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Effects of Aqua Aerobic Therapy Exercise for Older Adults on Muscular Strength, Agility and Balance to Prevent Falling during Gait

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Abstract. [Purpose] The purpose of the present study was to examine the effects of an aqua aerobic therapy exercise for older adults on biomechanical and physiological factors affecting gait. [Subjects] A total of 15 subjects participated in this study and they were randomly divided into the experimental and the control group. [Methods] Physiological variables, leg strength, power and flexibility, and biomechanical variables, both kinematic and kinetic, were measured before and after the aqua aerobic therapy exercise. Each subject was instructed to walk along an elevated walkway and during the trials a trapdoor opened at random to create a 10 cm falling perturbation. Full body motion and kinetics was gathered during the gait. [Results] There were significant reductions in body weight, and body fat mass, and stride time after the perturbation. Significant increases in leg strength corresponded to the maximum joint moment of the landing leg showing that the subjects' ability for recovery of balance after the perturbation improved. [Conclusion] As the results showed significant improvements in gait pattern and recovery time after perturbed gait, we conclude that aqua aerobic therapy is an effective exercise method for training older adults to reduce their risk of falling.
Key words: Older adults, Falling, Aging

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INTRODUCTION

Fall-related injuries are high in the developed countries, and in the US. They are recorded as the second largest source of unintentional fatal injuries and the main source of non fatal injuries[1–3)]. In 2005, the National Center of Injury Prevention and Control (NCIPC) of Korea reported elderly females to be more likely than men to have injuries due to falling. In 2005, Kannus[4)] found that over 80% of elderly patients were admitted to hospital due to falls, and Roach[5)] report that over 50% of these patients died within 1 year after they were hospitalized. It is well known that besides the acute injuries sustained, the long-term effects of hospitalization are more serious as they can prevent the recovery of a patient's muscle strength, reducing their ability to be self sufficient.

There are many factors that can cause falls by older adults: joint instability and muscle imbalance[6–9)], reduction in joint range of motion, reduction in the ability to ambulate proficiently[10)], and deficiencies in lower body strength[11–14)]. A decreased ability to ambulate proficiently arises from a loss of muscle mass and strength which is attributable to aging[2, 15)]. Other factors that can also cause serious falls are medicinal side effects, and chronic diseases associated with aging, e.g. arthritis.

Ultimately, preventing falls is better than cure, and Kavanagh[16)] and many researchers have concluded older adults should participate in exercise programs to prevent falls and maintain self-sufficiency, which is linked to a high quality life. Berg and his colleagues[17)] state that older adults should participate in regular exercise to prevent falls. It is recommended that a fall prevention exercise program should strengthen the lower body[18)], rectify muscle imbalances[16)], incorporate balance exercises[19)] and increase flexibility[20)]. Wolf[21)] implemented Tai chi as a falling prevention exercise program and reported that after 15 weeks of Tai chi, the frequency of falls was reduced by 47.5%. Dayhoff[22)] implemented an elastic band exercise for 14 weeks and reported an increase in the subjects' preferred gait speed. Skeleton[23)] had participants perform resistance training for 10 weeks and reported that subjects' muscle strength and gait speed both increased. However, since older adults are susceptible to arthritis, lower range of motion and chronic diseases exercise training programs should be carefully developed so as not to exacerbate any pre-existing problems.

Aqua aerobic exercise has been shown by many studies to be highly effective at reducing pain for patients with arthritis and disabled populations[24)], as well as improving flexibility, strength, and balance disorders[25)] and has a significant positive psychological effect[26)]. Kim[27)] reported that aqua therapy increases cardiovascular endurance, flexibility, muscle strength, muscle balance and reduces the percentage of body fat.

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SUBJECTS AND METHODS

Initially, 40 elderly female subjects were recruited for this study. Subjects' bone density was measured by whole body dual energy X-ray absoptiometry (DEXA; MA). Twenty of the subjects had a score below −1, and they were excluded from this study due to the high impact nature of the forced perturbation. Twenty subjects commenced the aqua aerobic therapy training, and they were divided randomly into two groups of 10. During the 12 weeks of aqua therapy exercise 5 subjects dropped out leaving only 7 in the control group and 8 in the experimental group (Table 1). This study met the required ethical standards as outlined by Harriss and Atkinson[28].

As in Rikli and Jones study[19], subjects' flexibility, agility, balance and muscle strength were measured and recorded (Table 4). Subjects' muscle strength was measured by a Cybex (770, New York). Both knee flexion and extension were measured at two speeds; 60°/s and 180°/s. Muscle power was defined as the peak torque generated at

Table 1. Subject demographics

Group	Number of subjects	Age (yrs)	Height (cm)	Weight (kg)
Experiment	8	70.86± 4.97	150.64±4.58	58.34±5.88
Control	7	72.57±5.09	155.77±4.06	56.87±7.04

Table 2. Aqua therapy exercise program

	Exercise Type		Time (mins)
Warm up	1. Walking 2. Aqua aerobic 3. Stretching 4. Joint relaxation		10
Adaptation	1. Aquatic adaptation & swimming 1) Aquatic adaptation Blowing–Breathing exercise Floating (working in pairs, curling up, jumping, Grading (jumping out of the water, kicking, etc) 2) Body control (increasing your flexibility) Sagittal rotation control Transversal rotation control Longitudinal rotation control Combined rotation control 3) Basic swimming Basic movement Diagonal exercise Free style		10
Main Exercise	Exercising in shallow water	1. Walking (forward, backward, side stepping) 2. Strengthening exercises Squat, Lunges 3. Balancing Weight bearing, shifting One leg standing	30
	Exercising in deeper water	► Dumbbell training 1. Exercise for the upper extremities strength & ROM 2. Movement of the trunk and upper extremities (Coordination & balance) ► Box training Exercise for the lower extremities and balance ► Noodle training Balance, coordination, ROM, strength ► Ball training Upper body strength exercise, recreation, balance	
Cool Down	1. Recreation 2. Stretching 3. Joint relaxation		10

a constant velocity of 180°/s. Similarly muscle strength was defined as the peak torque generated at a constant velocity of 60°/s. Each trial lasted 5 seconds and was repeated three times with three minutes of rest between each trial, as recommended by Rikli and Jones[19]. The peak torque was recorded for knee flexion strength and knee extension power, was testing was performed one week before the gait experiment.

Therefore this current study investigated the effects that an aqua exercise therapy has on the physiological and biomechanical factors of gait. A secondary aim was to examine if improvements in gait variables would improve older adults' responses in a perturbed gait condition.

During gait observations, kinematics at 60 Hz were recorded by 8 OQUS 500 cameras (Qualisys, Sweden), and kinetics on by 2 AMTI force platforms (AMTI, USA) were recorded at 1200 Hz by Qualisys Track Manager (QTM, Qualisys Sweden). After explanation of the testing procedures and obtaining subjects' informed consent, the experiment began. Subjects strapped into an overhead harness for safety. For the dynamic trials the participants walked at a self-selected pace three times down a walkway. The participants were then escorted out of the room while the walkway was raised and the perturbation device was set up. Next, the participants were instructed to walk along the walkway and then step down. The participants were informed that this step-down procedure would have to be done three times. After each trial the participants were escorted back outside the laboratory and the perturbation device was reset. During these final 3 trials the perturbation platform would open up randomly and participants would fall 10 cm during the three steps down trials. Perturbation data was collected once for each participant as they became apprehensive of walking on the walkway after the perturbation.

The aqua therapy exercise program was carried out three times per week for one hour in each session (Table 2). There were three main parts to the exercise session: including warm up, aqua aerobics, and cool down. The indoor pool was 25 m long, 4 m wide and 1.3 m deep, and had a water temperature of 28±1°C and a room temperature of 26°C. The warm up consisted of walking. After the participants began to feel warmer a slow aqua aerobics pace was set which was then increased steadily. The aqua therapy consisted of aquatic adaption time, breathing techniques, floating and posturing. Equipment were introduced to maintain the participants' enjoyment, and as each piece of equipment could be used to train difference aspects of fitness, they were used for overall variation and stimulus of different muscles. The cool down gave the participants time to do stretching and have some free time. The intensity of the aqua therapy was set according to the ratings of the Borg perceived exertion (RPE) scale set at an intensity level of 7–11 for the first 3 weeks then the intensity was increased to 12–13.

After labeling of the data and interpolation in QTM, the data were exported to a c3d file, and modeling and manipulation were performed with Visual3D (C-motion, USA). A 2 × 2 (group × time) ANOVA with repeated measures were performed to compare the data between the two groups according to the measurement time. The significance level was set to $p<0.05$. Independent t tests were used to verify that there were no significant differences between the control and experimental group at the initial stage of the study. Further, significant differences were investigated using the paired t-test to investigate the differences between pre and post treatment.

RESULTS

Participants' weight, muscle mass, fat mass and mineral mass for both the control and experiment groups before and after the aqua aerobic therapy were measured using an InBody 720. There was no significant interaction between groups and time for the muscle mass and the mineral mass, but there were significant reductions in weight ($p<0.05$) and body fat mass ($p<0.05$) (Table 3).

There were no significant differences between before and after the intervention in muscle strength and power, but there were significant interaction effects ($p<0.05$). For flexibility and agility, there were significant interac-

Table 3. Inbody 720 measurement

Variable	Group	Time	
		Before	After
Weight (kg)*/**	Expt	58.34±5.88	57.03±5.19
	Control	56.87±7.04	56.64±7.26
Muscle Mass (kg)	Expt	35.75±3.13	35.93±2.92
	Control	36.31±2.97	36.23±3.25
Body Fat Mass (kg)*/**	Expt	20.38±3.26	18.8±2.86
	Control	18.34±3.96	18.07±4.07
Mineral Mass (kg)	Expt	37.96±3.27	38.16±3.05
	Control	38.53±3.16	38.57±3.48

** indicates a significant difference between before and after, $p<0.05$
*indicates a significant interaction between time and group, $p<0.05$

Table 4. Isokinetic muscle strength and power, flexibility, agility and balance

Variable	Group	Time	
		Before	After
Muscle Strength -flexion (deg/s)*	Expt	111.46±33.48	118.29±35.74
	Control	145.57±21.66	130.43±18.53
Muscle Power -extension (deg/s)*	Expt	66.71±25.64	76.29±23.16
	Control	94.71±15.11	91.86±11.67
Flexibility (cm)*/**	Expt	3.15±2.92	10.13±6.56
	Control	10±5.47	10.27±5.48
Agility (s)*/**	Expt	8.46±2.53	6.98±1.88
	Control	4.65±1.88	4.99±0.7
Balance (s)*	Expt	2.41±2.29	3.14±1.5
	Control	6.8±4.71	4.77±3.85

** indicates a significant difference between before and after, $p<0.05$
*indicates a significant interaction between time and group, $p<0.05$

tions. Similarly for balance, there were significant interactions ($p<0.05$). There were significant increases in muscle strength, power, flexibility, agility and balance of the participants in the aqua therapy group, whereas the control group demonstrated either reductions or no change (Table 4).

To investigate how participants recovered after the perturbation various gait-related variables were measured and calculated. There were no significant differences between the experiment and control groups before and after the intervention in support time, step length and jerk cost. There were statistical differences and interactions in stride and step times between the groups. These results demonstrate that the experiment group participants reduced their stride time, which shows that they recovered more quickly after the perturbation (Table 5).

The kinetic variables calculated were the maximum moments of the ankles, knees and hips, and the propulsion force of the perturbed foot after landing. There were both significant main effects ($p<0.05$) and interaction effects ($p<0.01$) of the maximum ankle moment. Similarly for the maximum knee moment there were both significant main ($p<0.05$) and interaction ($p<0.05$) effects. There were no significant effects found for the maximum hip moment and the propulsion impulse. To summarize the kinetic data, the participants in the experiment group were able to develop more ankle and knee moment to prevent their body falling and recover. The hip moments did not seem to affect the recovery of the participants (Table 6).

Table 5. Average and standard deviation after the perturbation

Variable	Group	Time	
		Before	After
Support time (s)	Expt	0.59±0.12	0.57±0.11
	Control	0.48±0.13	0.47±0.07
Stride time (s)*/**	Expt	1.10±0.21	0.84±0.06
	Control	0.84±0.06	0.89±0.11
Step time (s)**	Expt	0.52±0.14	0.54±0.03
	Control	0.41±0.07	0.41±0.05
Step length (m)	Expt	0.77±0.45	0.75±0.27
	Control	0.63±0.08	0.65±0.06
Jerk Cost	Expt	80.01±19.29	59.31±17.21
	Control	103.89±71.44	96.48±50.79

** indicates a significant difference between before and after, p<0.05
*indicates a significant interaction between time and group, p<0.05

DISCUSSION

The increasing risk of falls increases with aging, and the aims of this study were to investigate whether aqua exercise therapy can help the elderly by preventing falls and improving their gait patterns after a perturbation. It was our hypothesis that aqua exercise training would increase the elderly participants' physical strength, flexibility, and balance which would in turn help improve a subjects' ability to react to a perturbation. Our results are similar to those of previous studies which have reported that 12 weeks aqua therapy exercise improves lower body strength, power, flexibility, agility and balance[16, 19, 20]. Also, due to the training effect the weight and body fat mass was reduced, whereas no significant changes were seen in these variables in the control group.

Kinematics and kinetics were recorded and compared to evaluate subjects' reaction to perturbation. Our data show that the older adults of the experiment group managed the perturbation more efficiently and had a more stable gait pattern. Oddsson and his colleagues[29] demonstrated that recovery after a perturbation takes about 3 or 4 steps depending on limb strength and age. The present study found no significant differences in the support time, step time, step length and jerk cost after the perturbation. However, recovery started at the second step, shown by the significant difference in stride times between before and after the perturbation. The maximum joint moment of the landing leg show that subjects due to an increase in strength were able to create more ankle and knee moment which helped their quick recovery of balance after the perturbation.

One of the main limitations of this study was the danger associated with perturbed gait, especially with older adult subjects. Subjects with a high bone density were selected due to the risks of perturbed gait, and they might not have been representative of the general older adult female popu-

Table 6. Maximum moment of the lower extremities and propulsion impulse

	Variable	Group	Time	
			Before	After
Maximum Joint Moment (N/m)	Ankle*/**	Expt	−60.21±15.8	−70.65±18.91
		Control	−94.43±29.73	−51.06±13.8
	Knee*/**	Expt	34.48±18.15	70.65±18.91
		Control	62.36±34.42	61.03±33.11
	Hip	Expt	50.38±30.12	68.4±30.43
		Control	96.17±42.14	90.83±39.84
Ground Reaction Force (Ns)	Propulsion Impulse	Expt	147.76±56.64	113.04±16.63
		Control	123.91±20.29	115.03±25.69

** indicates a significant difference between before and after, p<0.05
*indicates a significant interaction between time and group, p<0.05

lation, as it has been shown that exercising has a positive effect on the bone density of older adults aged in their sixties to eighties[30].

To conclude, aqua exercise therapy may be used as a method of training for older female adults to prevent falls. We recommend further study of older adults' reaction to a perturbation, includingthe measurement of EMG as well as more detailed kinematic and kinetic data analysis of the first few steps after the perturbation.

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