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Research Article

The Effect of a Three-Month Aquatic Training Program on Physical Functioning in Elderly Men: A Randomized Controlled Trial

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Background: Aquatic training is emerging as a multifaceted therapy for enhancing health parameters, particularly among elderly populations. This study aimed to investigate the effects of a three-month aquatic training on physical functioning, including balance, muscular strength, and flexibility, among healthy older men.
Methods: From an initial sample of 80 elderly men, 45 healthy participants (mean age: 75.5 years) were randomly assigned to either the intervention ($n = 23$) or control group ($n = 22$). The intervention group participated in three 60-min sessions per week for 12 weeks. Functional fitness variables, encompassing upper and lower body flexibility and muscular strength, along with dynamic and static balance, were assessed using multiple tests at both baseline and postintervention. The training load increased gradually over the 12-week program, ranging between 50% and 70% of heart rate reserve (HRR). Exercise intensity was controlled using the rate of perceived exertion (RPE) scale, aiming for a targeted range of 12–15 on the Borg scale. The control group maintained their usual daily activities throughout the study period, providing a basis for comparison with the exercise intervention group.
Results: No significant baseline differences in demographic characteristics were observed between the study groups ($p > 0.05$). Compared to the control group, the intervention group demonstrated significant improvements across all outcome measures, including static balance, dynamic balance, upper and lower body flexibility, and upper and lower body muscular strength ($p < 0.001$).
Conclusion: The study findings highlight the efficacy of aquatic training in enhancing various aspects of physical functioning among older men, supporting the growing recognition of aquatic training as an effective therapeutic approach for promoting vitality and independence in elderly populations.

Keywords: aging; aquatic training; balance; flexibility; muscle strength

1. Introduction

The demographic composition of high-income nations has been undergoing a gradual transformation towards older age groups, a phenomenon known as population aging. This shift is primarily attributed to the combination of longer life spans and consistently declining fertility rates. Currently, many countries are experiencing a temporary increase in population aging due to the advancing age of substantial cohorts born during the mid-twentieth century [1]. Data show that the problem of population aging has spread globally, with the proportion of older people rising at an unprecedented rate in many low- and middle-income countries [2–4]. The proportion of the world's population aged 65 and over is projected to increase from 10% in 2022 to 16% in 2050 [5]. Countries with aging populations should adjust their public programs to accommodate the growing proportion of older individuals by improving the sustainability of social security and pension systems, as well as establishing universal health care and long-term care systems [6].

The aging process is characterized by a series of unfavorable structural and functional changes in the organism, with a gradual acceleration with advancing age [6, 7]. These modifications affect the performance of motor skills, make it difficult for the individual to adapt to the environment, and induce subsequent changes in social and psychological health parameters [7]. Loss of muscular strength begins in mid-adulthood and is caused by several factors [8]. It is associated with decreased flexibility in all joints, along with reductions in both static and dynamic balance, leading to adverse effects on posture and functional performance. This increases the risk of falling and respiratory problems, slows walking speed, and complicates daily living activities. Therefore, the maintenance or improving flexibility and muscular strength is crucial for maintaining the health of the elderly population [9]. Evidence suggests that physical training programs help mitigate the effects of the immobility cycle, reducing the risk of falls, alleviating pain, and addressing the associated fears in aging populations [10]. A balanced strengthening of musculature and optimized joint mobility, achieved through a long-term program of low- to moderate-intensity exercises, is widely recognized as essential for preventing age-related dysfunctions [11].

Hydrotherapy is a physical therapy modality that utilizes the physical, physiological, and kinesiological effects of immersing the body in water as an adjunct to rehabilitation or prevention of age-related functional alterations. Physical properties of water play important roles in improving and maintaining a joint range of movement, reducing muscular tension, and promoting relaxation [12]. The basic features of water (including hydrostatic pressure, buoyancy, viscosity, density, and temperature) along with dynamic features (such as flow resistance and turbulent flow) act as facilitators, enabling individuals immersed in water to engage in balanced and coordinated motions [13]. Reductions of the articulation effect during physical activities induced by flotation cause a decrease in pain sensitivity, decline the compress on the painful joints, and bring about the higher range of motion [12, 14]. In the absence of a static condition of the body in water, muscles are constantly activated to stabilize the body, which allows for the development of strength, flexibility, and balance [15–17]. Strengthening exercises with submerged patients are based on the physical principles of hydrostatics, which allow the generation of a constant multidimensional resistance to the movements, and this resistance increases proportionally as the force is exerted, generating a minimal overloading of the articulations [12, 14].

While the benefits of aquatic training for physical functioning have been well-documented, there remains a significant gap in tailored interventions specifically designed for older populations. With a growing interest in aquatic therapy to mitigate age-related declines in physical functioning, understanding the critical need for evidence-based interventions in this demographic is crucial. Therefore, the purpose of this study was to examine the efficacy of a semiprolonged aquatic training program on physical functioning of older adults, with the goal of providing insight into the development of exercise-based therapeutic programs. The ultimate objective is to contribute to strategies for promoting healthy aging and maintaining the independence in aging populations.

2. Materials and Methods

2.1. Study Design and Participants. Following a public announcement, an initial sample of 80 elderly men was assessed for eligibility, resulting in the inclusion of 45 healthy sedentary elderly men (age: 75.53 ± 4.41 years). Enrollment and interventions were carried out from June 1, 2017 to March 15, 2018 in Mashhad, Iran. The sample size was calculated using the G* Power software (version 3.1.9.6), determining that a total of 40 elderly men would achieve a power of 80% at $\alpha = 0.05$, with an estimated meaningful detectable effect size (ES) of 0.7 based on the outcome measure. Inclusion criteria were as follows: men aged 65 years or older, able to walk independently and not using walking aids, able to perform their activities of daily living, and able to understand basic motor commands. The exclusion criteria were as follows: history of falls, urinary or fecal incontinence, renal insufficiency, open wounds, contagious skin diseases, infectious diseases, catheters, vascular thrombi, cardiac insufficiency, uncontrolled arterial pressure, dyspnea on minimal exertion, use of psychotropic drugs (benzodiazepines), active lifestyle (participated in regular exercise more than once a week) during the last 6 months, or participation in any other physical activity or physical therapy program throughout the intervention period. The principal investigator was responsible for making the final decisions regarding the inclusion/exclusion criteria. The study followed the principles of the Declaration of Helsinki, and the study protocol was approved by the Ethics Committee of Sport Sciences Research Institute of Iran (IR.SSRI.REC.1400.016). Informed written consent was obtained from all participants. The study flow diagram is shown in Figure 1.

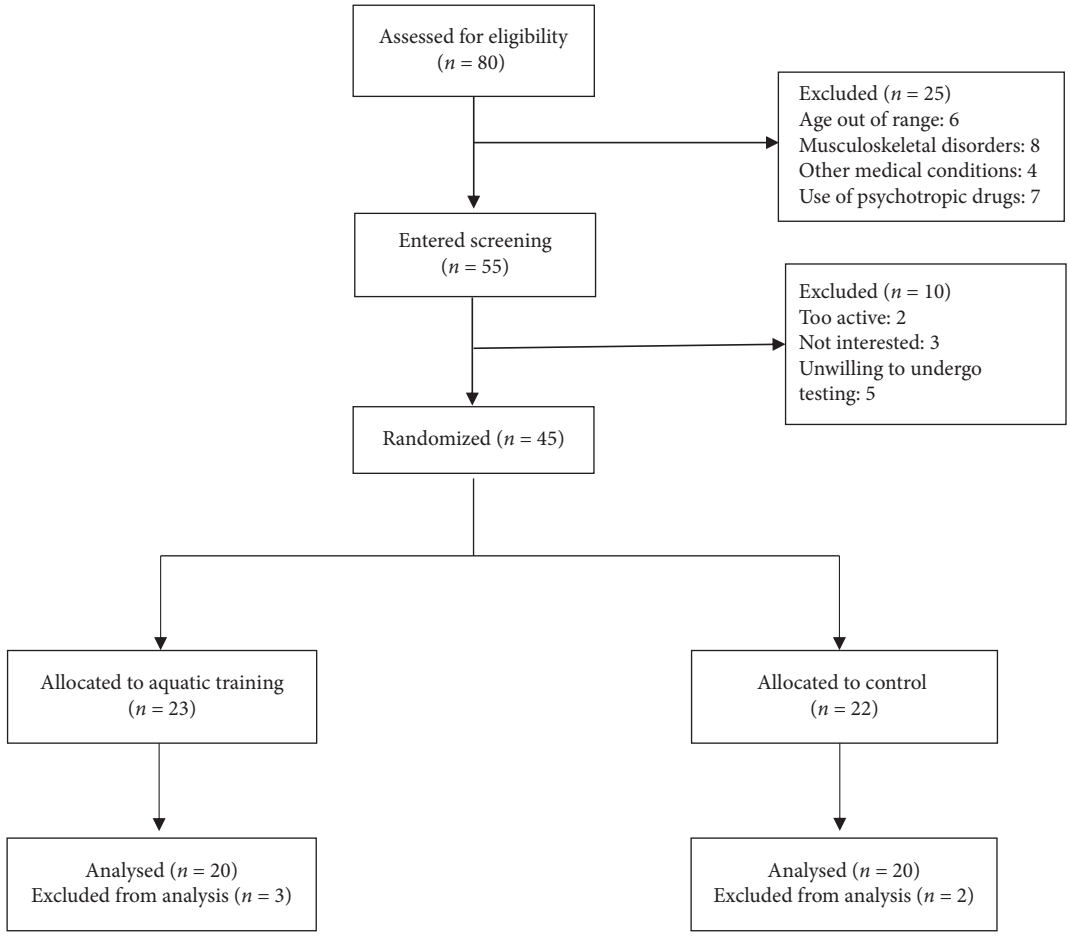

Figure 1: Study flow diagram.

2.2. Randomization. After the initial evaluation, subjects were randomly assigned to aquatic training ($n = 23$) and control ($n = 22$) groups, with an allocation ratio of 1:1. Randomization was performed using a computer-generated random number sequence to ensure equal distribution of participants between the two groups. The investigators responsible for conducting the assessments and analyzing the data were blinded to the group allocation throughout the duration of the trial.

2.3. Intervention. The aquatic training program consisted of 60 min for a group of participants in the intervention group, three sessions per week (Saturdays, Mondays, and Wednesdays) for 12 weeks in the indoor pool of a community center. The aquatic training sessions were held in the afternoon in a pool with a depth of 1.20 m, dimensions of 25×12.5 m, with water in the approximate temperature range of 30°C to 31°C, and a ambient temperature of 29°C. Participants in the intervention group underwent aquatic training together, supervised by investigators. They were never alone at any time during the procedures and were always monitored for their physical and emotional health. Before and after each session, blood pressure and heart rate (HR) were measured for the participants' safety. One week of familiarization was provided to allow for better adaptation to the training and aquatic environment.

Each session was divided into three phases: a warm-up phase (10 min) and the main training phase (45 min), followed by a cool-down phase (5 min). The HR was monitored with the Polar H10 Waterproof HR Sensor every 30 s (Polar, USA) [18], and the rate of perceived exertion (RPE; Borg scale) was measured in the final 10 s of each stage [19]. The intensity was moderate to vigorous (RPE: 12–15 out of the scale of 6–20) for 12 weeks. Exercise intensity was increased every 4 weeks as follows: 50%–60% of heart rate reserve (HRR) for weeks 1–4, 60%–65% of HRR for weeks 5–8, and 65%–70% of HRR for weeks 9–12. Each session consisted of 20 workouts, with each exercise being completed in 4 sets of 30 s, with 10 s rests between sets and one-min rest between workouts. The exercises involved large muscle groups, with upper and lower limbs together. The main exercise session included a series of workouts such as ankle inversion and eversion, kicks, jogging, jumping jacks, cross country, pendulum movements, sidesteps, steps, crosses, leg swings and curls, leaping, twisting heel and toe movements, fog jumps, tuck jumps, scissors and jumps, jigs, and aqua bar exercises [20, 21]. During the training sessions, if there was any adverse event, such as cramps, discomfort, and hypotension, it was recommended to stop the activity immediately to receive the necessary care. The intervention was resumed only after total improvement. The control group abstained from engaging in any type of physical activity

during this period as part of the study protocol, and they were instructed and asked to maintain their usual daily routines. Table 1 shows the details of the exercise program.

2.4. Measurement

2.4.1. Anthropometry. Body mass (kg) and height (cm) were measured using a digital scale (Digital Height Rod Bariatric Scales—Detecto 6857DHR, USA) to the nearest 0.1 kg and 0.1 cm, respectively. Height, weight, and BMI were displayed on the screen simultaneously by raising the digital height rod while the person was being weighed.

2.4.2. Timed the 8 Foot Up and Go Trial. The 8 Foot Up and Go test was conducted to measure participants' agility and balance. They started in a seated position on a chair, and upon command, they had to quickly rise from the chair, cover a distance of 8 feet (2.44 m), and return to the seated position as quickly as possible [22]. The time needed for this task was measured to 1/10 s accuracy, and an intraclass correlation coefficient of 0.97 was calculated.

2.4.3. Static Balance Trial. The Sharpened Romberg Test was performed with the subject standing with one foot in front of the other, arms crossed in front of the body, and eyes closed. A stopwatch was used to time each attempt, and the trial was stopped if the subject opened their eyes, moved their feet, moved their arms, or fell over [23]. The intraclass correlation coefficient was calculated for the Sharpened Romberg Test (eyes closed, ICC = 0.99).

2.4.4. Upper Body Flexibility Trial. The "back scratch" test requires the dominant hand to be placed over the ipsilateral shoulder with the fingers extended downward and the other hand placed behind the back with the palm facing outward. A 30-cm ruler is used to measure the distance between the middle fingers of each hand, and a result of "+" or "−" is reported to an accuracy of 0.5 cm [24]. The intraclass correlation coefficient was calculated for the Back Scratch Test (right hand, ICC = 0.97 and left hand, ICC = 0.98).

2.4.5. Lower Body Flexibility Trial. The "chair sit" is a test used to measure the elasticity of the popliteal tendons. The participant sits on the edge of a chair with one leg resting on the floor and one leg extended. They then try to reach their toes with their fingers, holding the position for 2 seconds. The distance between the middle finger and the toe is measured and recorded as a positive or negative value with an accuracy of 0.5 cm [22, 25]. The intraclass correlation coefficient was calculated for the Chair Sit-and-Reach Test (right leg, ICC = 0.91 and left leg, ICC = 0.92).

2.4.6. Lower Body Strength Trial. Participants sat in a 44-cm high chair, with their feet on the floor and their hands crossed at the wrists and held to their chest. On the command of an examiner, they had 30 s to stand up and sit down as many times as possible [24]. The intraclass correlation coefficient was calculated for the Chair Stand Test (ICC = 0.83).

Table 1: Aquatic exercise program.

Warm-up (10 min)	Stretching, slow walking, and bounce
Main exercise (45 min)	- Ankle inversion and eversion - Kick (soccer, Russian, and back) - Jogging - Jumping jack - Cross country - Pendulum - Sidestep, step, and cross - Leg swing and curl - Leaping - Twist heel and toe - Fog jump and tuck jump - Scissors and jump - Jig - Aqua bar
Cool-down (5 min)	Stretching, slow walking, and bounce

2.4.7. Upper Body Strength Trial. The hand held dynamometer (HHD) is a small, reliable tool used to assess muscle strength [26]. The Jamar hand dynamometer (JHD) is a popular choice because of its reliability and ease of use [27]. It has five grip positions, with position two being the most reliable. To measure hand grip strength (HGS), the patient should be seated with the test arm at 90° and the elbow flexed. Familiarization with the JHD was offered before measuring HGS, and consideration was given to whether a subject was right or left handed when measuring. This device has been proven to have acceptable validity in adults [28]. The intraclass correlation coefficient was calculated for the hand dynamometer test (right hand, ICC = 0.98 and left hand, ICC = 0.98).

2.5. Statistical Analysis. Data are presented as mean ± standard deviation (SD). Shapiro–Wilk and Levene's F tests were used to analyze normality and homogeneity of data, respectively. Changes in variables were determined using a 2 (group: aquatic training and control) × 2 (time: pretest and post-test) repeated measure analysis of variance. If the main effect (time) was significant, the aired t-test was used to analyze differences between time points in the same group. All data were analyzed using the SPSS software (Version 27, IBM, Armonk, NY).

3. Results

Of the 45 healthy sedentary older men who started the study, five subjects (two in the control group and three in the aquatic group) dropped out due to low attendance (< 80%) at the intervention sessions (Figure 1). No adverse effects of aquatic exercise were reported during the study. Baseline characteristics of the study participants are shown in Table 2, with no significant differences between groups in demographic characteristics.

Table 2: Participants' demographic data at baseline.

Demographic data	Aquatic training ($n = 20$)	Control ($n = 20$)
Age (years)	76.54 ± 4.25	74.6 ± 4.48
Weight (kg)	67.3 ± 9.59	68 ± 12.37
Height (cm)	164.8 ± 5.57	167.70 ± 9.05
Body mass index (kg/m^2)	24.78 ± 3.13	24.15 ± 3.57

3.1. Flexibility: Upper and Lower Body. Our results revealed that the interventions utilized in the current investigation were effective in improving flexibility in both the upper and lower body ($p < 0.001$ for both sides). All changes were significantly different as compared with the control group ($p < 0.001$ for both sides) (Figures 2(a), 2(b), 2(c), and 2(d)).

3.2. Balance. Aquatic training led to an improvement in the timed up and go test, with a significant difference between groups; mean improvement in the timed up and go test was 3.0 s (Figure 3(a)). Moreover, aquatic exercise significantly affected static balance (as measured by the Sharpened Romberg test); the mean change in the Sharpened Romberg test was 55.6% in the aquatic training group and −4.0% in the controls (between groups $p < 0.001$) (Figure 3(b)).

3.3. Upper and Lower Body Strength. Upper body strength was assessed using a handgrip test for both hands. Our results reveal that aquatic training resulted in increases in upper body strength for both the right (6.6%) and left (14.4%) hands. However, the control group showed no improvement in either the right hand or left hand. In addition, the increase in strength in the aquatic group was significantly different compared with the control group for both hands ($p < 0.001$) (Figures 4(a) and 4(b)).

Lower body muscle strength was measured using the chair-stand test. Lower body strength was significantly increased in the aquatic training group compared to pretraining. Additionally, it was significantly different in the training group compared to the control group (+50% vs. −1.1%; $p < 0.001$) (Figure 4(c)).

4. Discussion

This study aimed to assess the advantages of aquatic exercise training on the functional status of elderly people. We hypothesized that those who received aquatic training would improve in all aspects of functional fitness compared to a control group that did not receive the intervention. We observed significant between-group differences in all outcome measures including flexibility (both the upper and lower body), balance variables (timed and go and Sharpened Romberg tests), and upper- and lower-body muscle strength following the intervention.

4.1. Impact of Aquatic Training on Flexibility. With aging, axial stiffness can develop and decrease flexibility and elasticity in the neck and trunk, creating a postural imbalance that reduces balance and raises the probability of falls [29–31]. The American College of Sports Medicine [21] emphasizes the importance of flexibility training during the aging process to prevent falls; however, it is usually neglected in exercise plans. Our results showed significant improvements in flexibility levels (both the upper and lower limbs) as a result of the 12 weeks of aquatic training, which is consistent with findings from previous studies [32–34]. It has been suggested that immersion in water decreases the axial load on the spine and, through the effects of buoyancy, allows the performance of movements that are normally difficult or impossible on land. Additionally, it has been observed that the physical properties of water (buoyancy, reduction of gravitational stress, viscosity, and hydrostatic pressure) may relieve muscle and joint stress in the elderly population. Regarding the rule of specificity and the relationship between flexibility and the risk of falling, evidence demonstrates that the rigidity of the pelvic muscles causes an alteration in the gait of the elderly, which increases the risk of falling [33]. In this situation, a specific program of hip flexor stretching is needed to reverse the components that heighten the risk of falls in the elderly [33, 35]. For instance, specific exercises such as pendulum movements, leg swings, kicks, and scissors and jumps, which were included in the aquatic training program of the present study, proved to be beneficial for improving hip flexor flexibility.

4.2. Impact of Aquatic Training on Balance. Studies that have assessed balance within training programs have found significant improvements following the intervention [32, 36–38]. These findings are consistent with our results, as balance scores (dynamic and static) were increased in the aquatic intervention group, with the exception of two studies [39, 40], which may be attributed to several factors, including variations in the duration and intensity of the intervention, differences in participant demographics, and potential methodological discrepancies across studies. In previous studies, the most commonly used exercise for balance training is interchangeable movements of the upper and lower body parts [32, 33, 36, 38]. However, the individual factors of the training, such as the regulation of intensity or specialized exercises, are not specified in the methodology. Balance is considered to be the most significant factor in developing fall prevention instructions [41], and thus, the accuracy of the workouts and supervision of training should mimic the outcomes documented in the investigations. Hence, certain criteria or rules that support the decisions made during the fall prevention regimens should be considered when designing procedures to enhance the ability of balance in elderly people [33, 42]. These may include cutting back the support base, shifting the center of gravity, activating the limbs, and minimizing the visual field [41, 42]. It has been suggested that due to the turbulence of the water during aquatic exercise, muscles should be constantly engaged to maintain one's balance [43]. However, the intensity of the water and the speed of the exercise should be regulated to modify muscle activation during balance exercises [44, 45]. Future studies, however, should aim to provide more detailed protocols for

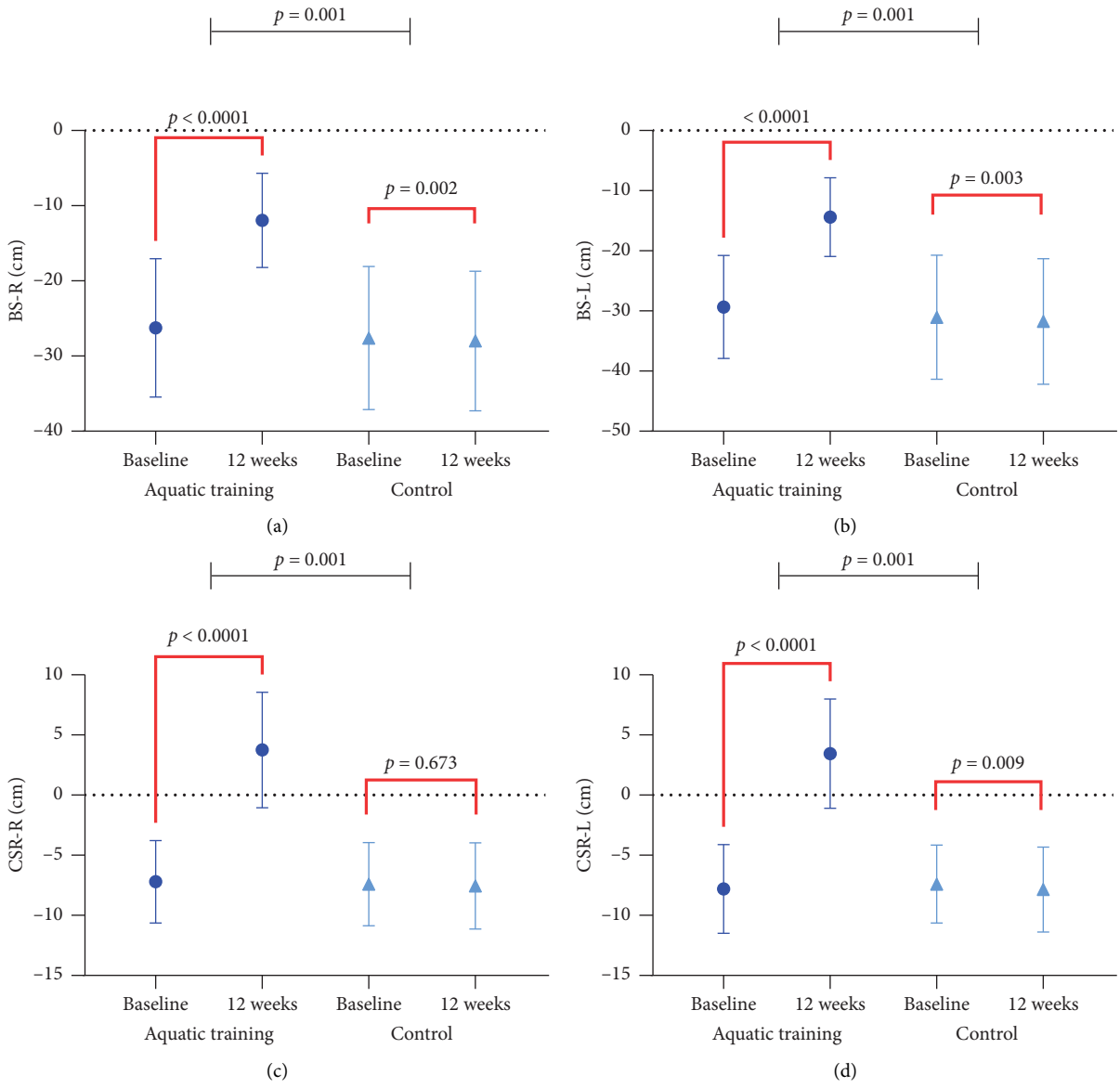

FIGURE 2: Flexibility measured before (baseline) and after (12 weeks) the end of aquatic training and control condition. (a) Back scratch test-right (BS-R). (b) Back scratch test—left (BS-L). (c) Chair sit and reach test—right (CSR-R). (d) Chair sit and reach test—left (CSR-L). Data were expressed as means ± SD.

balance training interventions, including specific guidelines for intensity regulation and supervision, thus offering practical insights crucial for designing effective fall prevention programs tailored to elderly individuals. The physical properties of water may account for the improved performance in response to the exercise program. Water turbulence can improve muscle resistance, especially when performed at increased velocity, alteration of direction, and using resistive instruments, necessitating increased effort from the motor cortex [19, 32].

4.3. Impact of Aquatic Training on Strength. In the present study, muscle strength (in both the upper and lower limb) was increased in the aquatic intervention group; these findings are consistent with those of previous studies [37, 43, 46, 47]. Although the methodologies of these protocols vary (e.g., duration of intervention, frequency of sessions, participants' demographics, and types of aquatic exercises performed), all the results indicate that an aquatic environment is beneficial for promoting muscle hypertrophy. When designing aquatic exercise programs, the main focus should be on the lower body parts, as this follows the guideline of training specificity. Weakness of the lower limbs in the elderly is considered to be a major factor contributing to falls, and preserving it enables them to remain independent. Specifically, the maximum voluntary isometric strength and the rate of force production of the hip abductors are considered useful measures for distinguishing between older adults who fall and those who do not [48].

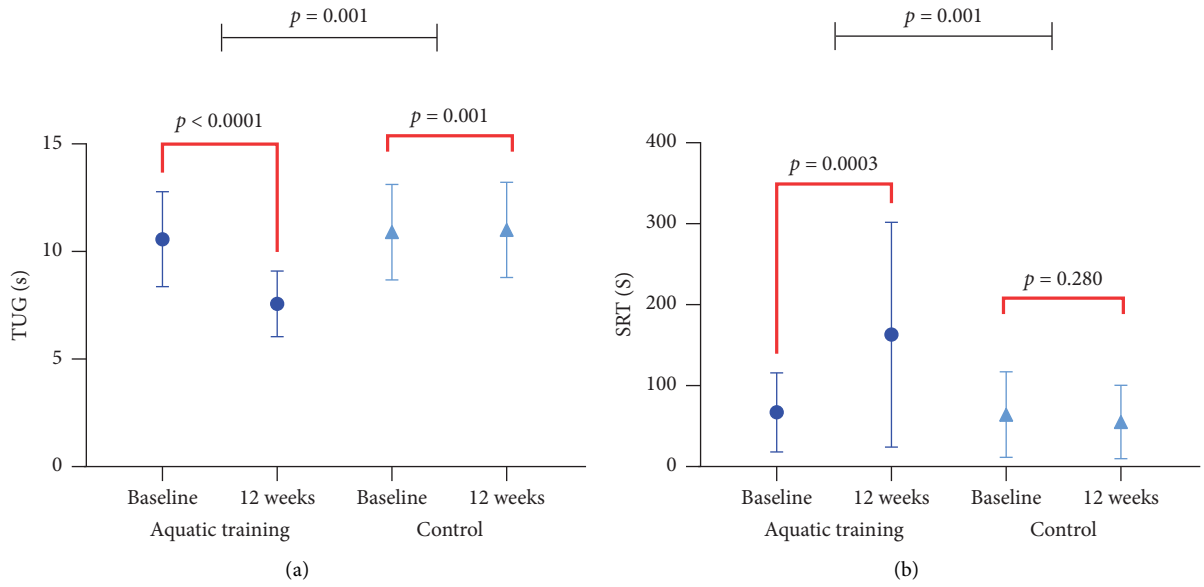

FIGURE 3: Balance measured before (baseline) and after (12 weeks) the end of aquatic training and control condition. (a) Timed up and go test (TUG). (b) Sharpened Romberg test (SRT). Data were expressed as means ± SD.

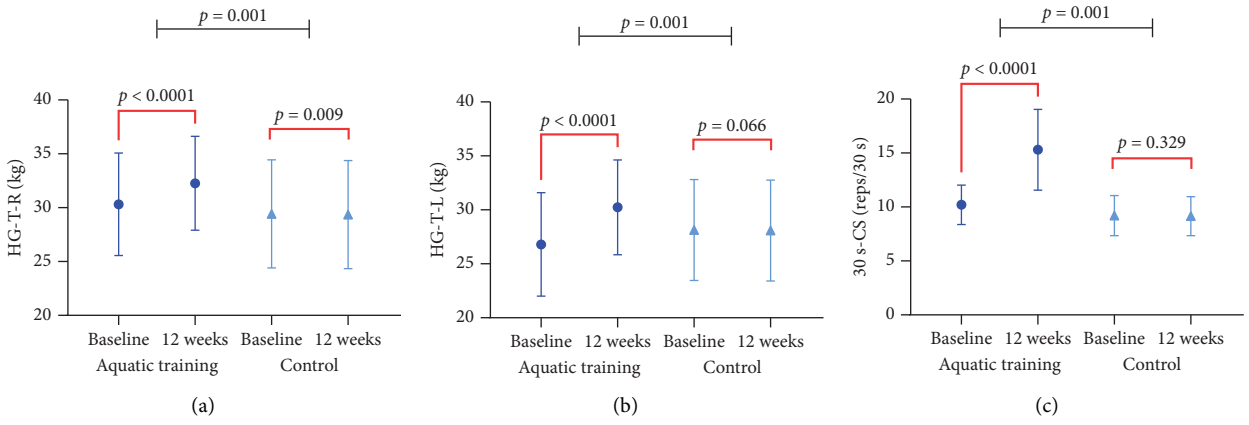

FIGURE 4: Muscle strength measured before (baseline) and after (12 weeks) the end of aquatic training and control condition. (a) Hand grip test—right (HG-T-R). (b) Hand grip test—left (HG-T-L). (c) Chair stand test (30 s-CS). Data were expressed as means ± SD.

However, several studies have used the handgrip dynamometer as a measure of strength in the elderly [37, 47]. Despite the fact that this outcome measure is related to upper limb strength, a recent research conducted by the Cooperative Health Research in the Region of Augsburg [49] on 808 people aged 65 years and older revealed a tendency toward an indirect effect of grip strength on balance problems. In addition, handgrip strength has been suggested as an indicator of the health-related quality of life in elderly people and as a means of preventing falls [50, 51]. While these data suggest a potential link between handgrip strength and overall health status, further investigation is needed to explore the correlation between handgrip strength and other physical functioning measures. Studies suggest that water exercises could be used to improve factors related to the probability of falls in elderly people. It is documented that aquatic exercise can reduce the negative physical impacts of getting older, which are factors that increase the risk of falling. Enhancing these risks is likely to make a positive difference in the rate at which falls occur, so aquatic exercise could be considered an appropriate form of training for those most prone to falling. Future studies, however, should explore how aquatic exercise impacts muscle hypertrophy, particularly focusing on its role in preserving strength to prevent falls in the elderly.

The present research had some limitations that needed to be addressed. First, the sample size was relatively small, limiting our power of analysis. Due to logistical constraints in an Islamic country, only male participants were included in the study, limiting the generalizability of the findings to a broader population including both genders. Although participants were instructed and asked to continue their usual dietary habits during the study, the inability to control their dietary patterns can be another potential limitation

influencing the outcomes and, therefore, may introduce confounding factors that could affect the reliability and validity of the results. Future studies should aim to overcome limitations by increasing the sample size for better statistical power, ensuring inclusion of both genders for broader generalizability, and implementing improved methods to control participants' dietary habits to enhance the reliability of the findings.

5. Conclusion

The study findings support the hypothesis that participation in aquatic training leads to significant improvements in various aspects of functional fitness, including static and dynamic balance, upper and lower body flexibility, as well as upper and lower body muscular strength among older adults. These improvements signify the effectiveness of aquatic training as a therapeutic approach for enhancing physical functioning in elderly populations. In general, our study underscores the efficacy of aquatic training as a valuable intervention for promoting vitality and independence in elderly men. Incorporating aquatic exercises into fitness routines can contribute to improved physical performance and overall quality of life in this health-vulnerable demographic.

Data Availability Statement

The authors claim that this manuscript describes an original research work that has not been preregistered. The data presented in this study are available on request from the corresponding author. The data are not publicly available due to compliance with privacy laws.

Conflicts of Interest

The authors declare no conflicts of interest.

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