ORIGINAL RESEARCH

Medicina Sportiva
Med Sport 13 (1): 5-12, 2009
DOI: 10.2478/v10036-009-0002-9

CIRCUIT BASED DEEP WATER RUNNING IMPROVES CARDIOVASCULAR FITNESS, STRENGTH AND ABDOMINAL OBESITY IN OLDER, OVERWEIGHT WOMEN

AQUATIC EXERCISE INTERVENTION IN OLDER ADULTS

Kimberley Meredith-Jones[1 (A,B,C,D,E,F)], Michael Legge[2 (A,E,G)], Lynnette M. Jones[1(A,E,G)]

[1] School of Physical Education, University of Otago, Dunedin, New Zealand
[2] Departments of Biochemistry and Pathology, Dunedin, New Zealand

Abstract

Introduction: Sedentary habits are associated with an increased risk of numerous chronic diseases; however, the type of exercise that may be most beneficial to improve health is still unclear. Water based exercise is rapidly growing in popularity as individuals, such as the elderly or the obese, can exercise at relatively high levels of intensity while imposing minimal strain on joints. However, little research has been conducted substantiating the health benefits of exercise in this medium.

Aim of the study: The purpose of this study was to evaluate the effects of a circuit based deep water running exercise program on aerobic capacity ($\dot{V}O_2$peak), strength and abdominal obesity in older, overweight/obese women

Materials and Methods: The participants (mean ± SD age 59 ± 9 years, BMI 33 ± 5 kg/m^2, n=18) took part in a circuit based deep water running program with continuous deep water running (70-75% HR_{peak}) interspersed with 90 seconds of resistance exercises for 12 weeks, 60 min.day^{-1}and 3 days.week^{-1}.

Results: There were significant increases (p<.05) in $\dot{V}O_2$peak (1.37 ± 0.10 vs 1.51 ± 0.08 L·min^{-1}), and muscle strength (upper body 20 ± 7.1%, knee flexion 33 ± 7.9%, knee extension 32 ± 17.9%). There were significant reductions (p<.05) in waist circumference (105 ± 2.5 vs 100 ± 2.6 cm) and waist-hip ratio (0.90 ± 0.01 vs 0.87 ± 0.01).

Conclusions: These results indicate circuit based deep water running can elicit significant improvements in cardiorespiratory fitness, strength and abdominal obesity.

Keywords: *cardiovascular disease, aquatic exercise, obesity*

Introduction

Advancing age is generally accompanied by a progressive decline in physical activity, with physical inactivity associated with a higher risk for metabolic diseases such as cardiovascular disease and Type 2 diabetes. In addition, aging and physical inactivity may contribute to increased abdominal obesity, thereby increasing risk for cardiovascular disease, and to the loss of muscle strength (1,2). Although it is accepted that sedentary habits are associated with an increased risk of numerous chronic diseases, there is continued debate as to the optimal volume, frequency, intensity, duration and mode of physical activity required to reduce disease risk. Recent data suggest physical activity of moderate intensity that elicits an energy expenditure of approximately 1000 kcal/week (4200 kJ/week) as desirable, however, the type of exercise that may be most beneficial to improve health is still unclear (3). Evidence shows that cardiorespiratory capacity in older adults can be enhanced through aerobic modalities such as walking, cycling, and swimming; although these activities have an inconsistent effect on muscle strength (4,5). Thus, the addition of resistance exercise may be particularly important in older women; in whom muscle strength is usually poor (6). The therapeutic role of exercise in the prevention, treatment and control of cardiovascular and metabolic disease may involve multiple pathways; training programs that combine the two modalities may be most advantageous (2,4,7,8).

Water based exercise is rapidly growing in popularity as individuals, such as the elderly or the obese, can exercise at relatively high levels of intensity while imposing minimal strain on joints. However, little research has been conducted substantiating the health benefits of exercise in this medium. Studies that have assessed the affect of shallow water exercise have shown improvements in metabolic and cardiorespiratory fitness in young and older adults (9-11). Shallow water-based exercise is an effective medium for improving aerobic fitness, body composition and lipid profiles in coronary artery disease patients, physical functioning in community dwelling elderly, abdominal obesity in obese women and upper and lower body strength in healthy women (12-16). However, although minimal, impact forces are still apparent during shallow water exercise therefore, deep water may be the preferred exercise medium for obese or older individuals. Deep-water running provides sufficient load to develop cardiorespiratory fitness in young and middle-aged adults and stroke patients, and high intensity deep water running appears to be an effective exercise modality to increase aerobic power in the elderly (17-19). There is a paucity of data on the effects of deep-water training in older, overweight/obese individuals and, to our knowledge, there have been no attempts to study the effects of adding a resistance component to a deep water running program. Therefore, the purpose of this study was to evaluate whether a 12-week circuit type water based training (water-based resistance training and deep water running) program would improve abdominal obesity, strength and aerobic fitness in older, overweight women.

Materials and Methods

Participants: Sedentary overweight women were recruited through advertisements placed in the local area, including the community aquatic centre. Participants were included in the study if they were overweight (BMI 25kg/m^2 to 29.9 kg/m^2) or obese (BMI >30 kg/m^2) which was determined using the World Health Organization (WHO) definition (20). All included participants were sedentary which was defined as regularly participating in one bout of exercise or less per week. Exclusion criteria included use of hormone replacement therapy and any known medical condition that would prevent participation in an exercise intervention. Twenty-four respondents underwent telephone screening for compliance with inclusion and exclusion criteria, which resulted in twenty-one eligible individuals. Before pre-tests were conducted two individuals withdrew due to personal commitments and illness, while one participant withdrew one week following commencement of the study due to recurrent illness. Thus, eighteen individuals completed the study (Figure 1). Prior to acceptance into the study all participants were

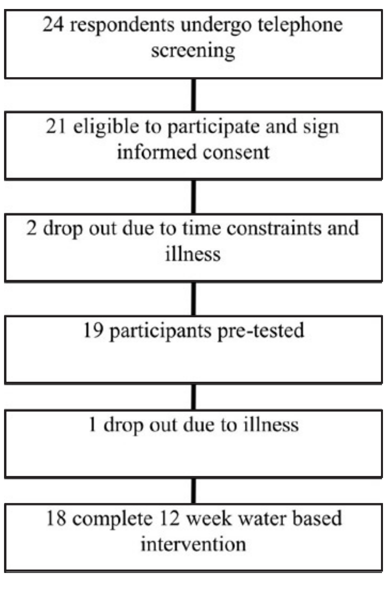

Fig. 1. *Participant flow diagram*

medically screened using a modified PAR-Q (21). Ten of the eighteen participants were taking a minimum of one medication or a combination of prescription medications. Four participants were taking β-blockers; three were taking angiotensin-converting enzyme (ACE) inhibitors; three were taking lipid-lowering therapy; three were taking a diuretic; three were taking thyroxin; two were taking an alpha-1 adrenoreceptor inhibitor; three were taking an oral hypoglycemic (metformin, 2; nateglinide, 1; insulin, 1); and two participants were taking antidepressants. Participants who were medicated were tested and underwent training while taking their usual prescriptions without any alteration in dose or type of medication for the duration of the study. Sixteen participants were postmenopausal and two participants were premenopausal. Postmenopausal status was defined as absence of menses for at least one year prior to testing. Both premenopausal participants were tested in the follicular phase of their menstrual cycle before and after the intervention to control for any possible affect of menstrual phase on performance (22). Written informed consent was obtained prior to participation in the study, which was conducted according to the ethical guidelines of the University Human Ethics Committee.

Peak Oxygen Consumption: Peak oxygen consumption ($\dot{V}O_2$peak) was measured in the swimming flume at the School of Physical Education, University of Otago. As heart rate and oxygen uptake kinetics are affected by water temperature, the flume was maintained at a thermoneutral level of 29^{o}C and the depth constant at 1.80 metres. All participants were required to refrain from alcohol use and strenuous exercise for 24 hours before the test and to avoid caffeine intake for four hours before the test. $\dot{V}O_2$peak was determined using the progressive deep water protocol of Mercer and Jensen to voluntary exhaustion (23). The protocol is continuous and consisted of 1-min stages (23). Test participants were submerged to neck level (C7) while wearing a flotation belt, with a tether attached to the back and run through a series of pulleys. The other end of the tether was attached to a bucket suspended in front of the participant and above a wooden plank that rested across the flume deck. To provide a graded response a 0.57 kg weight was added to the bucket at the beginning of each 1-min stage. This weight increment was chosen as it was similar to the weight increment used in the validation of the Mercer and Jensen (23) protocol and pilot testing was conducted to ensure the weight would be appropriate for use in the current investigation. If the participant was not able to meet the intensity at a given stage the bucket dropped onto the wooden plank; this was accepted as the endpoint of the test. This test has been found to be valid and reliable for assessing maximal aerobic uptake while deep water running (23). Respiratory gas analysis was carried out during the protocol, with oxygen uptake ($\dot{V}O_2$) determined using a Beckman metabolic cart (Sensormedics, Yorba Linda, CA). Gas analyzers were calibrated prior to each test with a known concentration of oxygen and carbon dioxide and volume was calibrated prior to each test using a standard 3L syringe. Samples were collected every 20 seconds and three $\dot{V}O_2$ and HR values measured in the final 60 seconds of the exercise phase were averaged to obtain the $\dot{V}O_2$peak and HR_{peak}. Rating of perceived exertion (RPE) was measured on a 6 (minimal effort) to 20 (maximal effort) point scale and recorded immediately at the end of the deep water run maximal test (24). To minimize any learning effect, participants were instructed on correct deep water running technique prior to the test and researchers encouraged participants to maintain proper form throughout the deep water run maximal test. Peak oxygen consumption tests were undertaken before commencing the exercise intervention and again at the end of the 12 week intervention period.

Anthropometry: Anthropometric measurements of waist and hip circumference were used for determination of abdominal obesity. Waist circumference (WC) was defined as the narrowest part in the trunk between the last rib and the anterior superior iliac spine and hip circumference (HC) as the widest part between the anterior superior iliac spine and the greater trochanter (25,26). Waist-hip ratio (WHR) was calculated for each participant and body mass index (BMI) was calculated as weight (kg) / height squared (m^2). Participants were measured while wearing a swimsuit to ensure the tape measure would be placed as close to the skin as possible while ensuring participants remained comfortable. Height and weight were measured without shoes and in a swimsuit using a stadiometer and Digi electronic scales (D1-10, Teraoka Seiko Ltd, Tokyo, Japan), respectively. Anthropometric measurements were taken immediately prior to the initial deep water run test for aerobic fitness and again, three to five days after the final training session. Measurements were taken in duplicate and a tolerance limit of 1 kg was set for weight measurement and 1 cm for height and circumference measurements. A third measurement was taken if the difference of the first two measures was greater than the tolerance limit. The average of the two closest measurements was used in the analyses. The same trained researcher performed all pre and post measurements.

Strength: Upper body strength was assessed from a seated chest press exercise, while lower body strength was determined using knee extension and flexion. Strength measures were undertaken on an isokinetic dynamometer (Biodex Corporation, Shirley, NY, USA). Participants were seated on the Biodex isokinetic dynamometer with a hip angle of 90° flexion. The depth of the seat was adjusted to allow the alignment of the lateral femoral condyle of the right knee with the axis of the dynamometer. The calf pad was placed 5 cm proximal to the lateral malleolus and secured with a padded shin strap. Participants were stabilized with thigh, pelvic and shoulder straps. Shoulder straps were applied diagonally across the chest to attenuate excessive upper body movement. A strap was also placed across the lap and the involved thigh in order to minimize excessive lower body motion. The Biodex was adapted for the seated chest press with a vertical lever arm attached to a horizontal bar. The lever arm length was the same for each participant, but the seat height was adjusted so that participants sat with shoulders horizontally flexed to 90° and elbows flexed to 90° with hands placed shoulder width apart on the horizontal bar. Participants performed the chest press by pushing the horizontal bar away from them until elbows were almost fully extended. For knee flexion and extension range of motion limits were set from 90°of knee flexion to -5° of full knee extension and for the upper body movement range of motion limits were set at 90° of elbow flexion to -5° of full elbow extension. For knee extension and flexion, maximal voluntary concentric isokinetic torque was assessed in Newton meters at an angular velocity of 90°/s. The right leg was used unless contraindicated by pain or history of joint problems. For upper body strength, maximal voluntary concentric isokinetic torque was assessed in Newton meters at an angular velocity of 30°/s during a seated chest press. Upper and lower body angular speeds were selected to ensure the majority of women could produce peak torque and replicated the speeds at which they would perform chest press, knee flexion and knee extension during the training intervention. For both lower and upper body strength, three maximal efforts were performed to produce three overlying curves; the maximal torque was recorded and used for the analysis. In order to minimize the risk for injury and familiarize participants with the testing procedure, participants were asked to perform submaximal repetitions of each exercise for five minutes and then perform one repetition at maximal effort prior to the test. During the measurement session participants were instructed to perform each exercise as explosively as possible.

Exercise Intervention: Participants attended a 60 minute aquatic circuit class, three days per week for 12 weeks. "Aquatic circuit-training" was operationally defined for the present study, as a program characterized by a series of aquatic resistance training exercises combined with aerobic exercise (deep water running). Each class consisted of a 5 minute warm up followed by deep water running interspersed with resistance exercises using either foam dumbbells or the resistance of the medium itself. The circuit consisted of 3 minutes of deep water running followed by 90 seconds of resistance exercise. Each training session consisted of one set of five primary exercises for the upper body: 1) chest press, 2) chest flys, 3) tricep kickback, 4) press down/pull up 5) bicep curl; four primary exercises for the lower body: 1) starjumps (hip adduction and abduction, 2) scissor kicks (hip flexion and extension), 3) leg press, 4) leg extension/flexion; and two primary exercises for the abdominals: 1) abdominal curls 2) oblique abdominal curls. The resistance exercises were chosen to train all major muscle groups. In water, the effect of the movement velocity on the resistance produced by water is emphasized. When the velocity doubles, the drag produced by water quadruples (14). Therefore, the participants were instructed to perform each resistance exercise with the maximal effort they could maintain for 90 seconds in order to achieve the highest possible movement velocity, thereby increasing resistance. Encouragement by the instructor was provided to maintain movement velocity and ensure strength progression throughout the program. Throughout the exercise sessions participants were suspended in the water while wearing flotation belts. The flotation belts allowed the participant's head to remain above water and helped maintain an upright posture.

Pool temperature was kept at a thermoneutral temperature of 28.5°C. All exercise participants were asked to exercise at a target heart rate that represented 70-75% of the peak heart rate attained during their peak oxygen consumption test and at a level of exertion corresponding to between "fairly light" (RPE 11) to "somewhat hard" (RPE 14) on the 20 point Borg RPE scale (24). Heart rate monitors (Polar Favor, Kempele, Finland) were worn by each participant at every session and average exercise heart rates were recorded immediately on cessation of each exercise session by the researcher to ensure prescribed intensities were being met.

Statistical Analysis

Results are reported as group means (±SE), unless otherwise indicated. Percentage change scores are the mean percentage change from baseline to post exercise training. Shapiro-Wilk normality test showed normal distribution for all data. To assess the effect of the exercise intervention on changes in aerobic fitness, strength and measures of abdominal obesity paired t-tests were conducted on pre and post data. In order to obtain an impression of the magnitude of the results obtained after the exercise intervention, Cohen's d (*d*) of the effect size was calculated on outcome measures (27). The effect size was calculated within the intervention by subtracting post-test from pre-test scores and dividing the difference by the pooled standard deviation (27). As the study involved a matched or repeated measures design, the standardized difference was computed taking into account the correlation between measures (28). Statistical Package for the Social Sciences (SPSS) was used for all statistical analyses (SPSS Inc, v14.0, Chicago, IL). Significance was accepted at $p<.05$.

Results

Participant baseline characteristics are outlined in Table 1. All women completed the study, with individuals attending all 36 scheduled exercise sessions. Paired t-tests revealed significant pre to post intervention reductions in WC, WHR, and HC ($p<.05$) but, weight and BMI were not significantly altered ($p>.05$). Furthermore, there was a significant improvement in upper body strength of 20% and knee extension

Table 1. *Participant Baseline Characteristics*

Characteristic	
N	18
Age (yr)	59 ± 8.6
BMI (kg/m^2)	33.4 ± 5.5
Weight (kg)	87.6 ± 16.2
$\dot{V}O_2$peak (L·min^{-1})	1.37 ± 0.41

Note. Data are presented as means ± SE

Table 2. *Aerobic Fitness, Anthropometric and Strength Changes After 12 Weeks of Circuit Based Deep Water Running in a Group (n=18) of Older, Overweight Women*

Circuit based deep water running (n=18)					
	Pre	Post	Chg (%)	ES (95% CI)	p-value
$\dot{V}O_2$peak (L·min^{-1})	1.37 ± 0.10	1.51 ± 0.08	13%	ES -0.91 (-1.1 to -0.8)	.02
BMI (kg/m^3)	33.4 ± 1.3	33.1 ± 1.3	-0.9%	ES 0.55 (-2.0 to 3.1)	.11
Weight (kg)	87.6 ± 16.2	86.6 ± 16.4	-1.1%	ES 0.75 (-6.8 to 8.3)	.05
Waist-hip ratio	0.90 ± 0.01	0.87 ± 0.01	-3.2%	ES 1.07 (1.0 to 1.1)	<.01
Waist Circumference (cm)	105.3 ± 2.5	100.2 ± 2.6	-4.9%	ES 2.18 (-2.6 to 7.3)	<.01
Hip Circumference (cm)	117.6 ± 2.8	115.7 ± 2.4	1.5%	ES 0.84 (-4.6 to 5.6)	.04
Chest Press (Nm)	171.4 ± 11.8	196.7 ± 10.4	20%	ES -1.07 (-24.3 to 19.3)	<.01
Knee Extension (Nm)	86.0 ± 6.7	101 ± 6.1	32%	ES -1.65 (-14.8 to10.4)	<.01
Knee Flexion (Nm)	54.7 ± 3.4	68.5 ± 2.8	33%	ES -1.88 (-9.4 to3.6)	<.01

Note. Data are means ± SE, percentage (%) change from baseline and ES with 95% confidence intervals and flexion significantly improved by 32% and 33%, respectively (p<.05, Table 2). In addition to improvements in abdominal obesity and strength, $\dot{V}O_2$peak improved pre to post training by 13% (Table 2).

Discussion

In this study, 12 weeks of circuit based deep water running elicited significant improvements in cardiorespiratory fitness and strength. In addition, circuit based deep water running was effective at reducing WC and WHR, despite no change in BMI. Recent evidence has shown that deep water running is effective at maintaining and improving cardiovascular fitness and resistance-type shallow water exercise improves strength and functional mobility across a range of populations (13,14,19,29). To our knowledge, our study is the first to combine deep water exercise with a prescribed resistance component and our results indicate that the addition of resistance exercise to a deep water running program can lead to improvements in body fat distribution, muscular strength and aerobic fitness.

Peak oxygen uptake increased by 13% after training, indicating that aerobic capacity can be improved in a circuit-based deep water running program. This is of clinical importance as studies indicate that low levels of cardiorespiratory fitness are associated with an increased risk of cardiovascular morbidity and mortality (30,31). The improvement in $\dot{V}O_2$peak is comparable to that found by Broman et al., where healthy elderly women performed interval deep water running at a high intensity (85% max HR) (19). High intensity exercise may not be suitable for an at-risk population; therefore our results have shown that deep water running at a moderate intensity is as effective at improving aerobic capacity as a high intensity interval program. Furthermore, this level of improvement in $\dot{V}O_2$peak is also comparable to improvements observed in other studies using shallow water aerobic training at similar exercise intensities (11,29,32). Thus, these data demonstrate moderate levels of water-based training can improve cardiovascular fitness in an older, overweight/obese population of women.

In its most recent publication, the American College of Sports Medicine emphasized the addition of resistance training to exercise programs to enhance overall fitness (33). Resistance training may be of particular benefit for older individuals, as muscle strength declines (14). In the present study, significant increases were observed for chest press (20%), knee flexion (32%) and knee extension (33%). Total body strength is important for performing activities of daily living, thus the addition of resistance exercises to a deep water running program may be more beneficial than deep-water running alone due to its ability to improve both upper and lower body strength. Cancela Carral and Ayán Pérez found that in addition to water-based aerobic training; the addition of high intensity land-based resistance training enhanced overall dynamic and static strength of their participants (34). Tsourlou et al. studied a group healthy women who participated in 24 weeks of shallow water aquatic training, and despite the longer duration of their training program, found similar increases in knee flexion, extension and chest press (14). Conversely, the magnitude of improvement in strength is higher in our study than those described by Takeshima et al. who reported increases of 8% and 7% for knee extensors and chest press, respectively, in a group of sedentary, older women after 12 weeks of shallow water circuit exercise (11). Poyhonen et al. studied a group of young, healthy, active women and found increases in knee extension of approximately 5-13% and increases in knee flexion of 9-13% after aquatic resistance training (16). The greater improvement in dynamic strength in our study compared to those of Takeshima et al., and Poyhonen et al., may be explained by variations in measurement technique, or possibly the higher training volume of the exercise protocol that was used in the present study (11,16). Furthermore, the participants in the current investigation were sedentary and it is known that individuals with lower levels of initial strength often have greater percentage increases in strength with respect to baseline levels (35).

The encouraging improvements in knee flexor strength in the current investigation confirm those reported in previous aquatic training studies (14,16) and may be explained by hydrodynamic principles. To optimally utilize water resistance, the leg movement should oppose the upward force of buoyancy during the major part of the ROM (16). Knee flexion exercises and the knee movement during deep water run training is likely to activate the hamstrings from the beginning of flexion when the orientation of the leg is perpendicular to the direction of the buoyant forces (14,16). Studies conducted on land have also demonstrated that elderly women are capable of increasing dynamic knee extensor strength by 14-35%, knee flexion strength by 24-76% and chest press strength by approximately 30% (11,36-39). Therefore, strength gains in this study can be favourably compared with those achieved on land, confirming the effectiveness of aquatic training. Previous investigations have stressed the importance of increasing leg strength to improve functional mobility in older people however, land-based strength training may not be appropriate for older people, obese individuals or those with significant mobility limitations (12,40). Therefore, preference should be given to water-based exercise in populations that cannot tolerate land-based exercise.

Obesity is a significant risk factor for cardiovascular disease however, the degree of abdominal obesity is thought to be more important for cardiovascular and metabolic risk (41). Specifically, increases in visceral fat and abdominal subcutaneous fat have been found to increase the risk for cardiovascular disease and diabetes.(41) Although simple clinical anthropometric measurements, such as WC, WHR and BMI, do not directly measure regional body fat accumulation, WC and WHR may be used to assess abdominal obesity and body fat distribution and are independently associated with an increase risk of coronary heart disease and stroke (41).

In the current investigation, there was no significant change in BMI after training. Similar results were seen by Taunton and colleagues following 12 weeks of shallow water aquatic training (32). Furthermore, BMI did not change in a study by Wallace et al. on land based circuit training in postmenopausal women (8). However, in the present study WC and WHR were significantly reduced after the training program. Results from a small number of exercise studies show that changes in abdominal obesity can occur in the absence of reductions in mass (42,43). While BMI has been criticized for its inability to detect training-induced changes in muscle and fat mass, WC and WHR can be used to detect changes in abdominal fat accumulation and may therefore, be better indicators of changes in cardiovascular risk (44). Of the few land based circuit training studies that have reported changes in abdominal obesity assessed by WHR, Wallace and colleagues found no change, whilst Maiorana et al. found a similar reduction in WHR (-1.2%) as that found in the present investigation (7,8). Few data exist regarding WC and WHR changes with water-based interventions. Taunton and colleagues did not find a significant reduction in WHR in a group of normal weight older women over 12 weeks of water based exercise (32). Although we did not directly assess muscle or fat mass, the fact that participants maintained body mass, had an increase in strength, and a decrease in waist circumference suggests participants gained muscle mass and lost fat mass. From our results, 12 weeks of moderate intensity circuit based deep water-based exercise was sufficient to induce changes in markers of abdominal obesity. Further research in the area of water-based exercise in which muscle and fat mass are directly assessed in a larger sample of overweight/obese women is needed to clarify this finding.

Despite the improvements in fitness, strength and body fat distribution, reported in this investigation one of the potential drawbacks of deep water conditioning is lack of stimulus on the skeletal system compared to weight-bearing activity. This is of particular concern for postmenopausal women because of the rapid loss of bone mineral density during this phase of life (45). However, the purpose of this investigation was to assess the effectiveness of a water-based exercise intervention in an overweight population. Moderate obesity is reported to be a protective factor in osteoporosis, and overweight individuals typically have higher bone mineral density than their lean counterparts (46). However, water-based activity may still be an appropriate exercise environment for older, lean individuals. Previous research has reported a positive correlation between bone mineral density and strength development (47). Thus, the addition of strengthening exercises to a water-based exercise program may positively influence bone density. Further research is required to assess the effect of strength training in non-weight bearing environments on bone mineral density. However, for older, non-obese individuals it may be prudent to recommend additional low-impact weight-bearing exercises, such as walking, to prevent bone loss.

There were additional benefits of water-based training for older women. The exercise program was found to be safe, as there were no reported injuries over the course of the intervention. Furthermore, we had 100% attendance throughout the 12 weeks of exercise training, which suggests additional psychological and social benefits (e.g. enjoyment, new friendships) were attained via the group based nature of the intervention.

The small sample size in this study restricts the generalizability of the study findings, but despite the small sample the prescribed water-based exercise intervention had several positive, statistically significant effects on health (improved strength and cardiorespiratory fitness and reduced indices of abdominal obesity) that have been observed in other studies with older adults and obese individuals (2,7,11,15,32). Further research with a larger sample of obese women needs to be conducted in order to verify the results reported here. In addition, with a larger group of participants a comparison between a circuit-based deep water running program and a deep water running program alone could be conducted in order to determine the effectiveness of one form of training over another. Finally, more sophisticated imaging techniques, such as dual-energy X-ray absorptiometry, may have provided more precise information regarding changes in body composition. Traditionally, girth measurements have been accepted for this purpose, but the increased muscle strength we observed does not necessarily infer increased muscular hypertrophy nor does waist circumference specifically differentiate subcutaneous from visceral fat accumulation. Additionally, learning effects may have contributed to the improvements seen for both aerobic fitness and strength as these were both novel tasks for our participants. However, a learning effect was not observed in the Mercer and Jensen (23) study, where participants unfamiliar with the protocol, underwent repeat testing within a two day period. Furthermore, with thorough and appropriate familiarization protocols in place no learning effect is apparent after strength testing using the Biodex isokinetic dynamometer (48). It is also unlikely that learning effects could explain the large improvements seen in aerobic fitness and strength in the current investigation. Despite these limitations we feel this paper contributes significantly to the body of research as it is, to our knowledge, the first to include a prescribed resistance component to aerobic exercise in deep water.

Conclusions

In conclusion, the results of the present study demonstrated that circuit type water-based exercise significantly improves muscular strength and cardiovascular fitness. Furthermore, the training program that we employed resulted in favourable changes in abdominal obesity despite maintenance of body mass. These results indicate that cardiovascular and metabolic risk factors may be ameliorated with an appropriate water-based exercise intervention. In addition, regular exercise is of great importance amongst the aging population; however, adherence to regular exercise programs in this group is usually poor. The adherence is this study demonstrates that aquatic exercise training is well tolerated by older women and can be safely used as part of a well rounded exercise program. Although the small sample limits generalizability, the results provide preliminary support for water-based circuit exercise programs as an intervention to decrease abdominal obesity and improve cardiorespiratory fitness and strength in overweight/obese women.

Acknowledgements

The authors acknowledge the participants for their enthusiastic involvement in this study and Vicky Phillips for her collaboration during the training sessions. We would also like to thank the City of Dunedin for the use of the community aquatic centre.

References

1. Dos Santos RE, Aldright JM, Lanz JR, et al. Relationship of body fat distribution by waist circumference, dual energy X-ray absorptiometry and ultrasonography to insulin resistance by homeostasis model assessment and lipid profile in obese and non-obese postmenopausal women. *Menopause* 2005; 21(5): 295-301.
2. Cuff D, Meneilly G, Martin A, et al. Effective exercise modality to reduce insulin resistance in women with type 2 diabetes. *Diabetes Care* 2003; 26(11): 2977-82.
3. Blair SN, LaMonte MJ, Nichaman MZ. The evolution of physical activity recommendations: how much is enough? *Am J Clin Nutr* 2004; 79(suppl): 913S-20S.
4. Eriksson JG, Tuominen J, Valle T, et al. Aerobic endurance exercise or circuit-type resistance training for individuals with impaired glucose tolerance? *Horm Metab Res* 1998; 30: 37-41.
5. Tessier D, Menard J, Fulop T, et al. Effects of aerobic physical exercise in the elderly with type 2 diabetes mellitus. *Arch Gerontol Geriatr* 2000; 31: 121-32.
6. Dionne IJ, Kinamen KA, Poehlman ET. Sarcopenia and muscle function during menopause and hormone-replacement therapy. *J Nutr Health Aging* 2000; 4(3):156-61.
7. Maiorana A, O'Driscoll G, Goodman C, et al. Combined aerobic and resistance exercise improves glycemic control and fitness in type 2 diabetes. *Diabetes Res Clin Pract* 2002; 56: 115-23.
8. Wallace MB, Mills BD, Browning CL. Effects of cross-training on markers of insulin resistance/hyperinsulinemia. *Med Sci Sports Exerc* 1997; 29(9): 1170-75.
9. Campbell JA, D'Acquisto LJ, D'Acquisto DM, et al. Metabolic and cardiovascular response to shallow water exercise in young and older women. *Med Sci Sports Exerc* 2003; 35: 675-81.
10. D'Acquisto LJ, D'Acquisto DM, Renne D. Metabolic and cardiovascular responses in older women during shallow water exercise. *J Strength Cond Res* 2000; 15: 12-19.
11. Takeshima N, Rogers ME, Watanabe E, et al. Water-based exercise improves health-related aspects of fitness in older women. *Med Sci Sports Exerc* 2002; 32: 544-51.
12. Lord SR, Matters B, St George R, et al. The effects of water exercise on physical functioning in older people. *Australas J Ageing* 2006; 25(1): 36-41.
13. Volaklis K, Spassis A, Tokmakidis SP. Land versus water exercise in patients with coronary artery disease: effects on body composition, blood lipids, and physical fitness. *Am Heart J* 2006; 154(3): 560e1-60e6.
14. Tsourlou T, Benik A, Dipla K, et al. The effects of a twenty-four-week aquatic training program on muscular strength performance in healthy elderly women. *J Strength Cond Res* 2006; 20(4): 811-18.
15. Gappmaier E, Lake W, Nelson AG, et al. Aerobic exercise in water versus walking on land: effects on indices of fat reduction and weight loss of obese women. *J Sports Med Phys Fitness* 2006; 46: 564-69.
16. Poyhonen T, Sipila S, Keskinen KI, et al. Effects of aquatic resistance training on neuromuscular performance in healthy women. *Med Sci Sports Exerc* 2002; 34(12): 2103-09.
17. Chu KS, Eng JJ, Dawson AS, et al. Water-based exercise for cardiovascular fitness in people with chronic stroke: A randomized controlled trial. *Arch Phys Med Rehabil* 2004; 85: 870-74.
18. Chu KS, Rhodes EC, Taunton JE, et al. Maximal physiological responses to deep-water and treadmill running in young and older women. *J Aging Phys Act* 2002; 10: 306-13.
19. Broman G, Quintana M, Lindberg T, et al. High intensity deep water training can improve aerobic power in elderly women. *EurJ Appl Physiol* 2006; 98: 117-23.
20. World Health Organization. Obesity: Preventing and Managing the Global Epidemic: Report of a WHO Consultation on Obesity. WHO Technical Report 894. Geneva: WHO; 1998.
21. Thomas S, Reading J, Shepard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can J Sport Sci* 1992; 17(4): 338-45.
22. de Jonge J, Xanne AK. Effects of the menstrual cycle on exercise performance. *Sports Med* 2003; 33(11): 833-51.
23. Mercer JA, Jensen RL. Reliability and validity of a deep water running graded exercise test. *Meas Phys Educ Exerc Sci* 1997; 1(4): 213-22.
24. Borg GV. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982; 14: 377-81.
25. Heyward VH. Advanced Fitness Assessment and Exercise Prescription 4th ed. Champaigne, IL: Human Kinetics 2002.
26. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 7th ed. Philadelphia: Lippincott Williams Wilkins 2006.
27. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale, NJ: Lawrence Earlbaum Associates. 1988.
28. Dunlap WP, Cortina JM, Vaslow JB, et al. Meta-analysis of experiments with matched groups or repeated measures designs. *Psychol Methods* 1996; 1:170-77.
29. Chu KS, Rhodes EC. Physiological and cardiovascular changes associated with deep water running in the young: Possible implications for the elderly. *Sports Med* 2001; 31(1): 33-46.

30. Blair SN, Kohl HW, Paffenbarger RS, et al. Physical fitness and all-cause mortality. A prospective study of healthy men and women. *JAMA* 1989; 262: 2395-401.
31. Myers J, Prakash M, Froelicher V, et al. Exercise capacity and mortality among men referred for exercise testing. *N Engl J Med* 2002; 346: 793-801.
32. Taunton JE, Rhodes EC, Wolski LA, et al. Effect of land-based and water-based fitness programs on the cardiovascular fitness, strength and flexibility of women aged 65-75. *Gerontology* 1996; 42: 204-10.
33. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 2007; 39(8): 1435-45.
34. Cancela Carral JM, Ayán Pérez C. Effects of high-intensity combined training on women over 65. *Gerontology* 2007; 53: 340-46.
35. Lexell J. Strength training and muscle hypertrophy in older men and women. *Top Geriatr Rehabil* 2000; 15(3): 41-6.
36. Cureton KJ, Collins MA, Hill DW, et al. Muscle hypertrophy in men and women. *Med Sci Sports Exerc* 1988; 20(4): 338-44.
37. Fielding RA, Lebasseur NK, Cuoco A, et al. High-velocity resistance training increases skeletal muscle peak power in older women. *J Am Geriatr Soc* 2002; 50: 665-62.
38. Hakkinen K, Kraemer WJ, Newton RU, et al. Changes in electromyographic activity, muscle fiber and force production characteristics during heavy resistance/power strength training in middle-aged and older men and women. *Acta Physiol Scand* 2001;171: 51-62.
39. Reeves ND, Naricii MV, Maganaris CN. Effect of resistance training on skeletal muscle-specific force in elderly humans. *J Appl Physiol* 2004; 96: 885-92.
40. Petrick M, T. P, George J. A comparison between quadriceps muscle strengthening on land and in water. *Physiotherapy* 2001; 87(6): 310-17.
41. Seidell JC, Perusse L, Despres JP, et al. Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study. *Am J Clin Nutr* 2001; 74: 315-21.
42. Boudou P, Sobngwi E, Mauvais-Jarvis F, et al. Absence of exercise-induced variations in adiponectin levels despite decreased abdominal adiposity and improved insulin sensitivity in type 2 diabetic men. *Eur J Endocrinol* 2003; 149: 421-24.
43. Mourier A, Gautier JF, De Kerviler E, et al. Mobilization of visceral adipose tissue related to the improvements in insulin sensitivity in response to physical training in NIDDM: Effects of branched-chain amino acid supplements. *Diabetes Care* 1997; 20: 385-91.
44. Schneider HJ, Glaesmer H, Klotsche J, et al. Accuracy of anthropometric indicators of obesity to predict cardiovascular risk. *J Clin Endocrinol Metab* 2007; 92: 589-94.
45. Warming L, Hassager C, Christiansen C. Changes in bone mineral density with age in men and women: a longitudinal study. *Osteoporos Int* 2002; 13: 102–12.
46. Bray GA. Medical consequences of obesity. *J Clin Endocrinol Metab* 2004; 89: 2583–89.
47. Rhodes EC, Martin A, Taunton JE, et al. Effects of one year of resistance training on the relation between muscular strength and bone density in elderly women. *Br J Sports Med* 2000; 34(1): 18-22.
48. Lund H, Sřndergaard K, Zachariassen T, et al. Learning effect of isokinetic measurements in healthy subjects, and reliability and comparability of Biodex and Lido dynamometers. *Clin Physiol Funct Imaging* 2005; 25: 75–82.

Received: December 02, 2008
Accepted: January 30, 2009
Published: February 02, 2009

Address for correspondence:
Kim Meredith-Jones
School of Physical Education
University of Otago
PO Box 56
Dunedin 9054
New Zealand
tel: +64-3-479-7089
fax: +64-3-479-8309
e-mail: kim.meredith-jones@otago.ac.nz

Michael Legge: mike.legge@stonebow.otago.ac.nz
Lynnette M. Jones: lynette.jones@otago.ac.nz