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Original article

Effects of aquatic exercise and land-based exercise on postural sway in elderly with knee osteoarthritis

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Background: Knee Osteoarthritis (knee OA) is the most common joint disease in the elderly. It is a major cause of walking disability and balance impairment. The balance impairment or increase postural sway may result in increased risk of fall.

Objectives: Compare effects of aquatic exercise and land-based exercise on postural sway and physical performance (pain, quality of life, leg muscle strength and leg muscle flexibility) in the elderly with knee OA.

Subjects and methods: Fifty elderly women with knee OA were recruited for this study. They were randomized into aquatic exercise (n=25) and land-based exercise group (n=25). Postural sway views by anterior-posterior amplitude, medio-lateral amplitude, and total area were measured in subjects with eye opened or closed during double and single leg stance after six-week training, using the Force platform. Functional outcome was tested by the modified WOMAC. Knee injury and Osteoarthritis Outcome Score (KOOS), and pain scale were tested by Visual Analog Scale (VAS). Leg muscle strength was measured by chair stand, and leg muscle flexibility was measured by sit-and-reach test. Aquatic group exercised at King Chulalongkorn Memorial Hospital therapeutic pool, while land-based group exercised at home.

Results: In comparing postural sway before and after exercise, reduction in postural sway and pain, and increase in strength, the aquatic group were significantly better than those for land-based group ($p < 0.05$). WOMAC, KOOS scores, and sit-and-reach test after six-weeks training were improved after exercise, but these were not significantly different between groups ($p > 0.05$).

Conclusion: Elderly patients with knee OA need exercise to improve balance and reduce sway. Six-week aquatic exercise was better than land-based exercise in sway reduction.

Keywords: Aquatic exercise, elderly, knee osteoarthritis, land-based exercise, postural sway

Osteoarthritis (OA) is the most common joint disease. It is a major cause of disability in the elderly. The prevalence of knee OA is estimated to be 10-50% in elderly patients aged over 60 years [1-5]. Most patients with knee OA complain of pain, deformities, difficulty walking and deterioration of quality of life. OA causes joint swelling, joint deformity, limitation of movement, decrease muscle strength, proprioception impairment and increase level of pain. Knee OA also causes difficulty of the knee motion and postural control impairment with increased risk of falling [6, 7]. Elderly with knee OA increase postural sway when the center of gravity deviates from body center. Therefore, this weakens balance while moving causing an increase risk for falling [8-11]. Moreover, risk for falling is associated with over-age. It may cause appendicular, hip, and spines fractures [12-14].

Exercise is very important in patients with knee OA. In general, exercise could reduce pain, increase balance control and improve activity of daily living [15, 16]. Land-based weight bearing exercise in the elderly with knee OA, such as walking, jogging, and aerobic dancing, may cause joint damage and increase pain [17]. Exercise in the water or aquatic exercise is more appropriate for patients with knee OA. Aquatic exercise is a non-weight bearing exercise. It reduces chance of injury resulting from joint overloading [14-17]. It has the benefit of water temperature and depth to fit the patient blood circulation system.

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Aquatic exercise is an important part of rehabilitation program in patients with knee OA [18, 19]. It is well recognized that aquatic exercise can increase strength, flexibility, balance control, decrease pain and improve quality of life [20-23]. Moreover, sway and balance control can be improved after aquatic exercise in patients with knee OA. However, there is no comparative study between aquatic and land-based exercise in knee OA patients.

In this study, we attempted to compare six-week effect of aquatic exercise and land-based exercise in elderly women with knee OA. Postural sway, knee pain, strength, flexibility, knee scores, and quality of life were examined in detailed.

Materials and methods

This study was approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University.

Fifty elderly women with knee OA patients were recruited from the out-patient department of King Chulalongkorn Memorial Hospital. Inclusion criteria included elderly women aged between 60 to 75 years old with mild to moderate degree (score 1-7 knee ISOA score) primary knee OA [24, 25], body mass index (BMI) between 20-30 kg/m^2, and no regular strengthening or aerobic exercise. Exclusion criteria included severe OA, received physical modalities within three months, cortisone or visco-supplement injection within three months, underwent arthroscopic surgery within one year, and patients with abnormal visualization. Sample size was calculated based on the study by Suomi et al. [26].

The subjects were randomized into two groups, aquatic exercise (n=25) and land-based exercise group (n=25). All subjects signed the consent forms after reviewed patient information.

All subjects in each group were instructed about the exercise program. The program was divided into two periods, first three weeks and last three weeks. It included warm-up 10 minutes, exercise 45 minutes, and cool-down 10 minutes. The warm-up consisted of stretching of hamstring, adductor and calf muscles, and slow walk. Exercise included double-leg squat, double-leg calf raise, stand stretch and bend knee, standing kick leg-to-side, standing kick leg-to-front, sitting stretch knee, sit spin bike, and fast walking forward and backward. The cool-down consisted of slow walking. During the last three weeks, single-leg squat and single calf raise were added.

Aquatic exercise subjects were exercised in the therapeutic pool of King Chulalongkorn Memorial Hospital. Water temperature was ambient, and water level was set at about waist height. The warm-up and cool-down were done beside the pool. All other exercises were done in the pool with light water flow. Land-based group subjects were exercised on normal floor at home while once a week home visited and three times a week telephone called monitoring. All subjects were strictly instructed not to participate in other exercise program or strenuous physical activities. They were allowed to take only paracetamol (500 mg) for pain rescue medication.

Pain score at rest was recorded using the Visual Analog Scale (VAS). Knee score and quality of life were evaluated by interviewers who questioned using the Modified Western Ontario and McMaster Universities Arthritis Index (modified WOMAC) and Knee and Osteoarthritis Outcome Scores (KOOS: Thai validated version) [27].

Postural sway (COP) of all subjects was defined by the deviation of center of the body on single- and double-legs stance with eyes opened or closed. The COP was measured in medio-lateral (COPx) and antero-posterior (COPy) direction, and total sway areas, using the Force platform (BERTEC # FP 4060-08) [11, 15, 28, 29], in both exercise groups before and after six-week training period. It consisted of two 30-second tests for each position with 30-second rest period between the tests.

Leg muscle strength was measured using senior’s chair standing test [30]. Flexibility was measured using the sit-and-reach test [31] at the beginning and the end of six-week training period. Satisfaction of all subjects before and after training was evaluated using four scale Likert scoring system.

Data analysis

Mean and standard deviation (SD) of the demographic data and duration of knee OA were compared between groups, using unpaired t-test. Values of COP, knee pain, quality of life, strength, and flexibility of leg muscles between groups before and after exercise during six-weeks were analyzed, using ANCOVA or Mann-Whitney U test. Within-group differences were analyzed, using Pair t test or Wilcoxon-Signed Rank test. Amount of paracetamol consumption in both groups were compared using Mann-Whitney test. Percentage of satisfaction of all subjects was calculated. A p-value <0.05 was considered to be significant. The variability of each outcome was tested with Kolmogorov-Smirnov test.

Results

Table 1 shows baseline characteristics of the subjects. There was no statistical significant difference between two groups according to age, weight, height, BMI, and OA period by unpaired t-test.

Table 2 shows mean and SD of the COP in double legs and single leg stance with eye opened and closed in x-axis, y-axis, and total area of sway.

Table 1. Baseline characteristics (n = 50).

Characteristics	Aquatic group (N=25)		Land-based group (N=25)		P-value
	Mean	SD	Mean	SD	
Age (year)	65.6	4.9	66.4	4.4	0.534
Weight (kg)	58.3	8.3	55.4	7.2	0.192
Heigh (cm)	154.6	6.2	152.8	4.5	0.236
BMI (kg/m^2)	24.4	2.7	23.7	2.2	0.685
OA period (year)	7.12	5.6	6.4	7.4	0.685

Unpaired t-test.

Table 2. Comparison of postural sway (COP) between aquatic exercise (n=25) and land-based exercise group (n = 25).

Parameters	Pre-test		Post-test		P-value
	Aquatic group (N=25) Mean ± SD	Land-based group (N=25) Mean ± SD	Aquatic group (N=25) Mean ± SD	Land-based group (N=25) Mean ± SD	
Double legs stance					
- DOx (mm)					
- DO y (mm)	28.6± 11.6	35.3 ± 17.0	26.0 ± 12.7	30.3 ± 14.1	0.239
- DOtotal (mm^2)	21.4 ± 11.8	23.1 ± 14.0	29.8 ± 13.2*	27.8 ± 13.2	0.577
- DC x (mm)	621.8 ± 482.1	808.7 ± 629.9	721.7 ± 407.3	802.8 ± 526.2	0.495
- DC y (mm)	28.3 ± 11.6	30.8 ± 13.8	24.6 ± 11.6	31.8 ± 13.2	0.039
- DCtotal (mm^2)	22.4 ± 11.9	23.3 ± 14.8	30.4 ± 12.8*	28.1 ± 11.6	0.488
	624.3 ± 438.8	727.7 ± 697.1	761.1 ± 455.8	880.3 ± 484.3	0.331
Single leg stance					
- RSLOx (mm)	69.1 ± 28.9	71.1 ± 26.8	47.0 ± 11.5*	48.3 ± 18.7*	0.775
- RSLOy (mm)	102.4 ± 26.3	117.9 ± 29.8	68.3 ± 35.7*	79.6 ± 44.2*	0.280
- RSLOtotal (mm^2)	7502.1± 4810.0	8707.1 ± 4591.3	3321.3 ± 2437.2*	4300.4 ± 3855.0*	0.255
- RSLCx (mm)	57.1 ± 22.6	64.2 ± 23.4	49.2 ± 17.2	41.0 ± 14.3*	0.042
- RSLCy (mm)	98.9 ± 36.6	99.3 ± 34.6	55.4 ± 23.6*	73.26 ± 27.63*	0.018
- RSLCtotal (mm^2)	6093.6 ± 4107.7	6494.1 ± 3606.6	2801.8 ± 1823.7*	3032.8 ± 1605.3*	0.705
- LSLOx (mm)	81.2 ± 35.3	71.6 ± 29.2	57.3 ± 28.2*	65.8 ± 25.6	0.165
- LSLOy (mm)	116.6 ± 35.3	107.4 ± 32.8	59.1 ± 30.4*	78.6 ± 33.7*	0.041
- LSLOtotal (mm^2)	9961.8 ± 6334.0	8252.7 ± 5903.1	3985.8 ± 4263.7*	5657.1 ± 4744.7	0.171
- LSLCx (mm)	73.2 ± 30.3	78.6 ± 33.1	56.6 ± 25.5*	56.5 ± 28.0*	0.970
- LSLCy (mm)	105.0 ± 31.7	100.3 ± 40.6	62.2 ± 26.5*	83.5 ± 39.2	0.029
-LSLCtotal (mm^2)	8024.0 ± 4822.0	8708.7 ± 6879.4	3848.0 ± 3445.9*	5427.3 ± 5829.3	0.239

ACOVA ($p < 0.05$). DOx = double leg stance with opened eyes in COPx, DOy = double leg stance with opened eyes in COPy, DOtotal = double leg stance with opened eyes in total sway area, DCx = double leg stance with closed eyes in COPx, DCy = double leg stance with closed eyes in COPy, DCtotal = double leg stance with closed eyes in total sway area, RSLOx = right single leg stance with opened eyes in COPx, RSLOy = right single leg stance with opened eyes in COPy, RSLOtotal = right single leg stance with opened eyes in total sway area, RSLCx = right single leg stance with closed eyes in COPx, RSLCy = right single leg stance with closed eyes in COPy, RSLCtotal = right single leg stance with closed eyes in total sway area, LSLOx = left single leg stance with opened eyes in COPx, LSLOy = left single leg stance with opened eyes in COPy, LSLOtotal = left single leg stance with opened eyes in total sway area, LSLCx = left single leg stance with closed eyes in COPx, LSLCy = left single leg stance with closed eyes in COPy, LSLCtotal = left single leg stance with closed eyes in total sway area. *within-group difference between pretest and post-test ($p < 0.05$).

Within-group differences were compared before and after exercise in each group using the paired t-test. After exercise, double-legs stance COP with eyes opened or closed in antero-posterior direction in aquatic exercise group increased significantly. The COP comparison between groups using ANCOVA showed that double-leg stance with closed eyes in medio-lateral direction (COPx) was reduced more than land-based exercise group significantly (p=0.039). The COP comparison between group, measured with single-leg stance, showed that six-week aquatic exercise reduced COP significantly, compared with land-based exercise group. The same result happened when it was measured with right single-leg stance with closed eyes in antero-posterior direction (COPy) (p=0.018), with left single-leg stance with opened eyes in antero-posterior direction (COPy) (p=0.041), and with left single-leg stance with closed eyes in antero-posterior direction (COPy) (p=029). The other situations showed no differences between groups.

Table 3 shows significant reduction of knee pain, improvement of WOMAC and KOOS knee score, increase in leg muscle strength, and improved leg muscle flexibility after six-week exercise in both groups (p <0.05).

Most of the subjects showed mild pain at the beginning with VAS pain score 3.68 and 2.81. After exercise during six weeks, the aquatic exercise group had less pain, compared to land-based group (p = 0.007). Aquatic exercise group showed more increment of the strength of leg muscles, measured with senior chair stand test, compared to land-based group (p = 0.00). Flexibility of leg muscles, measured with sit-and-reach test, and quality of life were no statistical different between two groups. Mean consumption of paracetamol during six-week exercise periods in aquatic exercise group was 23.74 tablets, while mean consumption in land-based group was 27.26 tablets. There was no statistical difference between two groups (**Table 4**).

Table 5 shows the level of satisfaction of volunteers between aquatic exercise group and land-based exercise group.

Table 3. The comparison of pain scale, quality of life and performance between of aquatic exercise (n=25) and land-based exercise group (n=25).

Parameter	Pre-test		Post-test		P-value
	Aquatic group (N=25) Mean ± SD	Land-based group (N=25) Mean ± SD	Aquatic group (N=25) Mean ± SD	Land-based group (N=25) Mean ± SD	
VAS (1-10 cm)	3.68 ± 1.65	2.81 ± 1.54	0.70 ± 0.53*	1.41 ± 1.30*	0.007
WOMAC (MAX120)	28.84 ± 12.05	27.08 ± 9.36	13.48 ± 13.84*	14.64 ± 15.28*	0.607
Part 1 (MAX=25)	6.48 ± 3.07	5.76 ± 3.05	3.04 ± 3.68*	3.12 ± 3.87*	0.756
Part 2 (MAX=10)	2.48 ± 1.05	2.16 ± 1.57	1.24 ± 1.27*	1.56 ± 1.71*	0.259
Part 3 (MAX=85)	19.88 ± 8.76	19.04 ± 6.43	9.20 ± 9.80*	9.96 ± 10.24*	0.683
KOOS (MAX=168)	54.80 ± 23.65	55.16 ± 18.61	26.72 ± 23.48*	32.48 ± 26.43*	0.393
Part 1 (MAX=20)	6.40 ± 3.27	5.72 ± 2.54	3.60 ± 3.63*	3.64 ± 3.48*	0.733
Part 2 (MAX=8)	2.48 ± 1.23	2.32 ± 1.11	1.08 ± 0.95*	1.40 ± 1.50	0.312
Part 3 (MAX=36)	10.48 ± 5.67	10.52 ± 4.57	4.16 ± 4.08*	5.04 ± 5.18*	0.496
Part 4 (MAX=68)	17.24 ± 9.88	18.28 ± 8.58	8.88 ± 10.08*	9.40 ± 10.11*	0.959
Part 5 (MAX=20)	9.96 ± 4.65	10.40 ± 4.42	4.72 ± 4.15*	7.64 ± 5.85*	0.020
Part 6 (MAX=16)	8.24 ± 2.65	8.32 ± 2.91	4.56 ± 3.22*	5.76 ± 3.36*	0.195
Senior's Chair stand (times)	13.80 ± 3.78	14.88 ± 5.43	25.12 ± 4.08*	21.08 ± 4.79*	0.000
Sit and Reach (cm)	6.98 ± 8.10	7.90 ± 11.47	10.96 ± 7.68*	10.54 ± 9.32*	0.399

AQNCOVA (p <0.05). VAS= Visual analog scale, WOMAC=Western Ontario and McMaster Universities Osteoarthritis index, KOOS= Knee injury and Osteoarthritis Outcome Score. *within-group difference between pretest and post test (p<0.05).

Table 4. The comparison of Paracetamol dose between of aquatic exercise group and land-based exercise group (n = 50).

Parameter	Aquatic group (N=25)		Land-based group (N=25)		P-value
	Mean rank	Sum of ranks	Mean rank	Sum of ranks	
Paracetamol (tablet)	23.74	593.50	27.26	681.50	0.239

Nonparametric test (Mann-Whitney test) (p <0.05)

Table 5. The level of satisfaction of volunteers between Aquatic exercise (n=25) and land-based exercise group (n=25).

Groups	Level of satisfaction			
	Very satisfied	Medium satisfied	Less satisfied	Not satisfied
Aquatic group (N=25)	96 %	4 %	0 %	0 %
Land-based group(N=25)	88 %	12 %	0 %	0 %

Apparently, most of the volunteers rated their satisfaction to be “very satisfy”, while few of them reported “medium satisfy”, and none of them reported “less satisfy” or “not satisfy” after six-week training period. The exercise in the water group rated their satisfaction levels to be 96% “very satisfy”.

Discussion

The present COP showed that double-legs stance measurement were not consistent between direction and area of measurement. In fact, the deviation of COP increased after training. Compared to double-leg stance measurement, single-leg stance measurement provided better congruent data before and after training. This inconsistence might be due to the lack of body control, because patients stand on both legs comfortably. Single-leg stance requires more efforts and body control with patients.

According to Mag and Ng [32], single-leg stance was the best discriminator for postural control in elderly patients. Du Pasquier et al. [33] reported that double-legs stance was a simple and reliable measurement for postural sway measurement. However, our result showed that balance control was improved after six-week training in both groups. In the study by Douris et al. [34], both aquatic exercise and land-based could increase the balance control. In our study, elderly female subjects with knee OA, trained in the therapeutic pool, reduced sway on the Force plate better than the land-based exercise group in single-leg stance and double-legs stance with opened or closed eyes. This agrees with the result by Suomi et al. [26]. Interestingly, the improvement of postural control in single leg stance would reduce the possibility of fall in elderly people [35].

In our experiment, knee pain of the subjects, trained with exercise in both groups, was reduced significantly, but this difference is not statistical significant. This is different from the study by Wyatt et al. [36]. Our patients with knee OA showed increases in thigh muscle strength, flexibility of legs, and quality of life at the end of the training. Compared between the two groups, aquatic exercise group increased muscle strength more than the land-based exercise group. The different improvement of muscle strength might be due to the resistance force of the water during exercise in the therapeutic pool.

Usually, balance control requires several key components, including the strength of muscle, visual, proprioception, vestibular, and somatosensory [37]. These systems must work to make the body stand and walk or move without falling. Another important factor is age [38]. The elderly with knee OA may lose control of balance and resulting fall [39]. Our study demonstrated that knee exercise was most important to improve the balance control, reducing risk of falling. Aquatic exercise showed superior result to land-based exercise. This may be because water resistance and buoyancy improve the ability of training in elderly patient with knee OA [14, 15].

Both exercise programs can reduce knee pain, compared to the primary pain score. In our experiment, knee pain in aquatic group was reduced more than the land-based group. This may be due to floating and buoyancy force that reduces shock across the knee during exercise and whirlpool of the water that helps stimulate work of muscles to reduce pain [14-16]. The present study showed the ability of both exercise programs to improve quality of life and activities of daily living by the reduction of WOMAC and KOOS scores similar to other studies [15, 16, 40, 41].

Conclusion

Female elderly patients with knee OA improved their postural sway control after six-week training. Both aquatic and land-based exercise program can increase muscle strength, flexibility, reduce pain, increase quality of life, and ability of daily living. Aquatic exercise showed better efficacy in the reduction of sway, compared to land-base exercise.

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