

Effect of aqua walking exercise on knee joint angles, muscular strength, and visual analogue scale for patients with limited range of motion of the knee

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The purpose of this study is to identify the effects of aqua walking exercise on the joint range of motion (ROM), muscular strength, and pain in patients who have limited knee ROM from surgery or joint fixation. Ten subjects were participated in this study and divided into two groups: continuous passive motion (CPM) therapy+walking exercise on dryland (CWD) and CPM+aqua walking exercise (CAW) groups. The repeated measures analysis of variance was used to verify the difference between the groups and the duration of the program. A paired *t*-test was used to verify the significance of the observed difference within the groups, and an independent *t*-test was used to verify the significance of the observed difference between different groups. In this study, ROM in the knee flexion showed interaction effect between the two groups. CAW had a significant increase of knee flexion angle compared to

those in CWD. Also, strength on the knee flexors showed interaction effect between the two groups. CAW had a significant increase of knee flexion angle compared to those in CWD, while strength on the knee extensors showed no significant interaction effect between groups. Visual analogue scale (VAS) score showed interaction between the two groups. CAW had a significant increase of the VAS scores compared to those in CWD. Given these findings reported in present study, aqua walking exercise for patients with osteoarthritis is a very safe and effective therapeutic strategies that can move the joint in the optimal ROM.

Keywords: Aqua walking exercise, Range of motion, Strength, Visual analogue scale, Knee pain


INTRODUCTION

Osteoarthritis has traditionally been classified as a noninflammatory degenerative joint disease that leads to breakdown of the cartilage and bone in weight-bearing joint, such as the hands, knees, hips, and spine (Glyn-Jones et al., 2015). The knee joint is one of the largest and most complex joints in the human body, and belongs to a synovial joint that connects the femur, tibia, and patella. The knee joint also is stabilized by surrounding skeletal muscles, tendons, and ligaments, but it is a joint with a high risk of injury in daily life or sports activities (Albtoush et al., 2018). In particular, it has been reported that overuse of the knee joint is closely related to osteoarthritis (Khawaja et al., 2021).

Chronic osteoarthritis causes deformation in the knee, and total

knee arthroplasty (TKA) is applied to secure the mobility and stability of the knee joint according to the severity of the. Most patients with TKA complain of limited range of motion (ROM), pain, edema, and muscle weakness around the knee joint as well as deterioration of skeletal muscle function (Yoshiko et al., 2020). To recover these dysfunctions, the important of exercise therapy is emphasized in the field of rehabilitation, and the main goal of exercise rehabilitation is to improve muscle strength and restore ROM in the knee joint.

A few days after TKA is the initial stage of excise rehabilitation, where various active ROM exercises including continuous passive motion (CPM), eccentric contraction exercises, proprioceptive neuromuscular facilitation, and aquatic exercise are performed. Previous studies have suggested that knee ROM in patients who un-

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derwent TKA is limited to 30–40 degrees, and daily life is possible only when ROM is increased to 100 degrees (Wu et al., 2017).

Among these therapeutic exercises for patients with TKA, aquatic exercise is known to have the advantage of reducing load on the knee joint, preventing soft tissue shortening, and restore ROM of the knee (Myles et al., 2002). Batterham et al. (2011) confirmed that both dry land exercise and aquatic exercise improved muscular strength and ROM in knee joint of the osteoarthritis patients. Hinman et al. (2007) represented that aquatic exercise therapy for 6 weeks applied for the treatment of hip and knee osteoarthritis had a positive effect on muscle function, quality of life, and pain. Also, some recent studies, aquatic exercise approach after TKA induced an increase in the muscle strength of the quadriceps and hamstrings, and an enhancement in walking speed, and a decrease in pain of the knee (Rewald et al., 2016; Taglietti et al., 2018).

Considering these previous studies, it can be seen that aquatic exercise is the main treatment strategy for promoting the functional recovery in patients with knee osteoarthritis. However, the lack of scientific evidence for effect of aquatic exercise in the field of osteoarthritis is pointed out as a limitation in clinical application. Therefore, the purpose of this study focuses on investigating the effect of aquatic exercise therapy on knee ROM, muscular strength, and pain in patients having limited ROM from TKA or joint fixation

MATERIALS AND METHODS

Participants

The participants in this study were 10 patients with limitation of the knee joint from TKA or joint fixation (Table 1), and they are divided into two groups: the CPM+walking exercise on dryland (CWD, n = 5) and the CPM+aqua walking exercise (CAW, n = 5) groups. Before beginning the study, all participants had a detailed explanation of this study and submitted their written informed consent to the researchers. This research was conducted ethically according to international guidelines.

Table 1. Physical characteristics of the subjects.

Variable	CWD (n=5)	CAW (n=5)
Age (yr)	24.4±4.2	34.4±18.3
Height (cm)	178.8±2.3	171.8±10.7
Weight (kg)	80.4±4.6	70.0±8.9

Values are presented as mean ± standard deviation.

CWD, continuous passive mode (CPM) and walking on dryland; CAW, CPM and aqua walking.

Training program

Dry land and aquatic exercises were performed for 5 days a week, and exercise program consisted of 30 min of CPM therapy and 30 min of walking exercise. On day 1 and 2, a cycle of 5 min of walking exercise followed by 5 min rest was repeated 3 times. On day 3 to 5, a cycle of 7 min of walking exercise followed by 3 min resting was repeated 3 times. Exercise intensity was adjusted to pain-free walking speed. CPM therapy was conducted in maximum ROM that patient could contract and relax the knee without pain (Wirries et al., 2020). The cycle of extension and flexion of the knee in CPM was determined to be 30 sec.

Knee ROM testing

The active ROM of the subject's knee was measured by a physical therapist using universal and reliable goniometer. The subjects lie on a bed in the supine position with their knee extended. And then the active ROM was measured by flexing the knee joint. In order to reduce the error between measurements, ROM test was repeated 3 times and the average value was applied.

Manual muscle testing

The manual muscle test was performed by applying the method used by Rätsepsoo et al. (2013). In order to reduce the error between measurements, ROM test was repeated 3 times and the average value was applied. It was quantitatively evaluated through scoring for grades.

Visual analogue scale

The visual analogue scale (VAS) is psychometric response scales to investigate a unidimensional measure of pain intensity, and it is widely used in clinical research to examine the intensity or frequency of pain (Gould et al., 2001; Paul-Dauphin et al., 1999). The VAS was a 10-cm horizontal or vertical line, and both ends were marked with no pain or the most severe pain. The subjects marked a point that matched the intensity of the pain they are currently feeling.

Statistical analysis

PASW Statistics ver. 18.0 (SPSS Inc., Chicago, IL, USA) was used to determine the effect of aquatic walking exercise in patients with knee osteoarthritis. To confirm the main effect, we used a two-way repeated analysis of variance. If there was a significant interaction effect, an independent *t*-test between groups or a paired *t*-test between times was applied. All values are expressed as mean ± standard deviation. *P* < 0.05 was considered significant.

Table 2. The result for ROM of the knee

Variable	Group	Pre	Post	F-value
Flexion	CWD	92.0±15.25	106.0±12.9**	G×P: 12.190 ^{††}
	CAW	100.0±7.9	130.0±6.1**	
Extension	CWD	18.0±4.5	14.0±5.5	G×P: 1.600
	CAW	16.0±8.2	8.0±4.5*	

Values are presented as mean ± standard deviation.

ROM, range of motion; CWD, continuous passive mode (CPM) and walking on dryland; CAW, CPM and aqua walking

* $P < 0.05$ and ** $P < 0.01$, significantly different from pretest. ^{††} $P < 0.01$, significantly interaction among group and period.

RESULTS

Dryland and aquatic exercises regulate ROM in the knee extension and flexion

Changes of ROM in the knee extension and flexion before and after dryland and aquatic exercise were investigated at the early phase of exercise rehabilitation. As shown in Table 2, ROM in the knee flexion ($F = 12.190$, $P = 0.008$) showed interaction effect between groups. CAW had a significant increase of knee flexion angle compared to those in CWD, and within groups, both CAW ($t = -7.171$, $P = 0.002$) and CWD ($t = -7.483$, $P = 0.002$) significantly increased values for ROM in knee flexion movement. ROM in the knee extension ($F = 1.600$, $P = 0.242$) showed no significant interaction effect between groups. There were significant differences only in the knee extension ROM of CAW ($t = 4.000$, $P = 0.016$).

Dryland and aquatic exercises control the knee extensors and flexors

Changes of the knee flexor muscle strength before and after dryland and aquatic exercise were investigated at the early phase of exercise rehabilitation. As shown in Table 3, strength on the knee flexors ($F = 5.333$, $P = 0.050$) showed interaction effect between groups. CAW had a significant increase of knee flexion angle compared to those in CWD, and within groups, there were significant differences only in the hamstring muscle strength of CAW ($t = -5.715$, $P = 0.005$). Strength on the knee extensors ($F = 3.600$, $P = 0.094$) showed no significant interaction effect between groups. Within groups, there were significant differences only in the hamstring muscle strength of CAW ($t = -6.000$, $P = 0.004$).

Dryland and aquatic exercises regulate the values in VAS

To examine the pain VAS, we performed a subjective measure before and after dryland and aquatic exercise. As shown in Table 4, VAS score ($F = 14.727$, $P = 0.005$) showed interaction between the

Table 3. The result for Manual muscle testing

Variable	Group	Pre	Post	F-value
Flexor	CWD	3.2±0.5	3.8±0.5	G×P: 5.333 [†]
	CAW	3.0±0.0	4.4±0.6**	
Extensor	CWD	3.4±0.6	4.0±0.0	G×P: 3.600
	CAW	3.4±0.9	4.6±0.6**	

Values are presented as mean ± standard deviation.

CWD, continuous passive mode (CPM) and walking on dryland; CAW, CPM and aqua walking.

** $P < 0.01$, significantly different from pretest. [†] $P < 0.05$, significantly interaction among group and period.

Table 4. The result for visual analogue scale

Variable	Group	Pre	Post	F-value
VAS	CWD	3.6±0.4	3.0±0.7	G×P: 14.727 ^{††}
	CAW	4.0±1.0	1.6±0.6**	

Values are presented as mean ± standard deviation.

CWD, continuous passive mode (CPM) and walking on dryland; CAW, CPM and aqua walking; VAS, visual analogue scale.

** $P < 0.01$, significantly different from pretest. ^{††} $P < 0.01$, significantly interaction among group and period.

two groups. CAW had a significant increase of the VAS scores compared to those in CWD, and within groups, there were significant differences only in the hamstring muscle strength of CAW ($t = 6.000$, $P = 0.004$).

DISCUSSION

ROM test has been often used in daily life and sports field to examine the joint mobility and performance capacity (Moreno-Pérez et al., 2020). In general, ROM of the joint is associated with increasing age and pain in specific area (Kennedy et al., 2013). In the present study, we found that ROM in the knee flexion was further increased in the knee flexion compared to CWD, but the value of ROM in the knee extension did not show a significant difference between the CWD and CAW groups. Application of CPM therapy in the initial rehabilitation of patient with limited ROM of the knee joint positively affected in the change of ROM and pain during the knee extension and flexion as well as reduced length of stay in hospital (Bakirhan et al., 2015; Liao et al., 2016; Yang et al., 2019). Also, recent studies reported that aquatic exercise for the treatment of knee osteoarthritis could be safe and improve pain, disability, and quality of life (Assar et al., 2020). The results of these previous studies support the importance of aquatic walking exercise in therapeutic strategy for developing the knee ROM.

Increased quadriceps muscle strength is associated with functional stability of the knee joint, quality of life, and improvement of exercise performance. In addition, it has been reported that, in patients with ROM limitation such as TKA, the increase in quadriceps muscle strength at the initial stage of rehabilitation is one of the important factors determining the success of rehabilitation (Greene and Schurman, 2008; Loyd et al., 2019). We confirmed that CAW significantly increased the strength in the knee extensors and flexors compared to those in CWD. These results are consistent with the study that reported that aquatic exercise, rather than dryland exercise, developed muscle strength in patients with TKA (Lee and Kim, 2021). In particular, in this study, aqua walking exercise was found to be effective in enhancing knee flexor muscles. The reason for these results is thought to be that the knee extension in the quadriceps and knee flexion in the hamstrings were rhythmically and smoothly performed according to the reduction of pain while walking in water (Kim et al., 2021).

Chronic pain in osteoarthritis is produced by weakness and imbalance in the muscular strength around the knee, knee instability caused by a deformity of the knee, and morphological changes in the synovial cyst, ligaments, and nerve tissue due to inflammatory substances in the knee joint (Courtney et al., 2017). Patients with osteoarthritis experience stiffness in the affected joints, and the pain tends to be worse after overuse or long periods of inactivity (Shadyab et al., 2018). As side effects of drug treatment for improvement in osteoarthritis pain have been reported, nonpharmacological interventions including exercise, stretching, stress relief are emphasized in the clinical field (Nejati et al., 2015). Among various non-pharmacological pain managements, exercise therapy is a self-controlled management method (Skou et al., 2018), and it is effective in reducing pain and body weight as well as increasing ROM of the knee joint and muscle strength. In our study, the values in VAS was significantly decreased in CAW when compared to CWD. These results are thought to be due to that aqua walking exercise only weighs 10% of the body weight compared to on the ground, minimizing stress on joints, bones, tendons, ligaments, and muscles.

Given these findings reported in present study, aqua walking exercise for patients with limited ROM of the knee is a very safe and effective therapeutic strategies that can move the joint in the optimal ROM.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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