Title:

Effects of Aquatic Exercise Training Using New Water-resistance Equipment on Trunk Muscles, Abdominal Circumference, and Activities of Daily Living in Elderly Women

Running title:

Effects of Aquatic Exercise in Elderly Women

Authors:

Yoshihiro Katsura¹, Shin-Ya Ueda², Takahiro Yoshikawa³, Tatsuya Usui³, Keisuke Orita³, Hiroshi Sakamoto⁴, Daisuke Sotobayashi⁵, Shigeo Fujimoto³,

Affiliation:

1. Kogakuin University, Basic General education Department, Health and Physical Education, 2665-1, Nakano-cho, Hachioji-city, Tokyo

2. National Cerebral and Cardiovascular Center Research Institute, 5-7-1, Fujishirodai, Suita-city, Osaka

3. Osaka City University, Graduate School of Medicine, 1-4-3, Asahi-machi,
Abeno-ku, Osaka-city

4. DESCENTE Co., Ltd. Health Management Institute, 1-11-3, Dogashiba, Tennoji-ku, Osaka-city

5. Morinomiya College of Medical Arts and Sciences, Department of Judo Therapy, 4-1-8, Nakamoto, Higashinari-ku, Osaka-city

E-mail:

osuocu@live.jp
Abstract

Recently, aquatic exercise has been more widely performed as it reduces the effects of weight-bearing on the lower extremities and leg joints. Moreover, decrease in trunk muscle strength is an important factor in chronic low-back pain in obese women. The purposes of this study were to evaluate the effects of aquatic exercise training using new water-resistance equipment on abdominal circumference measurements, trunk muscles strength, and ADL (Activity of Daily Living) in older women. Subjects were divided into a resistance training group (those using the equipment) and a non-resistance training group (those without the equipment). The aquatic exercise training mostly consisted of abdominal muscle activity. All subjects underwent physical testing. In the resistance training group, abdominal circumference, abdominal muscle strength, and ADL measurement were significantly improved. Additionally, a low negative correlation was found between the degree of change in abdominal circumference and ADL scores. As it became easier to maintain posture, stand, and move, activities in everyday life improved with the increase in strength of the lower extremities and trunk muscles. These results demonstrated improvements in abdominal and back muscle endurance and suggested that, as abdominal circumference decreased, ADL improved. This aquatic exercise training using the new water-resistance equipment may be used by
the elderly to improve abdominal and back muscle endurance.

**Key words**

aquatic exercise, water resistance, trunk muscle, abdominal circumference, lower extremities
1. Introduction

Aging leads to a loss of muscle strength, bringing weakness of the lower extremities, decline of balance function, and decreased quality of life (QOL) (Baumgartner, et al., 1999; Greenlund and Nair, 2003; Sayer, et al., 2006, Landers, et al., 2001; Wolfson, et al., 1995). Additionally, middle-aged women gradually gain visceral abdominal fat with age (Lovejoy, et al., 2008). 18-26% of women in the 40-49 years age bracket in Japan are obese (National Health and Nutrition Examination Survey, Health, Labour and Welfare Ministry, 2007). Therefore, it is thought that the risk for and number of cases of Metabolic Syndrome (MS) increase in women after reaching middle age (Felson, 1992; Felson, et al., 1992; Masuko, et al., 2009).

Recently, aquatic exercises using the characteristics of water viscosity, buoyancy, and water resistance are commonly performed by middle-aged and older persons. Previous studies reported that weight-bearing force on the skeletal joints during exercise is reduced by buoyancy (Konlian, 1999) and walking in water is often easier and safer for the elderly with osteoarthritis of the knee (Felson, 1992; Felson, et al., 1992; Lane and Thompson, 1997; Masuko, et al., 2009; Ruoti, et al., 1994; Takeshima, et al., 2002).

In fact, it has been reported that the strength of lower extremity, trunk muscle and dynamic balance function for prevention of accidental falls were improved by using
water-resistance-equipment (Colad, et al., 2009; Katsura, et al., 2010). As previously noted, many studies of aquatic exercise have reported its effects on muscle strength and balance function in elderly women. However, the influence of aquatic exercise for the reinforcement of trunk muscles and the decrease in abdominal circumference, which is an index of MS), were unknown. The main functions of the trunk muscles are to maintain posture and to reduce the stress on the lower back. It has been reported that a decrease in trunk muscle strength induces chronic low-back pain in middle-aged and older women (Bayramoğlu, et al., 2001). Therefore, it is important for elderly abdominally obese individuals to reinforce the trunk muscle in order to improve the strength of their lower extremities, and improve balance function. Since it has been reported that perimenopausal women exhibit increases in visceral abdominal fat (Lovejoy, et al., 2008), it is important for them to do aqua-exercise training aimed at decreasing abdominal circumference. For this purpose, we have produced a new form of water-resistance equipment. With the use of two water sacks, this equipment changes water resistance in proportion to walking speed.

The purposes of the present study were to evaluate the effects of aquatic exercise training using this new water-resistance equipment on the trunk muscles, abdominal circumference, and ADL in middle-aged to elderly women.
2. Methods

2.1. Subjects

Thirty-seven healthy middle-aged to elderly women individuals who did not exercise regularly were recruited in this protocol. Although thirteen subjects had been receiving treatment for diabetic (n=6), hypertension (n=8) and, hyperlipidemia (n=4), they experienced no difficulties participation in the program. Thus, during the training period, they did not change administration of these medications. Three subjects were excluded due to trouble at home and poor physical condition (n=3). Finally thirty-four middle-aged to elderly women 32-72 years of age (57.7 ± 8.4 years) were chosen for this study. We randomly assigned them to two groups a resistance training group of twenty-two subjects (age 56.8 ± 8.9 years, body mass 62.1±9.3 kg, %fat 35.0±6.1 %, body mass index (BMI) 25.1± 3.5 kg/m$^2$) who exercised in water using the equipment, and a non-resistance group of twelve subjects (age 59.4 ± 7.7 years, body mass 60.4±8.6 kg, %fat 34.7±8.0%, BMI 24.9 ± 4.5 kg/m$^2$) who exercised in water without the equipment (Table 1). All subjects provided written informed consent for participation in the study, which was approved by the Ethics Committee of Osaka City University Medical School (Admitting No. 1193).
2.2. New water-resistance equipment

The newly made water-resistance equipment in this study (DESCENTE Co., Ltd., Japan) consists of two water sacks connected by a strap, worn around the abdomen (Fig 1). Upon walking forward, these sacks “catch” the water, so that water resistance increases. We measured water resistance in kgw. We pulled a column form bucket resembling the trunk of a human body both with and without new water-resistance equipment attached. With the equipment attached, water resistance dramatically increased with increase in gait speed (0.8 kgw at 30 m/min, 2.1 kgw at 60 m/min, 3.7 kgw at 90 m/min). Without the equipment however, the change in water resistance was small (0.4 kgw at 30 m/min, 0.75 kgw at 60 m/min, 1.57 kgw at 90 m/min) (Fig 2). One of the characteristics of this equipment is the enhancement of water resistance in proportion to an increase in walking speed. Thus, the faster one walks in water, the greater the water resistance becomes.

2.3. Aquatic exercise training

The aquatic exercise training for both resistance training and non-resistance training groups were performed three times per week for 8 weeks, in the swimming pools of several fitness clubs in Kyoto and Osaka City. The water temperature was 30-32℃.
Aquatic exercise were led by one trained fitness instructor and supervised by researchers. The training protocol consisted of 60min with 10min warm-up exercises and flexibility; 45min main endurance; and strength exercises, and a 5min cool-down. The main exercise consisted of walking to forward, sideways, backwards, shuffling, walking with long strides, and heel gait. In addition, subjects performed knee up, leg curl, and knee extensions while jogging. In the present study, aquatic exercise training included abdominal extension, flexion and twisting training such as twisting knee ups, toe touches, holding one knee and jumping with the other leg, kicking to the front, kicking twists, and abdominal twists. Moreover, they performed both leg abduction and adduction muscle exercise. During the 45min main exercise period, they performed walking based movements for the first 10 minutes. The remaining 35 minutes consisted of more walking with trunk muscle exercises every 10 min. The intensity of the aquatic exercise was 60~70 % of HRmax, and we instructed subjects to adapt to a “somewhat hard” RPE level (Masumoto, K, et al., 2009). Body condition, body temperature, and blood pressure at rest were recorded before exercise each day.

3. Measurements

All subjects underwent anthropometric measurements (height, body mass), physical
performance tests, and a determination of arteriosclerotic parameters before and after the training period, measured by the same examiner. Percentage of body fat and BMI were determined using a bioelectrical impedance analyzer (BIA) (In body 3.0, Biospace Japan Inc., Japan).

Physical performance testing consisted of grip strength, knee extension force, sit and reach, one-leg standing with open eyes, center of gravity movement, timed up and go test (TUG), 10m obstacle walking time, shuttle stamina walk test (SSTw), and measurement of instantaneous and endurance forces of abdominal muscles and endurance force of back muscles. In addition to these, we measured arteriosclerotic parameters including brachial-ankle pulse wave velocity (baPWV), ankle brachial index (ABI), central blood pressure, and augmentation index (AI). Grip strength was measured twice on each side, and the average out of maximum value of each hand was recorded. Leg extension force was measured as isometric maximal strength using a leg-dynamometer (T.K.K 5710m, Takei Instruments., Japan), in a sitting position with the knee flexed at about 110 to 130 degrees. Extension force in both legs was measured twice, and the average of the maximum values for each leg was recorded. The sit-and-reach test was performed using a digital sit and reach meter (T.K.K 5112, Takei Instruments., Japan). With a slight modification to the starting position, the subject
began the test with the back flat against the wall, and then reached forward from that position. Sit-and-reach was recorded as the longest distance.

Test of standing on one leg were performed for 120 seconds. Subjects chose whichever foot which was easier to stand on, and placed both hands upon their waist. Center of gravity movement was calculated using a stabilometer (Gravicorder GS-11, ANIMA Co., Ltd., Japan), giving the stability index and postural sway during a static stance with both feet under eyes-open and eyes-closed conditions. In eyes-open condition, subjects looked at a marker 2m in front of them. Center of balance was defined as the point on the foot at which the body mass was equally distributed between the medial-lateral and anterior-posterior quadrants and was recorded in centimeters. Stability index was defined as the mean deviation in sway around the center of balance. Postural sway was expressed as the maximum sway distance recorded (cm) in the medial-lateral and anterior-posterior directions.

A test of TUG, evaluating balance function, was performed to measure the time required for the subject to stand up from a chair, walk a distance of 3m, walk back to the chair, and sit down. This simple test provides a comprehensive evaluation of the subject’s balance, gait, speed, and functional ability in seconds. The subjects were supported to prevent falling when standing up from the chair.
The 10m obstacle walking time was measured as the fastest time in seconds to walk over 6 obstacles (20cm-high) placed at distances of 2m from each other.

SSTw was measured as the total walking distance when subjects shuttle by maximum gait speed between 10m apart.

Furthermore, instantaneous and endurance forces of abdominal muscles and endurance of the back muscles were measured based on a Kraus-Weber Test (Sanya and Olajitan, 1999).

For the instantaneous of abdominal muscles test; subject clasps their hands behind the head at supine position. The examiner immobilizes the subject’s feet. The subject is asked to sit up. We performed the test using a 5-point scale (sitting up without support: 5 points, sitting up with support, 4 points, lumbar vertebrae not touching the floor, 3 points, the scapula not touching the floor, 2 points, the cervical vertebrae not touching the floor, 1 point).

In the endurance of abdominal muscles test (1); examiner holds the legs with extended. The subject holds the posture of lifting head, shoulders, and chest off the floor for 60 seconds. The endurance of abdominal muscles test (2) that subject maintain the same position as in abdominal muscles endurance test (1), but with the legs flexed.

In back muscles endurance test, the subject is prone with a cushion beneath the
abdomen and hands clasped behind the head. The examiner immobilizes the subject’s feet against the examining table. The subject is asked to raise her body off the examining table and to maintain that position for 60 seconds.

baPWV was measured using a volume-plethysmographic apparatus (Form PWV/ABI; OMRON-COLIN Co., Ltd, Kyoto, Japan). baPWV was calculated from the time interval between the wave fronts of the brachial and ankle waveforms and the path length from the brachium to ankle. Details of the methodology have been described elsewhere(Zhang, Y. And Li, JP., 2011). Measurements were taken with subjects lying in a supine position after resting. Cuffs were wrapped around the bilateral brachia and ankles.

Central blood pressure and AI were measured using a device for the measurement of central blood pressure (HEM-9000AI; OMRON-COLIN Co., Ltd, Kyoto, Japan). Measurements were taken with subjects in sitting position after resting.

Furthermore, we evaluated Activities of daily living (ADL) and subjective symptoms using the POMS.

The ADL was made based on new fitness test implementation guidelines established by the Ministry of Education, Culture, Sports, Science, and Technology. We evaluated subjects on a four point scale for each of the 14 questions, such as ”Time able to walk
without rest” ; “The width of the ditch one is able to step over” ; ” method to climb stairs” , and calculated the total points.

The POMS questionnaire contained 65 items regarding moods. Scores (on a five-point scale of 0-4) are grouped into six subscales: Tension-Anxiety (T-A), Depression-Dejection (D), Anger-Hostility (A-H), Vigor (V), Fatigue (F), and Confusion (C). Subscale scores were converted to T-scores for statistical analysis, and overall mood disturbance was also calculated.

For the subjective questionnaire, we investigated whether each subject improved in the questions of lower extremity muscle strength, stair climbing, walking, jogging, balance function; and fear of falling after aquatic exercise training.

Blood samples were taken (BML, Osaka, Japan) for measurement of glucose, triglyceride, high-density lipoprotein cholesterol (HDL-cho) levels. All samples were drawn from the median cubital vein after a 12 hour overnight fast.

3.1. Statistical analyses

All statistical analyses were performed using SPSS for Windows (SPSS Inc., Chicago, IL, USA). All data were normally distributed, and presented as mean ± S.D. The significance of differences in physical characteristics and POMS scores between groups
was determined by two-way ANOVA with repeated. Correlations between abdominal circumference and variation of physical performance were examined by determination of Spearman’s correlation coefficients. Differences at $p < 0.05$ were considered significant for all statistical analyses.

4. Results

The mean percentage attendance of aquatic exercise training sessions was 81.2±14.7%. All subjects continued this aquatic training through the full length of the study without impairments, injuries, or other problematic conditions. Table 1 shows the changes in physical characteristics, arteriosclerotic parameters, fitness parameters, POMS, ADL scores, and biochemical parameters in both groups.

In both groups, parameters of leg extension force, back muscle endurance, TUG, and SSTw were significantly improved by aquatic exercise training.

Additionally, in the resistance training group, percent of body fat (35.0±6.1 % → 34.3±6.2 %. $p < 0.01$); abdominal circumference (93.3±10.8 cm → 92.4±10.8 cm, $p < 0.05$); systolic blood pressure (137.3±16.0 mm/Hg → 132.3±14.6 mm/Hg, $p < 0.05$); central blood pressure (150.1±21.8 mm/Hg → 139.2±15.7 mm/Hg, $p < 0.01$); abdominal muscle endurance (2) (11.8±17.5 sec → 18.6±20.5 sec, $p < 0.05$); sit and
reach (36.5±9.7 cm → 39.4±8.7 cm, p<0.05); 10m obstacle waking (7.8±1.2 sec → 7.2±1.1 sec, p<0.01); POMS score of T-A (48.2±10.1 points → 44.1±5.6 points, p<0.05); F (45.7±9.1 points → 42.2±5.7 points, p<0.05); and ADL (33.3±6.1 points → 35.6±5.2 points, p<0.01) were all significantly improved by aquatic exercise training.

In the non-resistance group, diastolic blood pressure (82.5±13.4 mm/Hg → 74.6±8.9 mm/Hg, p<0.01); and POMS score of D (51.3±9.5 points → 48.3±7.8 points, p<0.05) were significantly improved.

Furthermore, in the resistance training group, the rate of improvement of abdominal circumference was significantly correlated with that of improvement of ADL score (Fig 3). However, in the non-resistance group, no correlation was observed between these parameters.

On the subjective questionnaire, subjects felt a decrease of strain in the knee and lower back (77.3 %), and found it easier to walk and jog (72.7 %), and climb stairs (63.6 %). The rate of improvement in each item of the subjective questionnaire tended to be higher in the resistance group than in the non-resistance group.

The biochemical parameters were analyzed for eighteen subjects in the resistance training group and eight subjects in the non-resistance group in this study. In the resistance training group, HDL-cho was significantly improved, while in the
non-resistance group glucose level were significantly improved by aquatic exercise training.

5. Discussion

At local fitness swimming clubs, the results of two months of aquatic exercise confirmed significant improvements in leg extension force, back muscle endurance, TUG, and SSTw in both the resistance training and non-resistance groups. Abdominal circumference, abdominal muscle (trunk muscle) instantaneous force and endurance, and ADL score were improved significantly in the resistance group.

In this study, aquatic exercise training using water-resistance equipment focused mostly on walking with large strides, walking on toes, and walking on heels, as on well as bending, extending, and twisting of the abdominal and back muscles. When exercising in the water, water resistance increases severely in relation to the speed of trunk movement (Ferrell, 1998). Results of a preliminary study using this water-resistance equipment showed that water resistance become greater in proportion to the increase in speed of movement. Compared to the non-resistance group, the subjects in the resistance group exercised with more water resistance at the same speed. Therefore, while exercising in the water using the water-resistance equipment, trunk
muscles exerted large muscle forces over a short period of time, and because the subjects actively bent, extended, and twisted their trunk by walking on toes, jumping with legs closed, kicking, and twisting, abdominal muscle instantaneous force increased. Using the buoyancy and viscosity of the water while exercising, subjects tightened the trunk muscles and maintained various body postures while recovering from unstable postures.

The resistance training group thus frequently bent and extended the trunk muscles. Furthermore, they maintained body postures that contracted the trunk muscles when meeting increased water resistance due to the use of water-resistance equipment. Subsequently, active movements of the abdominal, back, and lateral deep muscles improved abdominal and back muscle endurance.

In addition, abdominal circumference measurements in the resistance training group significantly decreased. An earlier study reported that fat synthesis and breakdown were more active in visceral fat compared to subcutaneous fat, so that visceral fat was reduced by aerobic exercise (Shimomura, et al., 1993). The exercise protocol in the present study was designed to increase the endurance force of abdominal and back muscles, which are trunk muscles. As water resistance increased against trunk muscles during exercise, especially in the resistance training group, abdominal muscle endurance
increased, and muscle mass and basic metabolism increased to burn abdominal visceral fat, decreasing the abdominal circumference (Kuk, et al., 2009). Also, bending forward in the long sitting posture, 10m obstacle walking, flexibility, and gait performance significantly improved in the resistance training group compared to the non-resistance group. These data findings suggest that improvements in these parameters led to increase in the range of activities of daily living and the duration of exercise, ultimately decreasing abdominal circumference.

An improvement in ADL scores following a decrease in abdominal circumference was also observed. Earlier studies reported that there was an improvement in ADL as lower extremity and trunk muscle strength were augmented by aquatic exercise training (Colado, et al., 2009). Katsura et al (2010) reported that lower extremity strength increased as a result of performing aquatic exercise training using water resistance equipment, and that the improvement in dynamic balance function was linked to alleviating fatigue in everyday life.

In this intervention, augmentation of strength of lower extremity (Fujita, et al., 2006; Hasegawa, et al., 2008) and strength of trunk muscle contribute towards the improvement of ADL in the same way as reported by the earlier studies, as well as an elevation in dynamic balance function was observed when aquatic exercise training was
performed while keeping in mind the activities of the lower extremities and trunk muscles. Further, we thought that because many more muscles were used during exercise in this study as compared to earlier studies, the body fat percentage decreased with an improvement in SSTw, which is an index of general body stamina, indicating that it is linked to a decrease in abdominal circumference.

A subjective survey showed that 70-90% of the subjects in the resistance training group experienced “less stress on the knees and lower back”, and that it was “easier to climb up and down stairs” and “easier to walk and jog”. In other words, ADL improved because of the improvements in subjective symptoms due to greater lower extremity and trunk muscleshp strength.

The study did not show improved peripheral blood test results or arteriosclerotic parameters. With regard to peripheral blood test results, Reinhart, et al. reported that the reason why patients with chronic heart failure are unable to improve their blood rheology by exercise training is not clear (Reinhart, et al., 1998). As far as arteriosclerotic parameters are concerned, many studies have found that long-term exercise intervention improves pulse wave velocity (Miura, et al., 2008; Okamoto, et al., 2009), but the present intervention lasted only eight weeks, and no improvements in arteriosclerotic parameters were observed. Therefore, in the future, we plan to
administer an exercise and diet intervention program and follow subjects for a longer period of time.

In terms of exercise safety, none of the subjects in either group quit during the training period, and in the resistance training group none of the subjects experienced injury due to use of the water-resistance equipment. While exercising in the water, buoyancy and viscosity reduce stress on load-bearing joints such as the knee, and none of the subjects had exercise-induced orthopedic injuries involving the muscles or joints. The target heart rate of the present water exercise program was 60-70% of the maximum, and was subjectively assessed as “slightly intense”. However, because water resistance changes depending on the speed of exercise, the risk of overloading is low even when increasing the intensity of exercise. The water resistance of the exercise equipment increased proportional to the speed, but quickly decreased with slowing down, preventing overloading. On the other hand, strength training on land can lead to muscle injuries when too much stress is applied at once (Levy, et al., 2001; Roth, et al., 2000). It has been reported that the incidence of injury in competitive swimmers is lower compared to athletes performing aerobic exercises on land (Pantoja, et al., 2009), supporting the notion that water exercise is safer than exercise on land. The present aquatic exercise training using water-resistance equipment was safe for middle-aged to elderly women.
6. Conclusions

Middle-aged to elderly women undertook the aquatic exercise training program wearing water-resistance equipment around their waists. Results showed improvements in abdominal and back muscle endurance and suggested that, as abdominal circumference decreased, ADL improved.


References


daily living and motor function in the community-dwelling elderly after hip fracture.

Nippon Ronen Igakkai Zasshi, 43: 241-245.


Name:

Yoshihiro Katsura

Affiliation:

Kogakuin University, Basic General education Department, Health and Physical Education

Address:

2665-1, Nakano-cyo, Hachioji-city, Tokyo

Brief Biographical History:

2005-2007 Master's program, Department of Physical Education, Osaka Sangyo University Graduate School of Education

2007-2011 Doctoral Program, Department of Sports Medicine, Osaka City University Graduate School of Medicine

2011-

Kogakuin University, Basic General education Department, Health and Physical Education
Education

Main Works:


Membership in Learned Societies:

Japanese Society of Physical Fitness and Sports Medicine

Japan Society of Exercise and Sports Physiology

Japanese Society of Clinical Sports Medicine

Japan Society of Exercise Therapy
TITLES OF TABLES

Table 1
Changes in physical characteristics, arteriosclerosis parameters, fitness tests, biochemical examinations, POMS, and ADL score by aquatic exercise training in the resistance training and non-resistance training groups.

TITLES OF FIGURES

Figure 1
The new water-resistance equipment using two water sacks.

Figure 2
Changes in water resistance with (●) and without (○) the water-resistance equipment as related to increase in speed of movement.

Figure 3
Relationship between changes in abdominal circumference and changes in ADL by aquatic exercise training using the new water-resistance equipment.
Subjects wear water-resistance equipment strapped around the waist.
\[ \Delta \text{ADL} \]

\[ r = -0.513 \]

\[ p < 0.05 \]

\( n = 22 \)

\( \Delta \text{Abdominal circumference} \)
HDL cholesterol: pre 63.5±18.6 post 67.8±18.7 63.7±14.3 67.8±13.9
Triglyceride: pre 88.6±42.2 post 83.5±37.9 119.2±58.1 84.9±64.8
Glucose: pre 93.2±10.7 post 92.2±10.5 96.2±9.9 90.9±8.3

Results are expresses as mean ± S.D. Between resistance and non-resistance group. *p<0.05. **p<0.01