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Short-Term Effects of Home-Based Isometric Quadriceps Exercise Alleviated Pain and Improved Quality of Life in Elderly People with Dominant Symptomatic Pain of Knee Osteoarthritis: A Randomized Control Trial

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ABSTRACT

Maharan S, Sungkamanee S, Tapanya W, et al. Short-Term Effects of Home-Based Isometric Quadriceps Exercise Alleviated Pain and Improved Quality of Life in Elderly People with Dominant Symptomatic Pain of Knee Osteoarthritis: A Randomized Control Trial. **JEPonline** 2023;26(2):14-26. The purpose of this study was to evaluate the effects of quadriceps isometric exercise on pain level, muscle strength, and quality of life in 24 elderly adults with severe pain due to osteoarthritis of the knee (OA knee). The subjects were randomly divided into 2 groups: the Control Group (n = 12) and the Experimental Group (n = 12). The perception of knee pain, maximum isometric strength of the quadriceps muscle, and quality of life were measured at baseline and after 4 weeks using a numerical pain rating scale, a hand-held dynamometer, and a modified WOMAC questionnaire. The results showed that 4 weeks of home-based quadriceps isometric exercise resulted in a significant improvement in the level of pain (P = 0.000) and overall quality of life (P = 0.013), but there was not a significant increase in peak force of quadriceps muscle contraction (P = 0.075) when compared to the Control Group.

Key Words: Isometric Exercise, OA knee, Pain, Quadriceps

INTRODUCTION

Osteoarthritis of the knee (OA knee) is one of the foremost rheumatology problems that lead to pain and disability worldwide (14). The global prevalence of OA knee was reported at 654.1 million people 40 years of age and over, and it also increases with age, especially in the elderly adults (5,14). In Thailand, the prevalence of OA knee is quite high and has varying distribution. The latest survey of the Northeastern and Northern areas shows 4 to 31% (20,28) while the Bangkok area is around 34.5 to 45.6% (5,14). These findings point to the fact that the government experiences a great burden for the rehabilitation of those who are symptomatic and suffering from the disease.

The primary clinical characteristics of OA knee patients are pain, morning stiffness and joint crepitation, muscle weakness and atrophy over time, and the possibility of a deformity of the bone. Collectively, these conditions result in a decrease in knee function that ultimately has a negative effect on the quality of life (15,19,31). To try avoid the conditions, the American College of Rheumatology (ACR) guidelines for osteoarthritis management recommends both pharmacological and non-pharmacological treatments, such as physical, psychological, and mind) (15,16,31). For example, the quadriceps isometric exercise is one of today's popular non-pharmacological approaches that could promote physical activities in people with OA knee through muscle contraction without any considerable change in muscle length and it is a low-impact joint exercise (23).

In fact, recent studies have reported that the quadriceps isometric exercise training could mitigate pain levels and improve function in adults with an OA knee and non-specific symptomatic level of pain (2,12,13,27). This is particularly important, given that there remains a group of adults with severe symptomatic pain of OA knee in the north of Thailand who could not undergo the knee replacement procedure because they either prefer conservative treatment or have some underlying disease. As a result, there is less evidence to demonstrate the potential of isometric exercise in specific symptomatic levels of pain in OA knee patients. Therefore, this study was designed up to determine the effects of quadriceps isometric exercise at home on pain level, strength, and quality of life in elderly adults with symptomatic pain due to the OA knee.

METHODS

Subjects

The list of participants was collected between January 2020 and July 2021 from the database of the Medical Record Department, Phayao Hospital, Phayao province, Thailand. Males or females from 11 primary care units with age higher than 60 who were diagnostic primary osteoarthritis of the knee based on ACR criteria and Grade 2 or more along with radiological evidence followed by adherents to the Kellgren Lawrence method (i.e., pain scale more than 7, unilateral or bilateral involvement of knee, and in case of bilateral: more symptomatic side was included). On the other hand, the subjects who met a current history of severe medical problems such as cancer, fracture in lower limbs, uncontrollable hypertension, diabetes mellitus, knee arthroplasty, regular exercise, and poor communication were excluded (2).

Then, the eligible people who were willing to participate in the program were signed and informed before the experiment started. During the 4 weeks intervention period, they could withdraw from the study at any time. At the end of the study, they were excluded if the percentage of attendance was less than 80%. All methodology was approved by the human ethics committee of the University of Phayao, based on the Declaration of Helsinki. Thai Clinical Trials Registry (TCTR) identification number is TCTR20230130003. The population was calculated via the magnitude of the mean and standard error of the mean from previous studies by setting the $\alpha = 0.05$ and $\beta = 0.01$, respectively (2).

Procedures

Out-patients from 11 Primary Care Units of Mae-ka sub-districted, Maung district, Phayao province were listed and announced as the participants who met the inclusion criteria. They were enrolled in the experiment. The brief aims and exercise prescription were explained to the caregivers by a physical therapist. The simple randomization was developed via an envelope seal number to avoid selection bias. Then, the subjects were allocated into 2 Groups as indicated in Figure 1. Both Groups must avoid the exercise that influences LEs strengthening throughout the experiment. The variable outcomes were recorded at baseline and after 4 weeks of intervention.

Experimental Group

The subjects were expected to participate in a home base quadriceps isometric exercise by placing a simple plastics-like spring device beneath the affected knee. Specifically, each subject would sit in long sitting posture with the back against the wall. The plastic-like spring device was placed beneath the affected knee. Then, the subject would create a maximum active isometric contraction of the quadriceps for a time period of 10 seconds with the ankle in the dorsiflexed position. The isometric contraction was done 10 times per set, 3 sets per day, and 5 days per week. During the first week, the subjects and caregivers were provided a description and demonstration of how the exercise should be done before starting the experiment at the primary care units by a physical therapist. After that, it was expected that the exercise would be done at home throughout the 4 weeks of the study. The progression of exercise was recommended and justified by the physical therapist about 5 to 10 times each week. The satisfaction of participants was co-considered when the previous exercise could not be produced due to the adverse effects of pain. The approach was used to ensure attendance, acknowledgement of the subjects' level of pain, as well as the subjects' satisfaction in a diary every week via caregiver.

Control Group

The subjects were told to engage in normal daily activities that was consistent with their doctors' information regarding the care of their OA knee without any exercise during the experiment period.

Data Collection

The subjects' demographics (regarding age, weight, height, and Body Mass Index) were collected. Moreover, the three main important outcomes were assessed at baseline and at the end of the experiment. The outcomes consisted of the subjects' level of pain, quadriceps muscle strength, and quality of life.

Outcome Measures

Numerical Pain Rating Scale (NPRS)

The level of knee perception of pain was assessed using the NPRS. It is commonly used as the outcome measure for patients with OA knee. The NPRS is considered to be reliable, valid, and responsive (1). The subjects in the Control Group and the Experimental Group were evaluated to determine their level of pain. Their perception of the OA knee was recorded via an interview using the NPRS, which rated the pain from 0 (no pain) to 10 (the worst imaginable pain).

Quadriceps Muscle Strength by Using Hand-Held Dynamometer (HHD)

The Hand-Held Dynamometer (HHD) has the potential to overcome some of the logistic and economic limitations of isokinetic dynamometers for measuring knee extension muscle strength with a reliability that is more than 0.950 (24) and no significant difference was observed when compared with the gold standard Isokinetic Dynamometer (IKD) (11). Any change in muscle strength of the quadriceps on the affected side was measured by a well-trained physical therapist ($r > .90$) with the knee flexed at 90 degrees. The best value of peak force of muscle contraction was calculated in N unit via Hand-Held Dynamometer (Lafayette Hand-Held Dynamometer, Model 01165; England). The subject sat in a chair without a foot rest. The arms were crossed with both hands in a static position. The subject then underwent a maximum 5 second isometric effort of the extended knee.

Quality of Life by Using Modified WOMAC Questionnaire

The WOMAC index was developed by Bellamy et al. (3) for assessing the symptoms (pain and stiffness) and functional impairment. It was used in clinical trials with OA subjects, and it was validated in 1988. The test-retest reliability for pain, stiffness, and function is ICC = 0.74, 0.58, and 0.92, respectively (26). All the subjects were interviewed regarding their activities in daily living by using modified WOMAC questionnaires that were divided into 3 dimensions. The first dimension evaluated the subjects' pain symptoms related to daily life activities such as walking, going and down upstairs, standing, etc., and finalized into 5 choices. The score in each choice ranged from 0 (no pain) to 10 (severe pain). After that, the second and the third dimensions were related to the stiffness and the function of the knee, respectively. The scale was graded as same as the dimension of pain (9).

Statistical Analyses

All data were collected as Mean (± SE) in SPSS version 23. A Shapiro-Wilk Test was applied to evaluate the normal distributions of the outcome variables. In the case of normal distributions, a parametric test was used to analyze the data by using dependent and independent student *t*-tests to compare the mean difference within and between groups, respectively. On the other hand, the Mann-Whitney *U* test and the Wilcoxon Signed-Rank Test were applied when the variables were not normally distributed. The level of statistical significance was set at an alpha level of $P < 0.05$.

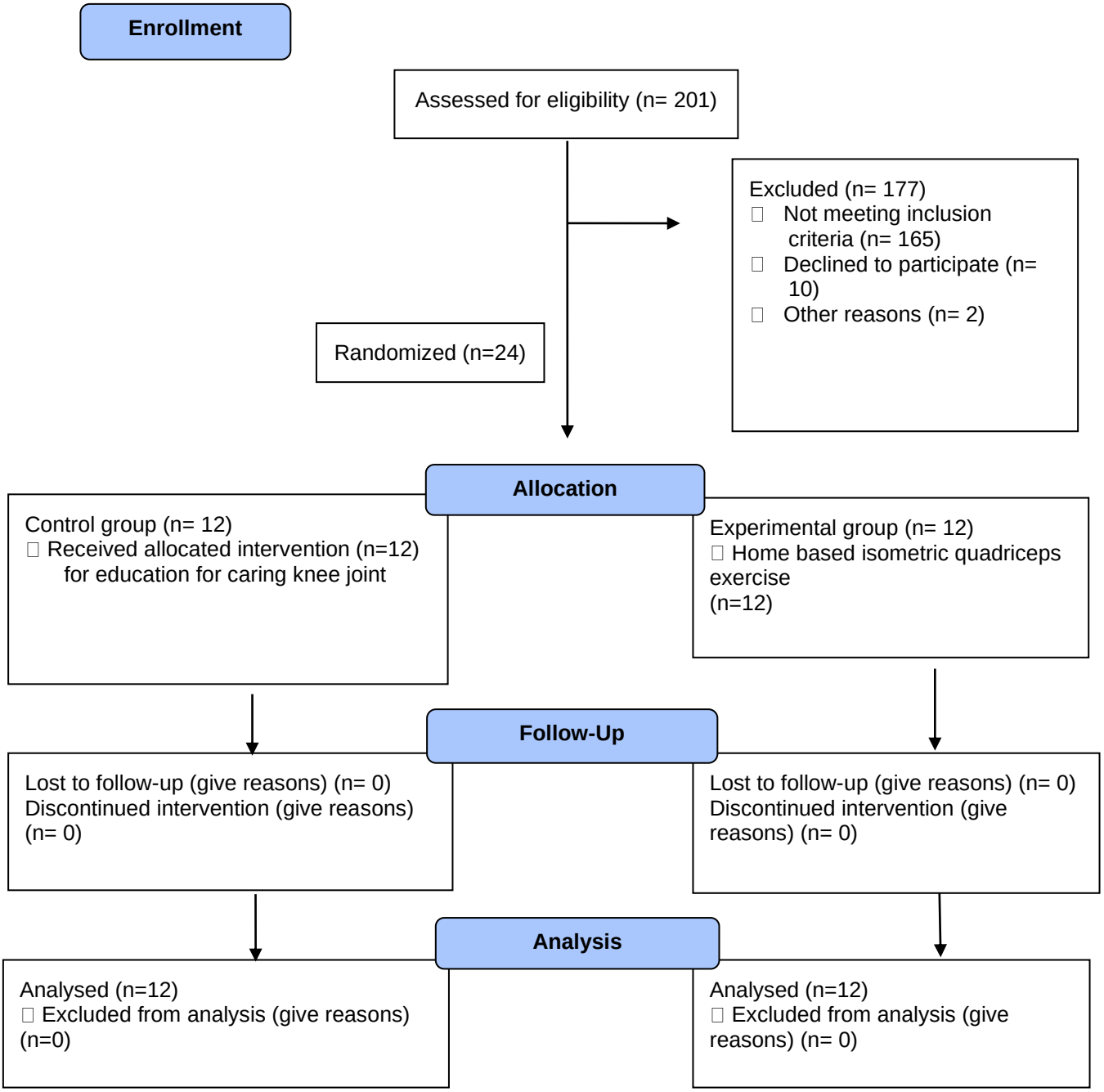

Figure 1. CONSORT Diagram of This Experiment.

RESULTS

A total of 201 participants were assessed for eligibility. Twenty-four participants were enrolled in this study (4 males and 20 females). They were randomly divided into 12 subjects in each group. There were no significant differences in the demographic details and the clinical characteristics of the subjects between the 2 Groups ($P > 0.05$) as shown in Table 1.

Table 1. Demographic and Clinical Characteristics Data of the Subjects in Each Group (n/gr = 12) (Mean ± SD).

Variables	Control Group (n/gr=12)	Experimental Group (n/gr=12)	P-value
Male (%)	2(16.67)	2(16.67)	-
Female (%)	10(83.33)	10(83.33)	-
Age (years)	72.42 ± 8.05	73.75 ± 9.76	0.719
Weight (kg)	52.33 ± 14.37	52.75 ± 9.39	0.934
Height (m)	1.54 ± 0.10	1.56 ± 0.09	0.771
Body Mass Index: BMI ($kg \cdot m^{-2}$)	21.67 ± 4.43	21.72 ± 2.67	0.974
Numeric Pain Rating Scale: NPRS (cm)	7.92 ± 1.18	7.58 ± 1.00	0.459
Total WOMAC Score (point)	76.58 ± 22.88	75.00 ± 50.42	0.922
- Pain	18.33 ± 8.71	20.58 ± 12.57	0.616
- Stiffness	6.83 ± 2.89	7.83 ± 4.28	0.510
- Function	49.42 ± 21.03	53.92 ± 29.64	0.673
Q Strength (N)	78.08 ± 42.87	85.12 ± 41.39	0.686

kg = Kilogram; **m** = Meters; **m^2** = Square Meters; **cm** = Centimeter; **WOMAC** = Western Ontario and McMaster Universities Osteoarthritis Index; **N** = Newton; **Q Strength** = Quadriceps Strength

At the end of 4 weeks of the Experimental Group, the main significant improvement was observed in NPRS (5.25 ± 1.14 vs. 7.58 ± 1.00, P = 0.000; Cohen's d = 2.17), Total WOMAC score (45.92 ± 25.29 vs. 75.00 ± 50.42, P = 0.006; Cohen's d = 0.73), stiffness subpart of WOMAC score (4.33 ± 2.74 vs. 7.83 ± 4.28, P = 0.023; Cohen's d = 0.97), and function (32.42 ± 14.32 vs. 53.92 ± 29.64, P = 0.047; Cohen's d = 0.92) when compared with baseline respectively. Besides the change in the subjects' Quadriceps strength and pain subpart of the WOMAC score, it did not reach a significant level (P > 0.05). There were no mean changes in the Control Group in all the parameters observed when compared to the baseline values (P > 0.05), as shown in Table 2.

Table 2. Mean Outcome Variables Compare at Baseline and After 4 Weeks in Each Group (Mean ± SD).

Groups/ Time	Outcome Variables	Baseline	After 4 Weeks	P-value	Cohen's d
Control Group (n = 12)	**NPRS** (cm)	7.92 ± 1.16	7.50 ± 1.09	0.137	0.37
	Q Strength (N)	78.08 ± 42.87	75.72 ± 28.03	0.825	0.06
	Total WOMAC (point)	76.58 ± 26.71	72.83 ± 23.34	0.061	0.15
	- Pain	18.33 ± 8.71	18.42 ± 7.01	0.975	0.01
	- Stiffness	6.83 ± 2.89	6.50 ± 2.94	0.718	0.11
	- Function	49.42 ± 21.03	50.67 ± 17.82	0.883	0.06
Experimental Group (n = 12)	**NPRS** (cm)	7.58 ± 1.00	5.25 ± 1.14	0.000***	2.17
	Q Strength (N)	85.12 ± 41.39	100.77 ± 36.07	0.264	0.40
	Total WOMAC (point)	75.00 ± 50.42	45.92 ± 25.29	0.006**	0.73
	- Pain	20.58 ± 12.57	13.00 ± 8.87	0.185	0.69
	- Stiffness	7.83 ± 4.28	4.33 ± 2.74	0.023*	0.97
	- Function	53.92 ± 29.64	32.42 ± 14.32	0.047*	0.92

Note: * P-value less than 0.05; ** P-value less than 0.01; *** P-value less than 0.001
NPRS = Numeric Pain Rating Scale; **Q Strength** = Quadriceps Strength; **WOMAC** = Western Ontario and McMaster Universities Osteoarthritis Index; **cm** = Centimeter; **N** = Newton; **Cohen's d** = Effect Side: 0.20 (Small), 0.50 (Medium), 0.80 (Large) (9)

In Table 3, the short duration of home-based isometric quadriceps exercise showed a significant difference between the Groups in NPRS (P = 0.000; Cohen's d = 2.01), total WOMAC score (P = 0.013; Cohen's d = 1.10), and function subpart of the WOMAC score (P = 0.012; Cohen's d = 1.13) when compared with the Control Group. The exercise tends to promote the strength of the quadriceps (P = 0.075), the stiffness subpart of WOMAC score (P = 0.075), and the pain subpart of the WOMAC score (P = 0.111).

Table 3. Mean Outcome Variables Compare Between Groups at the End of Experiment (Mean ± SD).

Groups/ Time	Outcome Variables	Control Group (n = 12)	Experimental Group (n = 12)	P-value	Cohen's d
After 4 weeks	**NPRS** (cm)	7.50 ± 1.09	5.25 ± 1.14	0.000***	2.01
	Q Strength (N)	75.72 ± 28.03	100.77 ± 36.07	0.075	0.77
	Total WOMAC (point)	72.83 ± 23.34	45.92 ± 25.29	0.013*	1.10
	- Pain	18.42 ± 7.01	13.00 ± 8.87	0.111	0.67
	- Stiffness	6.50 ± 2.94	4.33 ± 2.74	0.075	0.76
	- Function	50.67 ± 17.82	32.42 ± 14.32	0.012*	1.13

Note: ***P-value less than 0.05; ***P-value less than 0.001. **NPRS = Numeric Pain Rating Scale; **Q Strength** = Quadriceps Strength; **WOMAC** = Western Ontario and McMaster Universities Osteoarthritis Index; **cm** = Centimeter; **N** = Newton; **Cohen's d** = Effect Side: 0.20 (Small), 0.50 (Medium), 0.80 (Large) (9).

DISCUSSION

The purpose of this study was to evaluate the short-term effects of the home-based quadriceps isometric knee exercise on pain level, strength, and Quality of Life in elderly adults with severe symptomatic pain dominant in OA knee patients at Muang district, Phayao province, Thailand. The main finding after 4 weeks of progressive isometric exercise was that there was an improvement in the pain level of the effected training side and the subjects' quality of life. Moreover, there was a trend in the improvement of maximum peak force of muscle contraction of the quadriceps on the trained side. Furthermore, this is the first time that presents the effects of a prototype on pain and function in OA knee adults.

Almost 80% of the osteoarthritis adults were interested in the experiment, but their symptoms were less than the expected criteria. About 9% declined to participate for personal and other reasons, and 2 participants had a severe underlying disease as shown in Figure 1. It could be assured that our study concerns the default effect of selected bias at baseline ($P > 0.05$ all). Furthermore, during the test, the subjects were encouraged to receive the entire program and rechecked the class attendance, and daily living activity every week via a caregiver that led to the final dropout rate being zero. However, it was quite difficult to access elderly adults with OA knee who met the criteria because they had an arthroplasty already in the early phase of the extreme pain both before and after the pandemic of COVID 19 era.

Effects of Quadriceps Isometric Exercise on Pain and Quality of Life

Pain is the most common symptom caused by osteoarthritis. Unfortunately, the disability in OA knee adults have no definitive treatment. However, the factors that are related to pain and disability are different from each other. Regular exercise is considered an important means to treating OA knee patients. It increases muscle strength, range of motion, aerobic capacity, and it decreases pain and disability (30). Previous findings of a systematic review indicate that a short-term exercise therapy program for OA adults is better in reducing the effects of pain and improving function than a placebo (6).

With respect to the present study, at the end of the 4th week of the home-based isometric exercise, the subjects' level of pain in the Experimental Group was significantly improved (refer to Table 2, NPRS and WOMAC) vs. the subjects in the Control Group. This finding is in agreement with the study by Anwer and Alghadir (2). It is reasonably clear that the effects of the short-term isometric quadriceps exercise program help to improve the function of knee in the OA subjects. These findings indicate that the isometric exercise is essential for adults who are living with a symptomatic OA knee even should there not be an improvement in the strength of the muscles within a 4-week period.

The continuum of movement of the knee during pain could activate the mechanoreceptor large fiber to interfere with the pain ascending signals pathway and modulate sensation as a result of pain lower down in resting state (8,21,25) after 4 weeks of isometric exercise. More specifically, the reduction of pain could increase the function of the knee joint that would lead to an improvement of the overall WOMAC score. Nevertheless, it could not observe that the change in pain and stiffness levels in WOMAC subpart during exercise could not protect the wasting of cartilage in overtime. As researchers study the multifaceted evidence of exercise's role in animal models related to pain, it is possible that evidence may indicate that it also modulates transcription in several metabolic pathways associated with the improvement of inflammation/immune responses in healthy cartilage (4,17). According to the findings, it could be assumed that pain mediators also have relevant inflammation processes in the bodies. Therefore, the proper exercise program for symptomatic pain of OA knee might be modulated pain in both tracts of neurophysiology and inflammatory pathway of which the precise mechanisms will be confirmed in the future.

Effects of Quadriceps Isometric Exercise on Strength

Quadriceps muscles play a crucial role in the task of daily living, such as getting up from a chair, walking independently, climbing stairs, and squatting (7). Therefore, adults with the OA knee are likely to be at a disadvantage when performing the daily tasks due to the weakness of the muscles. The increased risk of falling is increased along with the involvement of other body systems when moving and increasing the workload on the body throughout the day (22).

In the present study, the peak force of the quadriceps muscle on the training side was increased after 4 weeks of consecutive isometric exercise (Table 2). This indicates that the proper workload was initiated and the program was successful. The adults with who had severe symptomatic pain dominant in the OA knee reported that they were without adverse effects throughout the experiment. Conversely, this finding was not evident with the Control Group (Table 3).

Many research studies have reported that the strength of the quadriceps muscles is increased after at least 6 weeks of training in the non-specific pain level of the OA knee subjects (2,6,8,12,13,18,21,23,27,30). Moreover, several factors that influenced the force of contraction, such as the physiological cross-section and internal architecture of the muscles (10,29) are likely to be affected with continued experimentation.

The application of this work is suited for the clinical trial in adults with symptomatic pain dominant of the OA knee and pre/post-operative arthroplasty rehabilitation program. However, it would be helpful if the size of the muscle change was observed by ultrasound imaging as well as a larger number of subjects per Control Group and Experimental Group. Moreover, further study should be observed for longer periods of training with specifically identified pain mediators and inflammation pathways.

CONCLUSIONS

The findings in this study indicate that an individual home-based quadriceps isometric exercise for a short period of 4 weeks improves the symptomatic pain level and the quality of life in older adults with knee osteoarthritis.

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