Original Research

The Effects of a Short-Term Novel Aquatic Exercise Program on Functional Strength and Performance of Older Adults

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ABSTRACT

International Journal of Exercise Science 5(4) : 321-333, 2012. The purpose of this study was to determine the effects of a short-term novel multidimensional aquatic exercise program on functional abilities of healthy older adults. Twenty-six men and women (mean age 76.33 ± 5.55 years) were recruited and assigned to an aquatic- (n = 15) or land-based (n = 11) training group. The aquatic training group completed a multidimensional water exercise program that incorporated resistance training, functional exercise movements and rudimentary aquatic plyometric activities. The active control group participated in a supervised land-based fitness program. Each exercise intervention was conducted over an 8-week period (16 sessions of 30 - 40 minutes) with the training load progression adjusted equally between groups using the 6 - 20 Rating of Perceived Exertion Scale (RPE). Prior to and immediately following the intervention, both groups were evaluated with select components of the Senior Fitness Test. The 30-second chair stand, 30-second arm curl, and 8 foot up and go were selected as measures of strength and functional abilities. The results of an independent t-test indicated that the control and experimental groups were matched for functional abilities prior to the intervention. A 2 (group) x 2 (time) analysis of covariance (ANCOVA) with repeated measures revealed significant differences in the pre- to post-testing measures for the aquatic training program for the arm curl ($p < 0.01$) and the 8 foot up and go ($p = 0.02$). Analysis of the active control revealed no pre-post differences for any measure. Thus, a short-term aquatic exercise program with multidimensional intervention strategies will significantly enhance functional abilities in older adults when compared to a functionally matched active control group.

KEY WORDS: Water aerobics, muscular strength, functional fitness, aging

INTRODUCTION

The aging process is marked by the diminishing physiological and functional capabilities of older adults. The result of this decline in function is due to the loss in muscular strength and related impaired functional mobility (5) which often leads to falls, reduced independence, and increased healthcare costs (23). At approximately fifty years of age, muscular strength begins to decline at a rate of 12-15% per decade, with a more rapid loss after the sixty-five years of age (11, 22). The quantity of muscle tissue and the quality of the force generating capacity of the muscle are diminished with advancing age, which contribute to physical frailty and loss of independence (45). Furthermore, this reduction in the quantity of muscle of older adults is described as an age related atrophy of the muscle mass resulting in a decrease in the total cross sectional area of the muscle (4). Additionally, the factors contributing to the reduction in force generating capacity have been attributed to the following: a selective atrophy of the Type II muscle fibers which are associated with higher force generating capacities (4), a reduction of motor neurons innervating the Type II muscle fibers and reinnervation with the slower Type I muscle fibers (22), and changes in specific movement properties (25).

Exercise intervention strategies such as resistance training may be an important factor for reducing the effects of these alterations that contribute to impaired function of the aging muscle (23). Recent research indicates that sedentary older adults can anticipate a 0.18 kg decline in lean body mass per year in contrast to a 1 kg increase for older adults who engage in resistance training exercise (27). Traditional modes of resistance training have been shown to enhance functional abilities in older adults including measures of strength, agility, and dynamic balance (5), and performance measures that relate to everyday activities (6). Recently, multidimensional programs, which emphasize speed and dynamic movement patterns have been shown to increase functional ability in older adults (26, 40). It is imperative to target exercise modalities and intervention strategies to prevent disability and to optimize independence in the older population (41).

Several studies have demonstrated the benefits of water-based conditioning for a variety of populations. Increases in aerobic fitness (3, 38, 39), muscular strength (32, 38), muscular power (24, 28, 30), and functional ability/mobility (35, 42) have been observed following participation in aquatic-based exercise programs. For some older adults, the aquatic environment may be an effective alternative to traditional land-based exercise to improve parameters of functional ability while reducing the risk of injury during exercise. First, water provides a safe and low impact medium for exercise. The buoyancy of the water permits movement without the added gravitational force on the joints, and the close proximity of the fluid medium to the body allows for support and freedom of movement while negating the risk of falling (35). Specifically, water emersion to xiphisternum reduces the weight-bearing demand of the body between 50 - 70% of dry land weight (17). The combination of a supportive medium and buoyancy may offer older adults with diminished musculoskeletal abilities more security to perform activities that they are not able to perform on land. Secondly, the drag properties associated with the body movements in a water environment allow for resistance during the full range of motion. The retention of these properties preserves the mechanical mechanisms behind functional movements and strength training (28). Thirdly, the combination of buoyancy and resistance properties allow for exercise modalities in an aquatic environment that are generally too stressful on land for older populations. For example, studies of similar aquatic and land plyometric exercise programs in younger women have found that the aquatic plyometric activity provided the same performance enhancement benefits as land plyometrics (30).

Therefore, aquatic intervention exercises that utilizes a multidimensional approach to training may be an ideal environment to introduce the benefits of functional training, specifically, using higher velocity resistance training and plyometric exercises for older adults. Studies on sedentary and recreationally active younger adults have found that participating in aquatic exercise programs, which incorporate power movements (e.g., plyometric exercise), resulted in significant improvements among areas of functional mobility including muscular power, muscular strength, and velocity of movement (20, 30). In older adults functional ability along with power, strength, and velocity of movement can be measured via the 8 foot up and go and the 30-second chair rise (29, 30). However, to our knowledge, no research to date has explored the use of a short-term aquatic exercise intervention that utilize multidimensional and plyometric exercise for older adults.

Thus, the purpose of our study was to assess the effects of an 8-week multidimensional aquatic exercise program that specifically integrated high velocity functional movements and plyometric exercises on functional abilities that incorporate muscular strength, muscular power and mobility. We hypothesized that a short-term multidimensional aquatic program would result in improved functional ability and muscular performance for older adults in comparison to an active land-based control group.

METHODS

Participants

Twenty-eight recreationally active (exercise or recreational activities three times per week) men and women (ages 65 - 90) were recruited from a retirement community to participate in a prospective quasi-experimental designed study. Upon arrival to the initial informational session, subjects were randomly assigned to the traditional or water group via a random number chart. However, in a few instances, a fear of water or the insistence of the facility staff required three participants to be placed in a land-based group. Each group received a detailed explanation of the study, including the methods and procedures, completed a health history questionnaire and signed a written informed consent prior to participation in the study. The testing methods, exercise interventions, and written informed consent were approved by the Institutional Review Board of the educational institution conducting the study and were also approved by the senior administration of the participating retirement community.

Multidimensional aquatic-based exercise: Fifteen (women, n = 11, men, n = 4) healthy and recreationally active older adults (mean age, 75.6 $\pm$ 4.8 years; height, 1.6 $\pm$ 0.2 m; body mass, 69.4 $\pm$ 10.09 kg) were recruited from a retirement community through advertisements on a campus-wide TV message board and through fliers inserted into mailboxes. To be considered for inclusion in the study, the participants met the following criteria: over the age of 65, recreationally active, free from musculoskeletal, neurological, or cardiovascular disorders, not taking medications that contraindicated exercise participation, and comfortable performing exercise in chest-deep water.

Active control (land-based) exercise: Eleven (women, n = 4, men, n = 7) healthy and physically active older adults (mean age 79.6 ± 10.1 years; height, 1.7 ± 0.09 m; body mass, 77.1 ± 16.3 kg) were recruited from the fitness and recreational program at the same retirement community as the subjects in the aquatic-based exercise group. To be considered for inclusion in the control group, the participants met the following requirements: were over the age of 65, were recreationally active, were free from musculoskeletal, neurological, or cardiovascular disorders, were not taking medications that contraindicated exercise participation, and agreed to participate, log, and be under the supervision of an exercise specialist for the 8-week period. The land-based exercise program for the control group included walking (treadmill and over-ground), low impact aerobics, or square dancing and refrained from strength training activities (16). Subject selection protocol is described in figure 1.

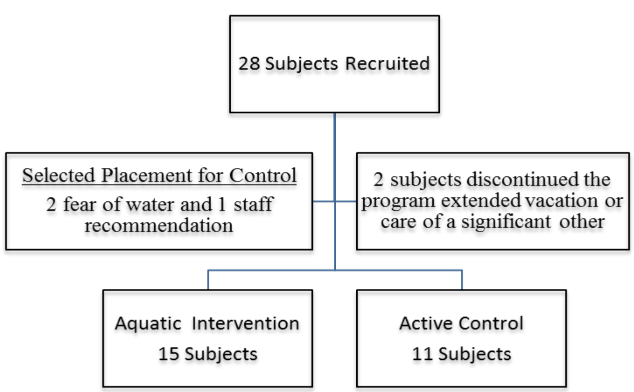

Figure 1. Subject selection.

Protocol

To establish pre-program functional fitness levels, each subject completed a series of testing procedures to measure the functional abilities of muscular strength, power and agility. The testing protocol included the 30-second chair stand, arm curl test, and 8 foot up and go as outlined and described by the Senior Fitness Test (29). The functional training group and the active control group were tested at baseline within one week prior to starting the 8-week program. Post-testing occurred within one week following the completion of the program.

Functional Testing Protocol

Chair Stand Test: A standard chair (seat height of 43.18 cm) was positioned against a wall to avoid movement of the chair during the test. The participants were instructed to sit in the chair with their buttocks positioned in the middle of the chair while keeping their back straight, feet flat on the floor and arms folded across their chest. On command, the participants were instructed to rise to a full standing position and return to the previous seated position as many times as possible in the 30-second time period. The number of successfully completed stands was recorded as the final score (29).

Arm Curl Test: A folding chair (seat height of 43.18 cm) was positioned against a wall to avoid movement during the test. The participants were instructed to sit in the middle of the seat with their body shifted close to the edge of the seat of the preferred arm to be used during the test (hand dominance was recorded to ensure that the post-test was conducted with the same arm). The test began with the weight (2.27

kg and 3.63 kg dumbbell for women and men, respectively) in the preferred hand and the arm completely extended by the side. On command, the participant performed full flexion of the elbow (curled the weight to the flexed position) and then extended the forearm back to the original position as many times as possible in the 30-second time period. The total number of completed curls was recorded (29).

8 Foot Up and Go Test: A chair (seat height 43.18 cm) was positioned against a wall to avoid movement during the test. Participants were instructed to sit in the chair with their buttocks positioned in the middle of the chair while keeping their back straight, feet flat on the floor, and hands resting on their thighs. A small cone was placed at a position of 8 feet (2.44 m) from the front edge of the chair. On the command of "go", the participant stood up, walked a path around the cone as quickly as possible and returned to the seated position in the same chair. The total time to navigate the course at one time was recorded. (A technical note: the stopwatch was started on the command of "go" and not the actual movement of the subject) (29). Each person completed three trials and the best time was used as the score for analysis.

Training Protocol

Functional/multi-directional aquatic-based training: The exercise sessions were performed in a heated pool with the water level at approximately the xiphoid process. Each exercise session was lead by an ACSM certified exercise specialist trained in aquatic exercise. The subjects attended a 45-minute exercise session twice a week for the 8-week training period. Each exercise session began with a 5 - 10 minute warm-up including water walking, passive stretching, and dynamic range of motion exercises corresponding to an intensity of 11 (Light) on the Borg Rating of Perceived Exertion Scale. The exercise and conditioning portion of the aquatic session included 30 minutes of resistance exercises, aerobic conditioning, and low-level plyometric training. To increase the functional and multi-directional component of the movements, the subjects were instructed to move the body through the full range of motion to the point of instability with or without the resistive devices (e.g., water dumbbells, noodles, inflatable balls and kickboards) depending on the exercise performed. The subjects were instructed to perform the movements at an intensity corresponding to an RPE of 13 - 15 (Somewhat Hard to Hard) (1). The use of the 6 - 20 RPE scale has been shown to be a valid and reliable tool for monitoring exercise intensity during resistance training programs (10, 37) and has been previously used in older populations (12). To obtain the desired intensity, the subjects were encouraged to increase the velocity of the resistive movements while maintaining complete range of motion. The aquatic aerobic conditioning program and the plyometric exercises were used in combination to vary the exercise routine. The aerobic conditioning program included water walking, water jogging, and other multi-directional movements. In addition, arm movements, resistive devices and directional changes were frequently used during the aerobic segment to add functional and multidimensional components. All exercises within the aerobic conditioning phase were performed

Table 1. Sample Aquatic Exercise Program.

Phase	Exercises	Time	Intensity
Warm-up/Stretching	Water walking 2 - 3 upper body stretches 6 - 8 lower body stretches	**5 - 10 minutes**	**RPE 11**
Resistance/Aerobic/Plyometric		**30 minutes**	**RPE 13 - 15**
Resistance (exercises could be performed with water dumbbells, noodles, inflatable balls and kickboards)	Chest flys Press downs Russian twist (trunk) Bench press Stork push Golf swings Hula hoops Variations: Perform on 1-leg Increase range of motion Reach past stable point	Resistance 10 min	
Aerobic Conditioning	Water walking Water running Side Steps Carioca (carry over step) Backwards running Ski machine Variations: Use arms Change directions	Aerobic 10 - 15 min	**RPE 13 - 15**
Plyometric Exercises	Skipping for height Skipping for distance 1-leg hops Bounding Jumping Jacks Vertical Jumps	Plyometric 5 - 10 min	**RPE 15**
Cool-down	Water walking Stretching Relaxation techniques	**5 - 10 minutes**	**RPE 11**

at an RPE of 13 - 15 (Somewhat Hard to Hard). To stress functional ability and power production, the low-level plyometric portion of the program involved activities such as bounding, single leg hops, varying forms of skipping, and vertical jumps. The subjects were encouraged to work at an RPE of 15 (Hard) during the plyometric phase (approximately 5 - 10 minutes of intermittent exercise). Each plyometric exercise was performed between 8 - 12 times at the prescribed RPE, and subjects were given approximately 1 - 2 minutes active recovery at an RPE of 11 (Light) within the plyometric portion of the class prior to beginning a new exercise. The subjects concluded their training session with a cool-down of walking, stretching, and relaxation techniques. Throughout the program, the subjects were encouraged to increase their self-selected intensity (to maintain the prescribed RPE) by increasing the speed and number of movements in each of the program areas of resistance training, aerobic conditioning, and plyometric drills. A sample program is outlined in table 1.

Active control (land-based) exercise: The exercise sessions for the control group were performed at the fitness facility of the retirement community under the supervision of an exercise specialist. The subjects within this group engaged in their normal fitness and recreational activities of walking, biking, running, and/or weight training at a minimum of 20 - 30 minutes per session, 3 times per week. Exercise session time of 20 - 30 minutes was matched for the actual "workout" time of the aquatic group. The exercise specialist encouraged the control group to warm-up, stretch, and cool down to achieve a total exercise time of 45 minutes, matching the exercise activity of the aquatic group. The intensity of the control group was set at an RPE of 13 - 15 (Somewhat Hard to Hard) and the subjects were encouraged to self-adjust their intensity to maintain the prescribed RPE. All activity was recorded in an activity log and reviewed by the exercise specialist.

Statistical Analysis
All data were analyzed using SPSS v.11 (SPSS Inc., Chicago, IL) statistical software package. Descriptive statistics (mean and standard deviations) were used to describe the population demographics for the subjects in the study. The pre-program functional fitness levels were compared using an independent t-test to test for initial group differences. A 2 (group) x 2 (time) analysis of covariance (ANCOVA) with repeated measures using the pre-test scores as the covariate was used for between group comparisons. Paired t-tests were used to analyze the difference between the pre-program and post-program measures. An α level was set at 0.05 a priori between groups and for the effect of time for each functional variable.

RESULTS

Functional Testing
The independent t-test revealed that there were no initial differences in pre-program

Table 2. Comparison of variables (mean ± standard deviation).

Variable	Aquatic Group			Control		
	Pre	Post	% Change	Pre	Post	% Change
Chair Stand	10.9 ± 3.7	14.1 ± 4.9**	28.8	13.6 ± 5.7	15.3 ± 6.7	12.7
Arm Curl¶	19.1 ± 5.0	23.8 ± 3.7***	24.5	22.6 ± 5.2	22.6 ± 5.6	0
8' Up and Go¶	7.0 ± 2.7	5.8 ± 1.4***	17.6	6.4 ± 2.0	6.7 ± 2.4	-4.8

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, significantly different from baseline (paired t-tests)
¶ Significant difference between groups, aquatic and control group (ANCOVA)

scores between the water-based group (n = 15) and the control group (n = 11) for any of the three testing measures. The 2 (group) x 2 (time) ANCOVA with repeated measures with the pre-score serving as the covariate revealed no significant differences for the main effect of group (aquatic- and land-based exercise) for any of the variables tested (table 2). Significant differences were found for the main effect of time (pre- to post-intervention). Interaction effects revealed that the aquatic exercise group gained statistically significant improvement for the arm curl ($p < 0.01$), and 8 foot up and go ($p < 0.01$) as compared to the land-based exercise group (table 2).

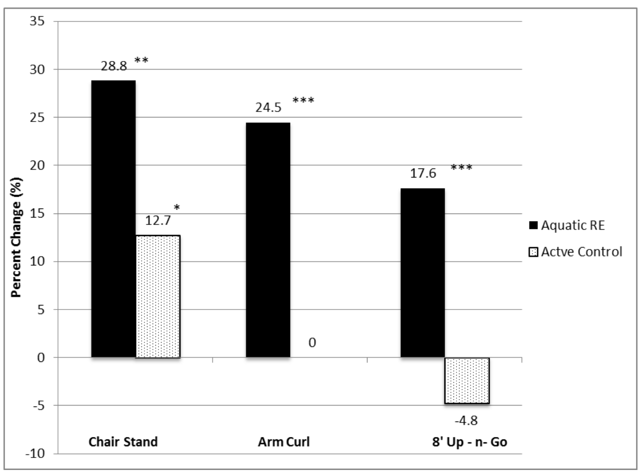

Figure 2. Percent change in performance variables from pre-test to post-test. *p < 0.05, **p < 0.01, ***p < 0.001, significantly different from baseline.

The results for the chair stand show the greatest improvement in percent change; however, the use of a pre-test covariate indicates that the group means are not significant at the alpha level of 0.05. Follow up paired t-tests for pre-post differences for the control group revealed a significant difference for only the chair stand ($p = 0.03$). Pre-post differences for the aquatic group showed significant differences for the chair stand, arm curl, and up and go ($p = 0.001$, $p = 0.000$, and $p = 0.01$, respectively). Pre- and post-test scores for the groups are expressed as percent change and are located in figure 2.

DISCUSSION

The results of this study demonstrated that an 8-week multidimensional exercise intervention performed in an aquatic environment significantly improved selective measures of muscular strength and functional ability (e.g., dynamic balance/mobility in older adults). In addition, the results of this study offer health care providers and exercise specialists insight to a novel aquatic exercise intervention designed to address the complications associated with the reduction in muscular strength and power of the aging population. Our study is unique from other comparative studies of aquatic- and land-based programs conducted to date since our short-term exercise intervention utilized a multidimensional program focused on incorporating high velocity resistance movements and plyometric exercises as a significant portion of the program to elicit functional improvements.

Previously, aquatic exercise interventions have demonstrated the benefits of water-based conditioning for a variety of populations (3, 24, 28, 30, 32, 35, 38, 39, 42). More recently, Tsourlou (41) studied a group of aquatically trained subjects over a twenty-four-week period and found similar results to those in this study for power, strength and functional mobility. In their study, the aquatically trained individuals significantly increased in all measurement variables, whereas the inactive control group failed to yield significant increases in any of the variables. In the present study, we elected to use an active control group to compare a short-term multidimensional aquatic training program to a traditional aerobic exercise program. The results from our study found similar gains in strength and functional mobility. The multidimensional aquatic group elicited significant improvement in all three assessments, whereas the traditional group only increased in the chair stand. Interestingly, the aquatic group showed significant improvement in arm curl and the timed up and go. This suggests that the multidimensional components integrated into the aquatic exercise program not only increased leg strength but also increased upperbody strength and functional ability as measured by the timed 8 foot up and go. Moreover, the ANCOVA revealed that while adjusting for baseline levels, the aquatic group increased significantly more than the active control group.

Functional or multidimensional interventions are based on the concept of specificity of training. These exercise stimuli mimic activities performed in everyday movements and are most likely associated with the individual's dynamic living environment (12). Additionally, multidimensional programs are exercise interventions that utilize multiple components of physical fitness and have been shown to increase functional abilities in older adults (26, 40). For example, a one year program incorporating traditional aerobic conditioning with specific functional training using a resistance component (stair climbing with a weighted vest) increased not only the functional ability of the female participants, but also muscle fiber area as assessed by muscle biopsy (9). The multidimensional and functional activities involved in this study utilized specific dynamic functional movements (e.g., forward/backward walking, carioca steps, changing directions, extended reaching), strength exercises (e.g., multiplanar movements against resistance of the water), and low-level plyometric exercises (e.g., bounding and hopping). In our study, the short-term multi-dimensional aquatic program incorporated activities that mimicked everyday activities. The aquatic environment up to the xiphoid process allowed for subjects to be supported by the water which in turn allowed the subjects to conduct the exercises at an increased velocity and throughout a full range of motion without the fear of falling. The 8 foot timed up and go is a measure of functional abilities and was significantly faster in the aquatic group following the intervention than the active control group.

Plyometric exercise is defined as an eccentric loading of a muscle immediately followed by a powerful concentric contraction (7). Additionally, low-level plyometric exercises can be described as a repeated series of stretch-shortening cycles that produce less stress on the body while following the same properties of traditional plyometric exercises (43). This type of exercises enhances neuromuscular adaptations to the stretch reflex, the elasticity of muscle, and enhanced proprioception. Specifically, the stretch reflex is a neuromuscular response initiated during eccentric loading (lengthening phase) of the muscle during the movement, which in turn, facilitates motor-unit recruitment during a subsequent concentric contraction. This neuromuscular response is important in studying the aging process because of the substantial changes in the neuromuscular reflex system, including weaker and slower muscle force generation, as a result of the aging process (8) and the ability to process information to activate a muscular response (36). However, physical training may enhance the human neuromuscular system when it undergoes significant and specific adaptations as a result of a particular mode and quantity of physical activity (21). Plyometric training has been reported as an exercise stimulus that reduces the time required for voluntary muscle activation, which may facilitate more rapid changes in movement direction (44). Miller et al. (24) and Robinson et al. (30) demonstrated that an aquatically based plyometric program could produce an increase in power and performance measures. Furthermore, Miller et al. determined that the aquatic plyometric program can be a viable alternative to land-based plyometric activity. The findings of this study did not demonstrate a significant difference between in chair stand scores between the aquatic and control group. Each group increased in their chair stand measures; however, the aquatic group increased 28.8% as compared to 12.7% in the active control. Further research needs to be conducted on the possible benefits of low-level plyometrics in older populations with more sensitive measures of strength and power.

The final consideration for the development of functional abilities, muscular strength, and muscular power is the intensity or effort generated during the exercise sessions. The methods of this study incorporated the use of the RPE to estimate session intensity at RPE 15 (Hard) or approximately 70% of maximal effort (37). The increased effort of the program was achieved by increasing the velocity and range of motion of the activities. The drag forces and resistive force generated through the range of motion in the aquatic environment elicit a condition in which the functional movements and plyometric exercises use repeated high velocity contractions during movement through the full range of motion. Poyhonen et al. (28) reported that when performing resistance exercise in water, the doubling of the velocity of movement will result in a quadruple increase in the drag forces of the water. It has been reported that high velocity training in older adults will increase functional outcomes and muscular power (13, 15, 18) and that high intensity training will produce greater improvements in power than traditional low velocity training (15, 33).

The results of the current study give significant insight to the adaptation of older individuals performing a multidimensional aquatic program with short-term interventional strategies specifically compared to an active control preforming a supervised exercise intervention that did not incorporate any strength training or multidimensional movements. However, limitations of the study do exist. First, the small sample size and exclusion of individuals with physical limitations may weaken generalizability of the study to a wide scope of older adults. The individuals in this population were healthy recreationally active older adults; therefore, future studies should investigate populations with impaired function, marked physical frailty, or specific chronic conditions, which could further benefit from a multidimensional aquatic program. In addition, recreationally active was defined as performing exercise or recreational activity at least three times per week. We did not measure baseline fitness levels, thus, the self-identification of recreationally active could have lead to unmatched groups. Secondly, the study relied upon purely functional measures for strength and power. Strength and power have been measured using isokinetic dynamometers (14, 19), isotonic leg press (2, 13, 18), pneumatic resistance device (15), vertical jump (22, 31), timed chair climb (18), 5-second chair rise (18), 10-second chair rise (34), and a 30-second chair rise (19). Although each measured a different aspect of strength or power, the 30-second chair rise was utilized in this study since it has been significantly correlated with strength and leg extensor average power (18, 19). Future research using other functional and/or biomechanical testing may help further define short-term gains comparable to those demonstrated in this study.

In conclusion, the production of muscular strength is important for the older population in various activities of daily living such as rising from a chair or climbing stairs. As a result, a high velocity exercise intervention such as a multidimensional aquatic program may be ideal to help develop functional abilities as well as lower body strength and power in older adults (12). Some resistance or weight bearing programs that are land-based may not be appropriate for the older population as a consequence of the stress that is placed on the bones and joints due to the impact forces generated with ground contact. Therefore, we conclude that a short-term aquatic program concentrating on functional movements creates a stimulus to improve functional abilities and is an effective mode of exercise for the older population, specifically for the acquisition of muscular strength and power associated with activities of daily living.

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REFERENCES

1. American College of Sports Medicine. ACSM’s Guidelines for Exercise Testing and Prescription (7th ed.) Baltimore, MD: Lippincott, Williams & Wilkins, 2005.

2. Bassey EJ, Fiatarone MA, O’Neill EF, Kelly M, Evans WJ, Lipsitz, LA. Leg extensor power and functional performance in very old men and women. Clin Sci 82: 321-327, 1992.

3. Benelli P, Ditroilo M, De Vito G. Physiological responses to fitness activities: A comparison between land-based and water aerobics exercise. J Strength Cond Res 18: 719-722, 2004.

4. Brooks SV, Faulkner JA. Skeletal muscle weakness in old age: Underlying mechanisms. Med Sci Sports Exerc 26: 432-439, 1994.

5. Cavani V, Mier C, Muston A, Tummers N. Effects of a 6-week resistance training program on functional fitness of older adults. J Aging Phys Act 10: 443-452, 2002.

6. Chandler JM, Duncan PW, Kochersberger G, Studenski S. Is lower extremity strength gain associated with improvement in physical

performance and disability in frail, community-dwelling elders? Arch Phys Med Rehabil 79: 24-39, 1998.

7. Chimera NJ, Swanik KA, Swanik CB, Straub SJ. Effects of plyometric training on muscle-activation strategies and performance in female athletes. J Athl Train 39: 24-31, 2004.

8. Chung SG, van Rey EM, Bai Z, Rogers MW, Roth EJ, Zhang L-Q. Aging-related neuromuscular changes characterized by tendon reflex system properties. Arch Phys Med Rehabil 86: 318-327, 2005.

9. Cress ME, Conley KE, Balding SL, Hansen-Smith F, Konczak J. Functional training: Muscle structure, function, and performance in older women. J Orthop Sports Phys Ther 24: 4-10, 1996.

10. Day ML, McGuigan MR, Brice G, Foster C. Monitoring exercise intensity during resistance training using the session RPE scale. J Strength Cond Res 18: 353-358, 2004.

11. DeVito G, Bernardi M, Forte R, Pulejo C, Macaluso A, Figura F. Determinants of maximal instantaneous muscle power in women aged 50-75 years. Eur J Appl Physiol Occup Physiol 78: 59-64, 1998.

12. de Vreede PL, Samson MM, van Meeteren NL, van der Bom JG, Duursma SA, Verhaar HJ. Functional tasks exercise versus resistance exercise to improve daily function in older women: A feasibility study. Arch Phys Med Rehabil 85:1952-1961, 2004.

13. Earles DR, Judge JO, Gunnarsson OT. Velocity training induces power-specific adaptations in highly functioning older adults. Arch Phys Med Rehabil 28: 872-878, 2001.

14. Ferri A, Scaglioni G, Pousson M, Capodaglio P, Van Hoecke J, Narici MJ. Strength and power changes of the human plantar flexors and knee extensors in response to resistance training in old age. Acta Physiol Scand 177: 69-78, 2003.

15. Fielding R, LeBrasseur NK, Cuoco A, Bean J, Mizer K, Singh F. High-velocity resistance training increases skeletal muscle peak power in elderly women. J Am Geriatr Soc 50: 655-662, 2002.

16. Hakkinen K, Kraemer WJ, Pakarinen A, Triplett-McBride JM, Hakkinen A, Alen M, McGuigan MR, Bronks R, Newton RU. Effects of heavy resistance/power training on maximal strength, muscle morphology, and hormonal response patterns in 60-75 year-old men and women. Can J Appl Physiol 27: 213-231, 2002.

17. Harrison RA, Hillman M, Bulstrode S. Loading of the lower limb when walking partially immersed: Implications for clinical practice. Physiotherapy 78: 164-166, 1992.

18. Henwood TR, Taaffe DR. Improved physical performance in older adults undertaking a short-term programme of high velocity resistance training. Gerontology 51: 108-115, 2005.

19. Hruda KV, Hicks AL, McCartney N. Training for muscle power in older adults: Effects of functional abilities. Can J Appl Physiol 28: 178-189, 2003.

20. Kalapotharakos VI, Michalopoulos M, Strimpakos N, Diamantopoulos K, Tokmakidis SP. Functional and neuromotor performance in older adults. Effects of 12 wks of aerobic exercise. Am J Phys Med Rehabil 85; 61-67, 2006.

21. Koceja DM, Davison E, Robertson CT. Neuromuscular characteristics of endurance- and power-trained athletes. Res Q 75: 23-30, 2004.

22. Macaluso A, DeVito G. Muscle strength, power and adaptations to resistance training in older people. Eur J Appl Physiol Occup Physiol 91: 450-472, 2004.

23. Marcell T. Sarcopenia: Causes, consequences, and preventions. J Gerontol A Biol Sci Med Sci 58: 911-919, 2003.

24. Miller MG, Berry DC, Bullard S, Gilders R. Comparisons of land-based and aquatic based plyometric programs during an 8-week training period. J Sport Rehabil 11: 268-283, 2002.

25. Narici MV, Reeves ND, Morse CI, Maganaris CN. Muscular adaptations to resistance exercise in the elderly. J Musculoskelet Neuronal Interact 4: 161-164, 2004.

26. Nelson ME, Layne JE, Bernstein MJ, Nuernberger A, Castaneda C, Kaliton D, Hausdorff J, Judge JO, Buchner DM, Roubenoff R, Fiataron Singh MA. The effects of multidimensional home-based exercise on functional performance in elderly people. J Gerontol A Biol Sci Med Sci 59:154-160, 2004.

27. Peterson MD, Sen A, Gordon PM. Influence of resistance exercise on lean body mass in aging adults: A meta-analysis. Med Sci Sports Exerc 42: 249-258, 2011.

28. Poyhonen T, Sipila S, Keskinen KL, Hautala A, Savolainen J, Malkia E. Effects of aquatic resistance training on neuromuscular performance in healthy women. Med Sci Sports Exerc 34: 2103-2109, 2002.

29. Rikli RE, Jones CJ. Senior Fitness Manual. Champaign, IL: Human Kinetics, 2000.

30. Robinson EL, Devor ST, Merrick MA, Buckworth J. The effects of land vs. aquatic plyometrics on power, torque, velocity, and muscle soreness in women. J Strength Cond Res 18: 84-91, 2004.

31. Runge M, Rittweger J, Russo CR, Schiessl H, Felsenberg D. Is muscle power output a key factor in age-related decline in physical performance? A comparison of muscle cross section, chair-rising test and jumping power. Clin Physiol Funct Imaging 24: 335-340, 2004.

32. Ruoti RG, Troup JT, Berger RA. The effects of non-swimming water exercises on older adults. J Orthop Sports Phys Ther 19: 140-145, 1994.

33. Sayers SP, Bean J, Cuoco A, LeBrasser NK, Jette A, Fielding RA. Changes in function and disability after resistance training: Does velocity matter? A pilot study. Am J Phys Med Rehabil 82: 605-613, 2003.

34. Shigematsu R, Okura T. A novel exercise for improving lower-extremity functional fitness in the elderly. Aging Clin Exp Res 18: 242-248, 2006.

35. Simmons V, Hansen PD. Effectiveness of water exercise on postural mobility in the well elderly: An experimental study on balance enhancement. J Gerontol A Biol Sci Med Sci 51A :M233-M238, 1996.

36. Spirduso WW. Physical development and decline. In: Physical dimensions of aging. Champaign IL: Human Kinetics, 2005.

37. Sweet TW, Foster C, McGuigan M, Brice G. Quantification of resistance training using the session rating of rating or perceived exertion method. J Strength Cond Res 18: 796-802, 2004.

38. Takeshima N, Rogers ME, Watanabe E, Brechue WF, Okada A, Yamada T, Islam MM, Hayano J. Water-based exercise improves health-related aspects of fitness in older women. Med Sci Sports Exerc 33: 544-551, 2002.

39. Taunton JE, Rhodes EC, Wolski LA, Donnely M, Warren J, Elliot J, McFarlane L, Leslie J, Mitchell J, Lauridsen B. Effect of land-based and water-based fitness programs on the cardiovascular fitness, strength and flexibility of women aged 65-75 years. Gerontology 42: 204-210, 1996.

40. Toraman F, Sahin G. Age responses to multicomponent training programme in older adults. Disabil Rehabil 26: 448-454, 2004.

41. Tsourlou T, Benik A, Dipla K, Zafeiridis A, Kellis S. The effects of a twenty-four week aquatic training program on muscular strength performance in healthy women. J Strength Cond Res 20: 811-818, 2006.

42. Watt FB, Milam S, Manske RC, Deere R. The effects of aquatic and traditional exercise programs on persons with knee osteoarthritis. J Strength Cond Res 15: 337-340, 2001.

43. Wilk KE, Voight ML, Keirns MA, Gambetta V, Andrews JR, Dillman CJ. Stretch-shortening drills for the upper extremities: Theory and clinical application. J Orthop Sports Phys Ther 17: 225-239, 1993.

44. Wilkerson GB, Colston MA, Short NI, Neal KL, Hoewisher PE, Pixley JJ. Neuromuscular Changes in Female Collegiate Athletes Resulting From a Plyometric Jump-Training Program. J Athl Train 39:17-23, 2004.

45. Yarasheski KE. Managing sarcopenia with progressive resistance exercise training. J Nutr Health Aging 5: 349-356, 2002.