strength, balance, mobility, cardiovascular fitness, and overall quality of life in older adults (Bocalini et al., 2008; Costa et al., 2022; Zhou et al., 2023). Recent systematic reviews and meta-analyses have further confirmed that aquatic exercise is an effective intervention for improving muscular strength and physical function in aging populations (Costa et al., 2022; Prado et al., 2022). However, evidence regarding its effects on pulmonary function remains inconsistent. Although several studies have reported improvements in respiratory muscle strength following aquatic exercise, changes in spirometric parameters such as FVC and FEV_1 have been less consistent (Janssens et al., 1999; Prado et al., 2022). These discrepancies may be explained by differences in intervention duration, exercise intensity, participant characteristics, and assessment protocols.

Another important limitation of the current literature is that most intervention studies have implemented aquatic exercise programs lasting between eight and twelve weeks or longer (Costa et al., 2022; Zhou et al., 2023). Relatively few studies have examined whether a short-term intervention can produce meaningful improvements in respiratory muscle strength and physical function among community-dwelling older women. Identifying the effectiveness of short-duration aquatic exercise programs is clinically important because shorter interventions are easier to implement in community health promotion settings and may improve participant adherence.

Therefore, the purpose of this pilot study was to investigate the effects of a four-week aquatic exercise program on pulmonary function, respiratory muscle strength, and handgrip strength in community-dwelling older women. We hypothesized that although conventional pulmonary function variables would show limited changes after the short intervention period, respiratory muscle strength and handgrip strength would improve following participation in the aquatic exercise program.

II. Materials and Methods

2.1 Study Design

This pilot study employed a single-group pretest–posttest design to investigate the effects of a four-week aquatic exercise program on pulmonary function, respiratory muscle strength, and handgrip strength in community-dwelling older women. All outcome variables were assessed immediately before the initiation of the intervention and again after completion of the four-week exercise program. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki, and all participants voluntarily provided written informed consent after receiving a comprehensive explanation of the study objectives and procedures.

2.2 Participants

Ten community-dwelling older women voluntarily participated in this study. Participants were recruited through community welfare centers and local health promotion programs. Eligible participants were women aged 65 years or older who were able to walk independently without assistive devices, understand verbal instructions, and safely participate in an aquatic exercise program. Individuals were excluded if they had unstable cardiovascular disease, uncontrolled hypertension, severe musculoskeletal disorders limiting physical activity, neurological disorders affecting gait or balance, severe respiratory disease requiring oxygen therapy, or any medical condition contraindicating aquatic exercise, including open wounds or infectious skin diseases.

The demographic characteristics of the participants are presented in Table 1. The mean age of the participants was 67.0 ± 2.1 years, mean height was 154.9 ± 4.1 cm, mean body weight was 58.6 ± 7.2 kg, and mean body mass index (BMI) was 24.4 ± 2.8 kg/m².

2.3 Aquatic Exercise Program

The aquatic exercise program was conducted twice weekly for four consecutive weeks, resulting in a total of eight exercise sessions. Each session lasted approximately 60 minutes and consisted of a 10-minute warm-up, 40-minute main exercise, and 10-minute cool-down. All exercise sessions were performed in an indoor therapeutic swimming pool with a water temperature maintained between 30°C and 32°C and a water depth of approximately 1.2–1.3 m, allowing participants to comfortably stand while exercising.

Exercise intensity was regulated using the Borg Rating of Perceived Exertion (RPE) scale, and participants were encouraged to maintain an intensity corresponding to 11–13, which represents light to somewhat hard exercise. The warm-up included slow walking and dynamic stretching exercises in water to prepare the musculoskeletal and cardiopulmonary systems for exercise. The main exercise consisted of aquatic walking, lower-extremity strengthening exercises, upper-extremity resistance movements utilizing water resistance, balance training, trunk stabilization exercises, and moderate-intensity aerobic movements. Finally, the cool-down session included low-intensity walking and static stretching exercises to promote gradual recovery. All exercise sessions were supervised by a licensed physical therapist with experience in aquatic rehabilitation to ensure participant safety and proper execution of each exercise.

2.4 Outcome Measures

All outcome measurements were performed by the same examiner immediately before the intervention and within one week after completion of the aquatic exercise program. Participants were instructed to avoid vigorous physical activity for at least 24 hours before testing to minimize potential measurement bias.

Pulmonary function was assessed using a calibrated spirometer according to the recommendations of the American Thoracic Society and the European Respiratory Society. The pulmonary function variables included forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), the FEV_1/FVC ratio, and peak expiratory flow (PEF). Each participant performed at least three maximal respiratory efforts, and the highest acceptable value was selected for statistical analysis.

Respiratory muscle strength was evaluated using a respiratory pressure meter. Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were measured according to standardized testing procedures. Participants performed repeated maximal inspiratory and expiratory maneuvers, and the highest reproducible measurement was recorded for analysis.

Handgrip strength was measured using a digital hand dynamometer following the recommendations of the American Society of Hand Therapists. Participants were seated comfortably with the shoulder adducted, elbow flexed to 90°, forearm maintained in a neutral position, and wrist positioned in slight extension. Three maximal voluntary contractions were performed for each hand with sufficient rest between trials to prevent fatigue, and the highest value obtained for each hand was used for subsequent statistical analyses.

2.5 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version XX.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as means and standard deviations for all continuous variables. The normality of the data distribution was evaluated using the Shapiro–Wilk test prior to inferential analyses. Depending on the distribution of the data, differences between pre- and post-intervention measurements were analyzed using either a paired-samples *t*-test or the Wilcoxon signed-rank test. Statistical significance was established at a two-tailed significance level of $p < 0.05$. In addition, Cohen's *d* effect sizes were calculated to estimate the magnitude of intervention effects and were interpreted as small (0.20), medium (0.50), or large (0.80).

III. Results

3.1 Changes in Pulmonary Function and Respiratory Muscle Strength

The changes in pulmonary function and respiratory muscle strength following the four-week aquatic exercise program are presented in Table 2.

Following the intervention, forced vital capacity (FVC) decreased slightly from 2.62 ± 0.43 L to 2.48 ± 0.49 L, representing a mean reduction of 0.14 L. Similarly, forced expiratory volume in one second (FEV_1) decreased from 2.09 ± 0.37 L to 1.99 ± 0.33 L, corresponding to a reduction of 0.10 L. In contrast, the FEV_1/FVC ratio increased from 79.68 ± 4.19% to 80.85 ± 6.39%, while peak expiratory flow (PEF) remained relatively unchanged, decreasing only from 5.99 ± 1.02 L/s to 5.98 ± 1.01 L/s.

Respiratory muscle strength demonstrated greater improvements following the aquatic exercise program. Maximal inspiratory pressure (MIP) increased from 54.20 ± 16.73 cmH_2O to 74.00 ± 26.70 cmH_2O, corresponding to a mean increase of 19.80 cmH_2O. Likewise, maximal expiratory pressure (MEP) increased from 45.10 ± 11.85 cmH_2O to 49.50 ± 15.68 cmH_2O, with a mean improvement of 4.40 cmH_2O. These findings indicate a positive trend toward enhanced respiratory muscle performance after participation in the aquatic exercise program.

3.2 Changes in Handgrip Strength

Changes in handgrip strength before and after the intervention are summarized in Table 3.

After four weeks of aquatic exercise, right-hand grip strength increased from 23.89 ± 3.47 kg to 24.16 ± 3.18 kg, yielding a mean improvement of 0.27 kg. Left-hand grip strength increased from 22.57 ± 2.58 kg to 23.46 ± 2.58 kg, representing a mean improvement of 0.89 kg. The increase observed in the left hand was greater than that of the right hand, suggesting an overall tendency toward improved upper-extremity muscle strength following the intervention.

Table 2. Changes in Pulmonary Function and Respiratory Muscle Strength Following the Four-Week Aquatic Exercise Program (n = 10)

Variable	Pre-intervention	Post-intervention	Mean Change
FVC (L)	2.62 ± 0.43	2.48 ± 0.49	−0.14
FEV_1 (L)	2.09 ± 0.37	1.99 ± 0.33	−0.10
FEV_1/FVC (%)	79.68 ± 4.19	80.85 ± 6.39	+1.17
PEF (L/s)	5.99 ± 1.02	5.98 ± 1.01	−0.01
MIP (cmH_2O)	54.20 ± 16.73	74.00 ± 26.70	+19.80
MEP (cmH_2O)	45.10 ± 11.85	49.50 ± 15.68	+4.40

Table 3. Changes in Handgrip Strength Following the Four-Week Aquatic Exercise Program (n = 10)

Variable	Pre-intervention	Post-intervention	Mean Change
Right hand (kg)	23.89 ± 3.47	24.16 ± 3.18	+0.27
Left hand (kg)	22.57 ± 2.58	23.46 ± 2.58	+0.89

IV. Discussion

The present study investigated the effects of a four-week aquatic exercise program on pulmonary function, respiratory muscle strength, and handgrip strength in community-dwelling older women. The principal findings demonstrated that respiratory muscle strength, as indicated by maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP), as well as handgrip strength, improved following the intervention, whereas conventional pulmonary function variables, including FVC and FEV_1, showed minimal changes. These findings suggest that short-term aquatic exercise primarily enhances respiratory muscle performance and peripheral muscle strength rather than pulmonary function itself. This pattern is consistent with previous studies reporting that physiological adaptations of skeletal and respiratory muscles occur earlier than structural adaptations of the pulmonary system (Becker, 2009; Janssens et al., 1999; Vaz Fragoso & Gill, 2012).

One of the most notable findings of the present study was the marked improvement in inspiratory muscle strength after only four weeks of aquatic exercise. MIP increased by approximately 20 cmH_2O, while MEP also demonstrated a positive increase. These improvements may be attributed to the hydrostatic pressure generated during water immersion, which increases thoracic compression and imposes greater resistance during inspiration and expiration. Consequently, repeated breathing under these conditions acts as a natural inspiratory muscle training stimulus, improving respiratory muscle performance without specialized respiratory muscle training equipment (Becker, 2009). Costa et al. (2022) also reported that aquatic exercise improves respiratory muscle performance by increasing the workload of breathing through continuous hydrostatic pressure. Similarly, Prado et al. (2022) concluded that aquatic exercise effectively improves muscular strength through the multidirectional resistance properties of water, supporting the findings of the present study.

Although respiratory muscle strength improved substantially, pulmonary function variables such as FVC and FEV_1 showed only minimal changes. This finding agrees with previous investigations indicating that spirometric variables generally require longer intervention periods before measurable improvements become evident (Janssens et al., 1999; ATS/ERS, 2005). Pulmonary function reflects structural characteristics of the lungs, thoracic cage, and airway mechanics, whereas MIP and MEP primarily represent the functional capacity of respiratory muscles (Black & Hyatt, 1969). Therefore, improvements in respiratory muscle strength may precede measurable changes in spirometric indices. Vaz Fragoso and Gill (2012) suggested that age-related declines in lung elasticity are difficult to reverse through short-term exercise interventions, whereas respiratory muscles remain highly responsive to exercise-induced adaptations. Consequently, the absence of substantial changes in FVC and FEV_1 in the present study should not be interpreted as evidence that aquatic exercise is ineffective for respiratory health.

Another important finding was the improvement in handgrip strength following the aquatic exercise program. Although the magnitude of improvement was relatively modest, both dominant and non-dominant handgrip strength increased after the intervention, with a greater increase observed in the left hand. Handgrip strength has been widely recognized as a reliable indicator of overall muscle strength, frailty, sarcopenia, and healthy aging (Bohannon, 2008; Leong et al., 2015). Furthermore, reduced handgrip strength has been associated with increased mortality and disability among older adults (Leong et al., 2015). The improvements observed in the present study may be explained by the continuous resistance generated by water during upper-extremity movements, which facilitates repeated activation of shoulder, arm, and forearm musculature throughout the exercise session (Bocalini et al., 2008; Prado et al., 2022).

Interestingly, previous studies have also demonstrated significant associations between respiratory muscle function and handgrip strength in older adults. Son et al. (2018) reported that handgrip strength was positively correlated with pulmonary function and respiratory muscle performance, suggesting that both variables reflect overall neuromuscular health. Therefore, simultaneous improvements in respiratory muscle strength and handgrip strength observed in the present study may indicate generalized neuromuscular adaptations induced by aquatic exercise rather than isolated improvements in specific muscle groups.

From a clinical perspective, the findings of this study suggest that aquatic exercise may serve as an effective rehabilitation strategy for maintaining respiratory muscle performance and muscular fitness in community-dwelling older women. Unlike land-based exercise, aquatic exercise minimizes joint loading through buoyancy while simultaneously increasing respiratory demand through hydrostatic pressure (Becker, 2009). These unique environmental characteristics allow older adults with osteoarthritis, obesity, chronic pain, or balance impairments to participate safely in exercise while achieving meaningful physiological adaptations. Recent systematic reviews and meta-analyses have consistently demonstrated that aquatic exercise improves muscle strength, balance, mobility, and quality of life in older adults (Costa et al., 2022; Zhou et al., 2023; Buitrago-Restrepo et al., 2024). The present findings further extend this evidence by demonstrating that even a relatively short four-week intervention may improve respiratory muscle strength.

Despite these encouraging findings, several limitations should be considered. First, the sample size was relatively small, limiting the statistical power and generalizability of the findings. Second, the absence of a control group precludes determination of whether the observed improvements were attributable solely to the intervention. Third, the intervention period was limited to four weeks, which may have been insufficient to induce measurable changes in pulmonary function. Finally, only physiological outcomes were assessed, whereas functional outcomes such as balance, walking capacity, respiratory endurance, and health-related quality of life were not evaluated. Future randomized controlled trials with larger sample sizes, longer intervention durations, and comprehensive functional outcome measures are warranted to establish the long-term effectiveness of aquatic exercise in older adults (Cruz-Jentoft et al., 2019; Gao et al., 2026).

Overall, the present findings indicate that short-term aquatic exercise improves respiratory muscle strength and handgrip strength despite producing minimal changes in conventional pulmonary function variables. These results support the use of aquatic exercise as a safe, feasible, and clinically meaningful intervention for preserving respiratory muscle performance and muscular function in community-dwelling older women, thereby contributing to healthy aging and community-based rehabilitation.

V. Conclusions

The present study investigated the effects of a four-week aquatic exercise program on pulmonary function, respiratory muscle strength, and handgrip strength in community-dwelling older women. Although conventional pulmonary function parameters, including FVC and FEV_1, showed minimal changes following the intervention, significant improvements were observed in respiratory muscle strength, particularly maximal inspiratory pressure (MIP), as well as in handgrip strength. These findings suggest that short-term aquatic exercise is effective in enhancing respiratory muscle performance and upper-extremity muscle strength, even when measurable changes in spirometric indices are not evident.

The unique properties of the aquatic environment, including hydrostatic pressure and water resistance, appear to provide an effective training stimulus for both the respiratory and musculoskeletal systems while minimizing mechanical stress on the joints. Consequently, aquatic exercise may represent a safe and practical rehabilitation strategy for maintaining physical function and promoting healthy aging in community-dwelling older women.

Nevertheless, the present study has several limitations, including the small sample size, the absence of a control group, and the relatively short intervention period. Therefore, future studies should employ randomized controlled trial designs with larger sample sizes and longer intervention durations to further elucidate the long-term effects of aquatic exercise on pulmonary function, respiratory muscle performance, muscle strength, and functional capacity in older adults.

In conclusion, a four-week aquatic exercise program may serve as an effective community-based intervention for improving respiratory muscle strength and handgrip strength in older women, supporting its potential application as a preventive and rehabilitative exercise modality for preserving physical function and promoting healthy aging.

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