J. Phys. Ther. Sci. 33: 375–383, 2021

The Journal of Physical Therapy Science

Original Article

Effects of hydrotherapy and land-based exercise on mobility and quality of life in patients with knee osteoarthritis: a randomized control trial

Santhanee Khruakhorn, PhD[1)], Sanon Chiwarakranon, MS[1)*]

[1)] *Department of Physical Therapy, Faculty of Allied Health Sciences, Thammasat University Rangsit Campus: 99 Moo.18 Phahonyothin Road, Khlong Nueng, Khlong Luang, Pathum Thani 12120, Thailand*

Abstract. [Purpose] To determine the effects of hydrotherapy and land-based exercises on functional mobility and quality of life among patients with knee osteoarthritis. [Participants and Methods] We conducted a randomized controlled trial with knee osteoarthritis patients randomly allocated into land-based (n=17) and hydrotherapy groups (n=17). The Time-Up and Go (TUG), Five Times Sit-to-Stand (5STS), Stair Climbing Test (SCT), and Quality of Life by questionnaires including the Modified Western Ontario and McMaster Universities Osteoarthritis Index questionnaire Thai version (Thai WOMAC) were assessed at baseline and 6 weeks. The World Health Organization Quality of Life BREF Thai version (WHOQOL-BREF-THAI) questionnaire were assessed at baseline and six weeks and 6 months. [Results] There was no significant difference in outcomes between the groups after 6-weeks and 6-months of follow-up. After 6 weeks, Thai WOMAC score improved in both groups. Only 5STS was improved in the land-based group, while the hydrotherapy group showed significant TUG, 5STS, and SCT improvement. Furthermore, only hydrotherapy showed significant improvement in WHOQOL-BREF-THAI scores in the mental, social, quality of health, and total domains after six months. [Conclusion] Both exercises equally improved functional mobility and quality of life. Hydrotherapy and land-based exercise could improve functional mobility and quality of life in patients with knee osteoarthritis.

Key words: Osteoarthritis knee, Hydrotherapy, Mobility

(This article was submitted Sep. 11, 2020, and was accepted Jan. 30, 2021)

INTRODUCTION

Osteoarthritis of the knee (knee OA) is a degenerative joint condition[1)] and affects the joint compression force[2)]. The increase in the joint compression force damages the joint articular cartilage. Upon aging, knee OA is a significant condition seen in individuals[3)]. The prevalence of knee OA correlates and increases with age[4)]. Pain is a significant symptom observed in knee OA caused by changes in knee joint compression force[3, 5)] and effects are seen on functional mobility (walking and ambulation)[6, 7)], and quality of life[7)] (physical, social, psychological, and environmental effects)[8, 9)]. According to previous studies, exercising has been observed to improve leg muscle strength, functional mobility, and quality of life[7)]. RCTs have shown that exercise can reduce pain and improve functional mobility in patients with knee OA[10)]. Moreover, exercise is the most common treatment for knee OA to improve functional mobility and quality of life[11, 12)].

The exercises preferred for knee OA are land-based exercises or hydrotherapy[10)]. Recently, hydrotherapy has become a popular treatment for knee OA[2)] because it has unique properties including turbulence, viscosity, hydrostatic pressure, and buoyancy[13–16)] that help to support the body, reduce the compression force, and reduce pain while exercising[11, 17, 18)]. In addition, hydrotherapy is known to promote functional mobility and quality of life. In a previous study, both land-based exercises

*Corresponding author. Sanon Chiwarakranon (E-mail: Sanon.c@allied.tu.ac.th)

and hydrotherapy improved functional mobility compared to the control group[2]. While land-based exercises focused on increasing muscle strength and improving pain and mobility[19, 20], hydrotherapy improved pain, quadriceps muscle strength, functional mobility, and quality of life in knee OA more than land-based exercises.

This study aimed to compare land-based exercises and hydrotherapy on the functional mobility and quality of life at six-week and six-month follow-up within and between groups of exercise.

PARTICIPANTS AND METHODS

The study design was a double-blinded randomized controlled trial (RCT) by computer-generated blocked randomization[17] to divide the group of participants into two groups (hydrotherapy and land-based exercise). A sealed envelope with a group identification number (1=Land-based exercise, 2=Hydrotherapy) was assigned to each participant. When we screened and included a patient, the sealed envelope was opened by the patient only. This study assessor was blinded to the group treatment throughout the study, and participants were blinded to the objective of this study. The Ethics Committee of the University Human Research Ethics Committee of Thammasat University (COA NO. 257/2560) approved our study on April 20, 2017. The clinical trial was committed in May 2017; the Thai Clinical Trials Registry identification number was TCTR20170527001. All the participants signed the consent form before participating in the study and were processed at the Physical Therapy Unit and Hydrotherapy Health Center, Faculty of Allied Health Sciences Thammasat University, Thailand.

Individuals with osteoarthritis of the knee between the ages of 45 and 75 years[17] (male and female) were diagnosed by orthopedic doctors with grades 2–3 of the Kellgren-Lawrence grading system of osteoarthritis[21]. The exclusion criteria included cardiovascular diseases[15, 18, 22], rheumatoid arthritis[18, 22], major surgery within six months, high blood pressure not controlled by medication[23], visual impairment[23], neurologic disorder[16, 17], dementia[17, 18, 22], cognitive dysfunction[16, 17], being overly fearful of water, and communication impairment.

The time-up and go test (TUG) evaluated functional mobility while walking and balancing. Standard chairs (44.5 cm wide and 38.0 cm high), a three-meter walkway, and a rotating cone were used. The physiotherapist explained assessment details for walking from the chair to turn around the cone and walk back to sit on the chair. This assessment comprised two trials, with one minute of rest before beginning the second round. The average time (seconds) of the two trials was assessed. The reliability of the TUG test was determined at 0.74[24].

The five times sit-to-stand (5STS) test was used to evaluate the leg muscle strength with a 5-time rise from standard chairs (44.5 cm wide and 38.0 cm high) without an armrest. The participant was requested to sit on a chair with their arms crossed over their chest. The physiotherapist explained the assessment to the participants, wherein they had to get up from the chair as fast as possible five times. This assessment included the evaluation of two trials, with a 1-minute rest between trials. The average time from the two trials were assessed. The reliability of 5STS was determined at 0.94–0.96[25].

The modified Thai WOMAC index comprises 22 items in the Thai version of self-assessment, with each item scoring 10 points; thus, a total score of 220. The WOMAC included pain level, stiffness of the joints, and symptoms during daily life movements. The test–retest reliability of the Thai WOMAC had correlation coefficients from 0.65–0.71 and an internal consistency ranging from 0.85–0.97[26]. The modified Thai WOMAC index had good psychometric properties for Thai patients with knee OA[26].

The stair climb test (SCT) is an assessment method of walking up and down the stairs, which is an activity of daily living. This assessment consists of four steps: going up and down stairs (ascending and descending stairs) with a width of 26.5 cm, length of 76 cm, and a height of 15.2 cm. The assessors explained the detailed keywords; “Walk up − turn back − and go down the stairs as soon as possible but safely” and subsequently started the assessment with the word “Start”. This assessment was measured in seconds (s) and two trials were evaluated, and the average time in seconds (s) was calculated[25]. There was a 5-minute rest between the trials.

WHOQOL-BREF-THAI[8, 9] is a self-quality assessment form developed by the World Health Organization. This assessment was reviewed and improved by experts in the language and passed tests. We observed that there was a significant level of confidence compared to the Thai version of the WHOQOL-100 scale (Cronbach’s alpha coefficient), at 0.84. The accuracy was 0.65, compared with the Thai version of the WHOQOL-100. The assessment form consisted of four domains: physical, psychological, social, and environmental.

Functional tests, including the five times sit-to-stand, stair climbing test, WOMAC, and WHOQOL-BREF-THAI were evaluated at baseline and six weeks after training. At six months after training, all participants were followed up on telephone for WHOQOL-BREF-THAI. The assessor was a musculoskeletal physical therapist who had a 15 years experience and was blinded to the participant groups.

Progressive strengthening exercises were used in this study[27–29]. The exercise protocols were designed based on a literature review[2, 11, 30, 31]. The face validity was assessed by a physical therapist who worked with hydrotherapy for more than 10 years. Both exercise groups were required to attend the exercise classes for 45−60 minutes, three times per week for 6 weeks. For the stretching exercises, the participant had to hold the position for 10 s in 10 sets. For the strengthening exercise, 15 repetitions of three sets, and cycling for 10 and 15 minutes in the second and third phases were conducted. There was a minute of rest between exercises. The phase was changed every six sessions of exercise, including the number of exercises, extra resistance, and time duration. Land-based exercises were performed on an exercise mat for 45–60 minutes per session, 3 sessions per week for 6 weeks. The various postures are displayed in Table 1. Both group exercise protocols were the same in position and movement, but at different locations. The gravity and water properties affected the exercise. This causes some postures to be modified to serve the purpose of the two-group exercise best. Elastic bands on land-based and flotation

Table 1. Hydrotherapy and land-based exercise protocols

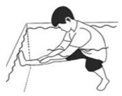
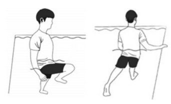
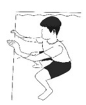
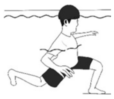
Exercise	Exercise details	Onset time
Hamstring muscle stretching (Hydro, Land) 	Standing with one foot on the floor and the opposite foot on a wall with straight knee. Lean forward and keep the back straight until felt a comfortable stretch at hamstring muscle. Hold 10 seconds and repeat 10 times of both side. Exercising is same on land.	Week 1–6
Quadriceps muscle stretching (Hydro, Land) 	Standing with one foot on the floor and the opposite leg was catch with same hand of opposite leg. Keep the back straight until felt a comfortable stretch at quadriceps muscle. Hold 10 seconds and repeat 10 times of both side. Exercising is same on land.	Week 1–6
Calf muscle stretching (Hydro, Land) 	Standing with both foot with straight knee on the wall of the pool. Both of hands catch at edge of the pool. Keep back straight and lean forward until felt a comfortable stretch at calf muscle. Hold 10 seconds and repeat 10 times of both side. Exercising is same on land.	Week 1–6
Hip abductor and trunk muscle stretching (Hydro, Land) 	Standing with both foot. Leg attached to the edge of the pool is crossed to the back of the other leg. Keep back straight and trunk lateral flexion until felt a comfortable stretch at hip abductor and trunk muscle. Hold 10 seconds and repeat 10 times of both side. Exercising is same on land.	Week 1–6
Hip adductor muscle stretching (Hydro, Land) 	Standing with both foot. Both of hands catch at the knee of same side. Keep back straight with squat and use both hands to spread the legs out until felt a comfortable stretch at hip adductor and trunk muscle. Hold 10 seconds and repeat 10 times of both side. Exercising is same on land.	Week 1–6
Forward single leg swing (Hydro, Land) 	Standing with one foot on the floor. Keep back straight and kick the opposite leg straight forward with straight knee. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 1–2
Backward single leg swing (Hydro, Land) 	Standing with one foot on the floor. Keep back straight kick the opposite leg straight backward with straight knee. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 1–2
Walk sideways (Hydro, Land) 	Keep back straight and walk sideways. Repeat 5 rounds of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 1–6
Forward marching (Hydro, Land) 	Keep back straight and walk with high knee. Repeat 5 rounds of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 1–2
Medial diagonal single leg swing (Hydro, Land) 	Standing with one foot on the floor. Keep back straight and kick the opposite leg diagonal forward with straight knee. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 3–4
Hip and knee flexion to extension (Hydro, Land) 	Standing with one foot on the floor. Participants flexion hip and knee as high as possible and push the foot faster back with straight knee. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 3–4
Knee extension with resistance (Hydro, Land) 	Standing with one foot on the floor and back against the edge of the pool. Flex hip and knee as high as possible and push the foot faster down with straight knee. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Use resistance band on land.	Week 3–6
Semi squat (Hydro, Land) 	Standing with both foot. Both of hands catch at the edge of the pool. Keep back straight with semi squat as possible. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 5–6

Table 1. Continued

Exercise		Exercise details	Onset time
Forward lunge (Hydro, Land)		Standing with both foot on the floor. Step forward lunge of both side as possible. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 3–6
Step-up (Hydro, Land)		Standing with both foot on the floor. Step up forward and step down backward with the same side. Repeat 15 times for 4 sets of both side. Progression resistance with speed as participants tolerance. Exercising is same on land.	Week 5–6
Jogging (Hydro only)		Standing with both foot on the floor. Alternate foot jogging with tip toe. Repeat 30 times for 4 sets. Progression resistance with speed as participants tolerance.	Week 5–6
Tiptoe (Land only)		Standing with both foot on the floor. Tip toe as high as possible. Repeat 15 times for 4 sets. Progression resistance with speed as participants tolerance.	Week 3–4
5 and 10 minutes' cycling (Hydro, Land)		Floated above water with noodle and both feet not touch the floor of the pool. Keep back straight and lean forward for 5-10 minutes cycling in the water or 5–10 minutes stationary cycling on Land. Progression with speed as participant tolerance.	Week 3–6

noodles on hydrotherapy were used to strengthen the knee extensor. A stationary bike on land-based and cycling in water with flotation noodles on hydrotherapy were used to enhance total leg muscle. Tiptoe on land-based and jogging in water on hydrotherapy for the calf muscle. The OA knee can be aggravated by pain if there is a lot of impact and compression force in the knee joint. Previous studies have shown that both groups tend to exercise this muscle group. The land exercise group used tiptoe[32], and hydrotherapy used running, jumping, or jogging[33, 34]. Although water exercise used tiptoe, the buoyancy of water could limit calf muscle performance. The calf muscles might not be able to generate force as land-based exercises. Thus, jogging was used in water instead of tiptoe in order to increase the strengthening of the calf muscles to match up with land-based exercise. Tiptoe on land-based for reducing joint compression force and jogging in the water on hydrotherapy reduces the joint compression force and strengthens the calf muscle.

The hydrotherapy group of exercises was performed at a hydrotherapy pool (32–33 °C). Noodles and water flotation were used for extra water resistance in strengthening exercises and deep water cycling. Both exercise groups performed the exercises under the supervision of a physiotherapist. Exercising all the leg muscles was important, and the latter objective of this study. The exercise protocols included the ankle plantar flexor muscles.

Statistical analysis was performed using SPSS version 17. The Kolmogorov-Smirnov Goodness of Fit test was used to evaluate data distribution. A two-way repeated ANOVA was used for within-and between-group analyses after six weeks and six months of follow-up. A p-value of maximum 0.05 was considered statistically significant. Intention-to-treat statistics were used for missing data.

RESULTS

We contacted 45 participants for recruitment into this trial. One participant (2.2%) did not meet the inclusion criteria, nine participants (20%) refused to participate, and one participant (2.2%) lost contact before the measurement process (Fig. 1). Therefore, 34 participants were included in this study. Seventeen participants (males=1, females=16) were randomly assigned to the land-based group, and 17 participants (males=2, females=15) were randomly assigned to the hydrotherapy group (Fig. 1). The baseline characteristics were not significantly different between the groups (Table 2). After six weeks of training, all participants completed the assessments (100% of the follow-up).

Thirty-four participants, aged 45–75 years old and diagnosed with osteoarthritis, participated in the study by an orthopedic doctor. The majority of participants were female (91.18%), with an average age of 57.8 years in the land-based exercise group and 64.88 years in the hydrotherapy group. The BMI was observed to be overweight in both groups (overweight=25–29.9). Four participants (23.33%) from the land-based exercise group and one participant from the hydrotherapy group (5.88%) had been administered a knee-joint injection before starting this study. One participant in both groups required the use of a walking-aid device for walking. This study used the modified 22-item Thai WOMAC version. The severity of knee OA participants' pain and function were reported as mean and SD, as shown in Table 2.

There was no significant difference between the groups in all outcomes for the between-group comparison at six weeks

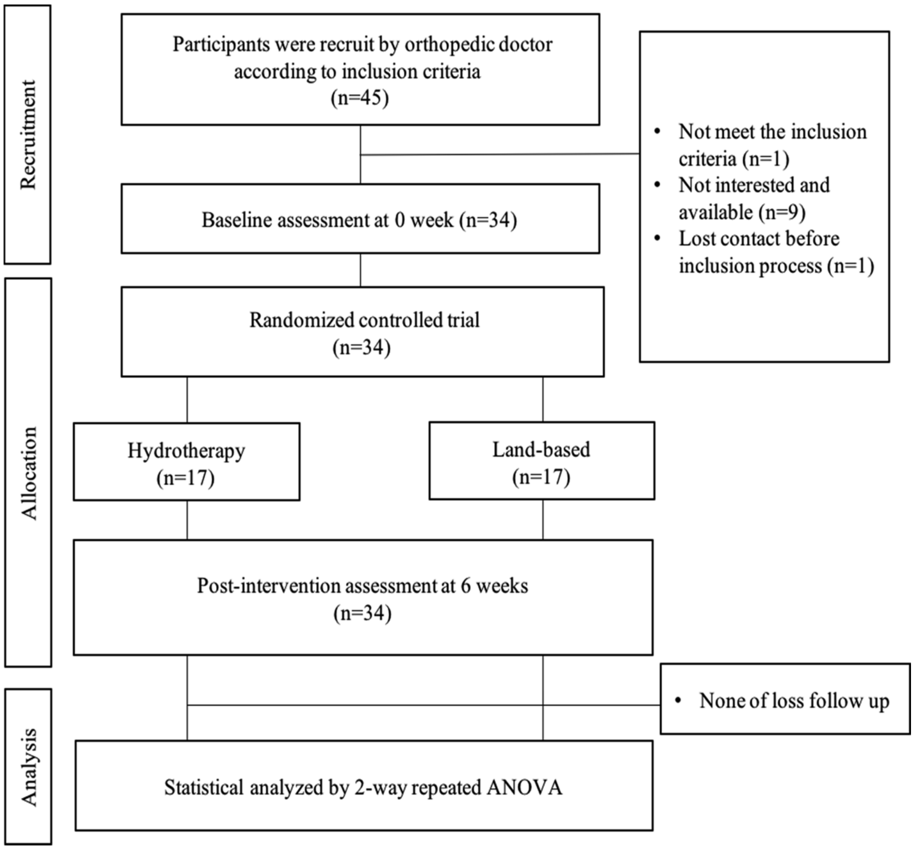


Fig. 1. Flow chart of all processes in this study.

Table 2. Characteristics of participants in both groups at baseline

Variables	Land-based (n=17) Mean ± SD	Hydrotherapy (n=17) Mean ± SD
Age (years)	57.88 ± 7.75	64.88 ± 7.44
Gender	Female=16 (94.12%) Male=1 (5.88%)	Female=15 (88.24%) Male=2 (11.76%)
Weight (kg)	66.27 ± 9.34	65.57 ± 7.8
Height (cm)	156.18 ± 5.19	157.71 ± 5.02
BMI (kg/m^2)	27.27 ± 4.38	26.34 ± 2.7
Total Modified WOMAC Thai ver. Score	90.71 ± 44.33	75.06 ± 50.71

and six months after training (Tables 3 and 4).

There was no significant difference in the SCT for the within-group comparison after six weeks of training in the land-based group compared with the baseline data (Table 2). In the hydrotherapy group, SCT was observed to improve significantly ($p<0.001$) (Table 3). In the land-based group, the quality of life showed significant improvement in the WHOQOL-BREF-THAI in the physical domain ($p<0.001$), WHO quality of health ($p<0.05$), and WHO total score ($p<0.05$) (Table 2). The hydrotherapy group showed significant improvement in the WHOQOL-BREF-THAI in the physical domain ($p<0.001$), WHO quality of health ($p<0.05$), WHO environment ($p<0.05$), and WHO total score ($p<0.001$) (Table 3).

The land-based group showed no significant difference in all the WHOQOL-BREF-THAI domains in the within-group comparison after six months. Conversely, the hydrotherapy group showed a substantial increase in the WHO mental ($p<0.05$), WHO social ($p<0.001$), WHO quality of health ($p<0.001$), and WHO total score ($p<0.05$) (Table 4).

Table 3. Comparison of functional mobility tests and WOMAC within-group and between-groups at 6 weeks follow-up

Parameters	Land-based (n=17)		Hydrotherapy (n=17)	
	Baseline	6 weeks	Baseline	6 weeks
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Time-up and go	10.29 ± 4.15	9.93 ± 5.09	10.97 ± 2.73	9.68 ± 2.34**
5 Times Sit-to-Stand	14.42 ± 3.71	11.2 ± 3.03**	15.36 ± 2.28	11.47 ± 3.04**
Stair Climbing Test	8.37 ± 4.49	8.1 ± 7.51	10.68 ± 5.85	6.86 ± 3.41**
WOMAC Pain	18.82 ± 10.89	7.94 ± 9.22**	17.53 ± 12.44	7.47 ± 6.85**
WOMAC Stiff	7.59 ± 6.12	3.47 ± 4.53*	6.06 ± 4.91	3.94 ± 4.66
WOMAC Function	64.29 ± 32.41	24.35 ± 28.61**	51.47 ± 36.43	20.24 ± 18.81**
WOMAC Total	90.71 ± 44.33	35.76 ± 41.15**	75.06 ± 50.71	31.65 ± 27.56**

*p<0.05; **p<0.01; significant differences within-group when comparing baseline and post-treatment values at 6 weeks by ANOVA.

Table 4. Comparison of WHOQOL within-group and between-groups at 6 months follow-up

Parameter	Land-based (n=17)			Hydrotherapy (n=17)		
	Baseline	6 weeks	6 months	Baseline	6 weeks	6 months
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
WHO physical	23.76 ± 3.93	27.24 ± 3.46**	28.53 ± 2.74	23.06 ± 3.25	27 ± 2.83**	29.06 ± 1.52
WHO mental	23.24 ± 4.09	24.18 ± 4.33	25.65 ± 2.91	22 ± 4.61	24.29 ± 1.69**	25.59 ± 1.42*
WHO social	10.12 ± 1.97	11.29 ± 2.17	12 ± 0.94	10.29 ± 3.22	10.71 ± 1.11	12.12 ± 0.8#
WHO environments	29.65 ± 4.99	30.18 ± 4.77	30.06 ± 2.99	28.53 ± 3.28	31.06 ± 2.79*	31.41 ± 1.70
WHO QOH	2.82 ± 1.33	4.12 ± 0.99*	3.82 ± 0.81	3.18 ± 0.88	3.71 ± 0.47*	4.00 ± 0.7#
WHO QOL	4.00 ± 0.87	3.94 ± 0.83	4.06 ± 0.66	3.82 ± 0.81	3.94 ± 0.75	4.12 ± 0.50
WHO total	86.76 ± 11.91	92.88 ± 12.23*	96.24 ± 8.05	83.88 ± 10.99	93.06 ± 5.80**	98.18 ± 3.43*
WHO QOL level	2.24 ± 0.44	2.35 ± 0.49	2.41 ± 0.51	2.29 ± 0.47	2.41 ± 0.51	2.88 ± 0.33

*p<0.05; **p<0.01; #p<0.001; significant differences within-group when comparing baseline, post-treatment at six weeks and six months of follow-up values by ANOVA.

DISCUSSION

There was no significant difference in any of the outcomes between the groups after six weeks and six months of follow-up. This study aimed to compare the effects of hydrotherapy and land-based progressive exercise on functional outcomes and quality of life in patients with knee OA. According to FITT, the details based on ACSM's Guidelines for Exercise Testing and Prescription were determined as optimal frequency, intensity, and time duration. Although the exercises were performed in different environmental situations (such as underwater and land-based), the exercise posture was designed with the same direction and range of motion. The exercise protocol was done completely same in terms of frequency, intensity, time, and duration and caused equal benefit[35] and no significant difference was observed between the groups.

For the within-group comparison after 6-weeks, there was a significant improvement in the WOMAC score in both groups. Pain was caused by the compression force that occurred within the knee[7]. According to Fransen et al., the Cochrane systematic review of 34 studies determined that exercise in people with knee OA could reduce knee pain and promote physical fitness[36]. Another previous study found that exercise protocols that determined increased leg muscle strength could reduce knee joint pressure. Increased leg muscle strength resulted in decreased knee pain and increased functional mobility (walking, sitting-to-standing, and up-down stairs)[33]. A previous study determined that increasing leg muscle strength was correlated with changes in pain relief, improved functional mobility, and improved quality of life[37]. This study utilized functional tasks (TUG, 5STS, and SCT) to assess lower extremity strengthening but did not consider individual muscle strengthening. Further studies should determine the duration of knee osteoarthritis, assessment of individual muscle strength, pain level during the exercise period (six weeks), and knee alignment for additional evidence to explain our results.

For the functional outcomes, only the sit-to-stand time improved in the land-based group, while the hydrotherapy group showed significant improvement in the TUG, 5STS, and stair climbing tests. The sit-to-stand test was used to assess the leg muscle strength. In this study, the exercise program did not provide exercises specific to the quadriceps muscles but focused on the global leg, improving the knee muscle strength[38, 39]. In addition, progressive strengthening exercises might lead to the increase in leg strength and affect functional mobility[37]. Moreover, exercise duration and frequency for six weeks[11, 40) might have been enough to affect leg muscle strength. However, in hydrotherapy, the body's movement must be coordinated to maintain the body's balance[41)].

Moreover, the body's metacenter must adjust the balance in water throughout the motion until the body is balanced between the center of gravity (COM) and buoyancy[42)]. Exercising of the knee OA may need to focus on the stimulation of proprioception during exercise[45)] because balance is important for adjusting the body position and proprioceptive sense. The body's movement must also be coordinated to maintain the body's compensation according to the principle of exercise in hydrotherapy[41)]. Previous studies have found that exercise in progressive hydrotherapy could promote leg muscle strength[30)], pain relief, and balance while in motion[43)]. The TUG test was used to evaluate functional mobility while walking and balancing[24)] and the SCT was a direct outcome measure of the ability to climb up and downstairs, which are common functional limitations and functional goals in patients with knee OA[25)]. Both TUG and SCT might require additional neuromuscular control and muscle co-contraction of the stance leg to maintain the center of gravity with a base of support while walking and up-down stairs[43)]. Hydrotherapy might enhance neuromuscular control and muscle co-contraction for walking and dynamic balance. Moreover, exercise protocols focused on functional movements such as stepping up and down and weight bearing in a single leg stance. A previous study reported that progressive exercise in hydrotherapy could promote leg muscle strength[30)], pain relief, and dynamic balance[43)].

Only hydrotherapy showed a significant improvement in the WHOQOL mental, social, quality of health, and total domains for the within-group comparison after six months of training. According to previous studies, the improvement of leg strength muscles would result directly in the reduction of pain and limit their functional movement[37)]. Strengthening leg muscles directly affect the efficiency of daily activities such as walking or climbing up and down the stairs. When the efficiency of daily activities increased, knee joint pain was alleviated. Moreover, possible psychosocial factors (depression, self-efficacy, avoidance of movement, and general health) were expected[37)]. Similar to Lim in 2010, we evaluated hydrotherapy with a generalized conditioning program with knee-specific exercises by physical therapy. The results revealed significant differences in the physical and mental domains of the Short Form 36-item Health Survey (SF-36) in hydrotherapy, similar to our results in the physical domain of WHOQOL-BREF-THAI. The exercise protocols used in this study were similar to those of the previous study. The exercise focused on increased strength by functional movements (squatting, multi-directional walking, and underwater bicycling)[33)]. The exercise frequency was the same; however, the duration was different from that in the previous study[33)]. Hydrotherapy might have reduced stress or anxiety of the participants. According to the study of Sevimli et al., the authors found that exercise with hydrotherapy could promote well-being (without physical, mental problems and can live in a society)[44)].

Moreover, a previous study reported that water movement was often comfortable and less painful than on land[12)]. The effects of water properties such as buoyancy could be applied to exercises to support the body[19)]. It was observed that the patients could exercise in water more easily than on land[12)]. It was determined that some patients in the hydrotherapy group felt relaxed while exercising in water and experienced reduced knee pain during the first two weeks of exercise. Previous studies found that exercising in water often made it comfortable and lessened knee pain significantly compared to land-based exercises[11, 12, 30, 32, 40)]. At the six months follow-up, several hydrotherapy groups still performed hydrotherapy exercises after completing the experiment. The increase in mobility and decreased knee joint pain would result in the improvement of psychological factors such as anxiety, self-confidence, and well-being[35)]. Finally, increasing leg muscle strength was correlated with changes in pain relief, improvement in mobility and in quality of life[37)].

According to the FITT based on ACSM's Guidelines for Exercise Testing and Prescription, we focused on optimal frequency, intensity, and time duration[45)]. The success of the exercise protocol in frequency, intensity, time, and duration could be used in the clinic. Hydrotherapy is suggested for improving mobility, functional tasks, and quality of life in knee OA. Moreover, some participants were reported to relax while performing hydrotherapy exercises. A previous study reported that water movement was often comfortable and less painful than on land[12)]. Hydrotherapy might have reduced the stress or anxiety of participants. The explanation for these unclear results could be that exercise generally affects individuals on components other than muscle strength components (neuromuscular function, physical fitness, and psychosocial factors), thereby leading to possible changes in clinical outcomes[46)]. In addition, we recommend that the long-term effect of exercise on mobility, functional task, and quality of life in knee OA be investigated. In this study, the exercise protocols were designed with three dimensions and a diagonal movement in a single leg. Moreover, the postures that promote daily life activity, double leg squats, step-up down, lunges, and calf raise were used in this study. For further study, we suggested increasing the frequency from three times per week for six weeks to long-term exercise and increase the intensity of exercise from mild to moderate or vigorous intensity. This protocol might apply to different water depths to increase weight-bearing as tolerance before transferring to land-based exercises.

Conflict of interest

None.

ACKNOWLEDGMENTS

The authors would like to thank all the patients who participated in this study. The Thammasat University research funding supported this study.

REFERENCES

1) Andriacchi TP, Mündermann A, Smith RL, et al.: A framework for the in vivo pathomechanics of osteoarthritis at the knee. Ann Biomed Eng, 2004, 32: 447–457. [Medline] [CrossRef]
2) Foley A, Halbert J, Hewitt T, et al.: Does hydrotherapy improve strength and physical function in patients with osteoarthritis--a randomised controlled trial comparing a gym based and a hydrotherapy based strengthening programme. Ann Rheum Dis, 2003, 62: 1162–1167. [Medline] [CrossRef]
3) Peungsuwan P, Sermcheep P, Harnmontree P, et al.: The effectiveness of Thai exercise with traditional massage on the pain, walking ability and QOL of older people with knee osteoarthritis: a randomized controlled trial in the community. J Phys Ther Sci, 2014, 26: 139–144. [Medline] [CrossRef]
4) Felson DT, Zhang Y: An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum, 1998, 41: 1343–1355. [Medline] [CrossRef]
5) Foley SJ, Lord SR, Srikanth V, et al.: Falls risk is associated with pain and dysfunction but not radiographic osteoarthritis in older adults: Tasmanian Older Adult Cohort study. Osteoarthritis Cartilage, 2006, 14: 533–539. [Medline] [CrossRef]
6) Mikesky AE, Mazzuca SA, Brandt KD, et al.: Effects of strength training on the incidence and progression of knee osteoarthritis. Arthritis Rheum, 2006, 55: 690–699. [Medline] [CrossRef]
7) O'Reilly SC, Jones A, Muir KR, et al.: Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. Ann Rheum Dis, 1998, 57: 588–594. [Medline] [CrossRef]
8) Luansritisakul C: Quality of life after total knee replacement at Siriraj hospital, Thailand. Siriraj Med J. 2016, 68.
9) Rukwong P, Chirawatkul S, Markovic M: Quality of life perceptions of middle-aged women living with a disability in Muang district, Khon Kaen, Thailand: WHOQOL perspective. J Med Assoc Thai, 2007, 90: 1640–1646. [Medline]
10) Jordan KM, Arden NK, Doherty M, et al. Standing Committee for International Clinical Studies Including Therapeutic Trials ESCISIT: EULAR Recommendations 2003: an evidence based approach to the management of knee osteoarthritis: report of a Task Force of the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCISIT). Ann Rheum Dis, 2003, 62: 1145–1155. [Medline] [CrossRef]
11) Fransen M, Nairn L, Winstanley J, et al.: Physical activity for osteoarthritis management: a randomized controlled clinical trial evaluating hydrotherapy or Tai Chi classes. Arthritis Rheum, 2007, 57: 407–414. [Medline] [CrossRef]
12) Wang TJ, Belza B, Elaine Thompson F, et al.: Effects of aquatic exercise on flexibility, strength and aerobic fitness in adults with osteoarthritis of the hip or knee. J Adv Nurs, 2007, 57: 141–152. [Medline] [CrossRef]
13) Giaquinto S, Ciotola E, Dall'Armi V, et al.: Hydrotherapy after total knee arthroplasty. A follow-up study. Arch Gerontol Geriatr, 2010, 51: 59–63. [Medline] [CrossRef]
14) Liebs TR, Herzberg W, Rüther W, et al. Multicenter Arthroplasty Aftercare Project: Multicenter randomized controlled trial comparing early versus late aquatic therapy after total hip or knee arthroplasty. Arch Phys Med Rehabil, 2012, 93: 192–199. [Medline] [CrossRef]
15) Piva SR, Gil AB, Almeida GJ, et al.: A balance exercise program appears to improve function for patients with total knee arthroplasty: a randomized clinical trial. Phys Ther, 2010, 90: 880–894. [Medline] [CrossRef]
16) Rahmann AE, Brauer SG, Nitz JC: A specific inpatient aquatic physiotherapy program improves strength after total hip or knee replacement surgery: a randomized controlled trial. Arch Phys Med Rehabil, 2009, 90: 745–755. [Medline] [CrossRef]
17) Harmer AR, Naylor JM, Crosbie J, et al.: Land-based versus water-based rehabilitation following total knee replacement: a randomized, single-blind trial. Arthritis Rheum, 2009, 61: 184–191. [Medline] [CrossRef]
18) Valtonen A, Pöyhönen T, Sipilä S, et al.: Maintenance of aquatic training-induced benefits on mobility and lower-extremity muscles among persons with unilateral knee replacement. Arch Phys Med Rehabil, 2011, 92: 1944–1950. [Medline] [CrossRef]
19) Bartels EM, Lund H, Hagen KB, et al.: Aquatic exercise for the treatment of knee and hip osteoarthritis. Cochrane Database Syst Rev, 2007, (4): CD005523. [Medline]
20) Stanley J, Buchheit M, Peake JM: The effect of post-exercise hydrotherapy on subsequent exercise performance and heart rate variability. Eur J Appl Physiol, 2012, 112: 951–961. [Medline] [CrossRef]
21) Kellgren JH, Lawrence JS: Radiological assessment of osteo-arthrosis. Ann Rheum Dis, 1957, 16: 494–502. [Medline] [CrossRef]
22) Valtonen A, Pöyhönen T, Sipilä S, et al.: Effects of aquatic resistance training on mobility limitation and lower-limb impairments after knee replacement. Arch Phys Med Rehabil, 2010, 91: 833–839. [Medline] [CrossRef]
23) Piva SR, Teixeira PE, Almeida GJ, et al.: Contribution of hip abductor strength to physical function in patients with total knee arthroplasty. Phys Ther, 2011, 91: 225–233. [Medline] [CrossRef]
24) Bennell K, Dobson F, Hinman R: Measures of physical performance assessments: Self-Paced Walk Test (SPWT), Stair Climb Test (SCT), Six-Minute Walk Test (6MWT), Chair Stand Test (CST), Timed Up & Go (TUG), Sock Test, Lift and Carry Test (LCT), and Car Task. Arthritis Care Res (Hoboken), 2011, 63: S350–S370. [Medline] [CrossRef]
25) Lin YC, Davey RC, Cochrane T: Tests for physical function of the elderly with knee and hip osteoarthritis. Scand J Med Sci Sports, 2001, 11: 280–286. [Medline] [CrossRef]
26) Kuptniratsaikul V, Rattanachaiyanont M: Validation of a modified Thai version of the Western Ontario and McMaster (WOMAC) osteoarthritis index for knee osteoarthritis. Clin Rheumatol, 2007, 26: 1641–1645. [Medline] [CrossRef]
27) Jakobsen TL, Kehlet H, Husted H, et al.: Early progressive strength training to enhance recovery after fast-track total knee arthroplasty: a randomized con-

trolled trial. Arthritis Care Res (Hoboken), 2014, 66: 1856–1866. [Medline] [CrossRef]

28) Jorge RT, Souza MC, Chiari A, et al.: Progressive resistance exercise in women with osteoarthritis of the knee: a randomized controlled trial. Clin Rehabil, 2015, 29: 234–243. [Medline] [CrossRef]
29) Latham NK, Bennett DA, Stretton CM, et al.: Systematic review of progressive resistance strength training in older adults. J Gerontol A Biol Sci Med Sci, 2004, 59: 48–61. [Medline] [CrossRef]
30) Hinman RS, Heywood SE, Day AR: Aquatic physical therapy for hip and knee osteoarthritis: results of a single-blind randomized controlled trial. Phys Ther, 2007, 87: 32–43. [Medline] [CrossRef]
31) Wyatt FB, Milam S, Manske RC, et al.: The effects of aquatic and traditional exercise programs on persons with knee osteoarthritis. J Strength Cond Res, 2001, 15: 337–340. [Medline]
32) Wang TJ, Lee SC, Liang SY, et al.: Comparing the efficacy of aquatic exercises and land-based exercises for patients with knee osteoarthritis. J Clin Nurs, 2011, 20: 2609–2622. [Medline] [CrossRef]
33) Lim JY, Tchai E, Jang SN: Effectiveness of aquatic exercise for obese patients with knee osteoarthritis: a randomized controlled trial. PM R, 2010, 2: 723–731, quiz 793. [Medline] [CrossRef]
34) Lund H, Weile U, Christensen R, et al.: A randomized controlled trial of aquatic and land-based exercise in patients with knee osteoarthritis. J Rehabil Med, 2008, 40: 137–144. [Medline] [CrossRef]
35) McAlindon TE, Bannuru RR, Sullivan MC, et al.: OARSI guidelines for the non-surgical management of knee osteoarthritis. Osteoarthritis Cartilage, 2014, 22: 363–388. [Medline] [CrossRef]
36) Fransen M, McConnell S, Bell M: Exercise for osteoarthritis of the hip or knee. Cochrane Database Syst Rev, 2003, (3): CD004286–CD004286. [Medline]
37) Knoop J, Steultjens MP, Roorda LD, et al.: Improvement in upper leg muscle strength underlies beneficial effects of exercise therapy in knee osteoarthritis: secondary analysis from a randomised controlled trial. Physiotherapy, 2015, 101: 171–177. [Medline] [CrossRef]
38) Filardo G, Kon E, Longo UG, et al.: Non-surgical treatments for the management of early osteoarthritis. Knee Surg Sports Traumatol Arthrosc, 2016, 24: 1775–1785. [Medline] [CrossRef]
39) Nguyen C, Lefèvre-Colau MM, Poiraudeau S, et al.: Rehabilitation (exercise and strength training) and osteoarthritis: a critical narrative review. Ann Phys Rehabil Med, 2016, 59: 190–195. [Medline] [CrossRef]
40) Silva LE, Valim V, Pessanha AP, et al.: Hydrotherapy versus conventional land-based exercise for the management of patients with osteoarthritis of the knee: a randomized clinical trial. Phys Ther, 2008, 88: 12–21. [Medline] [CrossRef]
41) So BC, Kong IS, Lee RK, et al.: The effect of Ai Chi aquatic therapy on individuals with knee osteoarthritis: a pilot study. J Phys Ther Sci, 2017, 29: 884–890. [Medline] [CrossRef]
42) Atkinson K, Coutts FJ, Hassenkamp AM, MCSPM. Physiotherapy in orthopaedics: a problem-solving approach, 2nd ed. Edinburgh: Elsevier Churchill Livingstone, 2005.
43) Al-Khlaifat L, Herrington LC, Tyson SF, et al.: The effectiveness of an exercise programme on dynamic balance in patients with medial knee osteoarthritis: a pilot study. Knee, 2016, 23: 849–856. [Medline] [CrossRef]
44) Sevimli D, Kozanoglu E, Guzel R, et al.: The effects of aquatic, isometric strength-stretching and aerobic exercise on physical and psychological parameters of female patients with fibromyalgia syndrome. J Phys Ther Sci, 2015, 27: 1781–1786. [Medline] [CrossRef]
45) American College of Sports Medicine: ACSM's guidelines for exercise testing and prescription: Lippincott Williams & Wilkins; 2013.
46) Bartholdy C, Juhl C, Christensen R, et al., editors.: The role of muscle strengthening in exercise therapy for knee osteoarthritis: a systematic review and meta-regression analysis of randomized trials. Seminars in arthritis and rheumatism. Philadelphia: WB Saunders, 2017.