

Knee function measured by timed up-and-go test and stair-climbing test after isometric exercise of quadriceps femoris muscles in female patients with knee osteoarthritis

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ABSTRACT

Background: Osteoarthritis (OA), the most common form of joint disease, can result in long-term disability. Limitation of activity in OA patients may result in a decline in the strength of quadriceps femoris muscles and thus further reduce mobility. Isometric exercise has been known to increase muscle strength, decrease pain, and improve knee function.

Objective: To evaluate knee function measured by timed up-and-go test (TUGT) and stair-climbing test (SCT) as well as muscle strength in the fourth and sixth week after isometric exercise of quadriceps femoris muscles and the correlation between these variables.

Methods: Female patients with OA underwent isometric exercise of quadriceps femoris muscles 3 times a week for 6 weeks. Muscle strength (measured by tensiometer cable) and knee function (measured by TUGT and SCT) were evaluated before and at week 4 and 6 of the exercise.

Results: Thirty five female patients were recruited in this study. The majority of the patients (45.7%) were between 60 to 65 years old. Obesity was found in 62.86% of the patients. At week 6, there was significant decrease in mean TUGT and SCT (by 39.0% and 45.6%, respectively; $p < 0.001$), and significant increase in mean right and left quadriceps muscles strength (by 47.9% and 36.7%, respectively; $p < 0.001$). There was a weak negative correlation (nonsignificant) of the increased strength of quadriceps muscles with the increase of knee function according to TUGT (right leg: $r = -0.172$, $p = 0.323$; left leg: $r = -0.303$, $p = 0.077$) and SCT (right leg: $r = -0.031$, $p = 0.860$; left leg: $r = -0.058$, $p = 0.742$).

Conclusion: In female patients in this study, significant improvement was found in the strength of quadriceps muscles, TUGT, and SCT after 6 weeks of isometric exercise. There was no significant correlation between muscle strength and knee function according to TUGT and SCT.

Osteoarthritis (OA) is the most common form of joint disease and has been known to cause long-term disability in patients.¹ Data from the World Health Organization (WHO) showed that along with the increase in life expectancy, in 2025 there will be a 414% increase in the elderly population.² Since age is one of the most important risk factor

for the development of OA, it is likely that there will be also an increase in the incidence of this disease.^{2,3}

Wachjudi et al² reported that OA comprised of 69% of all rheumatic diseases in outpatient clinic, with 87% being knee OA. Data from our institution showed that from 394 patients with OA, there were 207 (52.54%) patients who were diagnosed with knee OA. Seventy eight of those patients were women older than 50 years.⁴ The prevalence of OA is roughly equal in men and women under the age of 50 years old, but with older age the prevalence is higher in women.^{1,5}

Knee OA manifests as knee pain and joint stiffness,¹ which will cause patients to limit their knee movement in order to reduce pain.³ This limitation may result in disuse atrophy of the quadriceps muscles,⁶ 30% loss of muscle mass in 1 week, and up to 5% reduction in muscle strength per day,⁷ which will cause muscle weakness, limitation in daily activities, and reduce independence in self-care.⁷

The management of OA involves the combination of both pharmacologic and nonpharmacologic treatment.^{1,2} Exercise therapy performed in medical rehabilitation facilities is one of the nonpharmacologic approaches. Several studies had shown that exercise therapy in knee OA patients resulted in significant improvement in quadriceps muscle strength, pain intensity, and knee function.⁸⁻¹³ The exercise therapy may be given as isometric, isotonic, or isokinetic exercise.¹⁰

Knee function in OA patients is usually assessed with visual analog scale (VAS), Lequesne algofunctional index, or Western Ontario and McMaster Universities (WOMAC) Index.¹⁴ More simple, easily applied, and yet objective indicators such as timed up-and-go test (TUGT)^{15,16} and stair-climbing test (SCT)¹⁷ have not been widely used.

The TUGT is known as the examination to evaluate mobility, balance, and movement in the elderly, which related to the risk of falling.¹⁶ The application of TUGT as a method to evaluate knee function has been done previously by Piva et al¹⁵ in a cross-sectional study of knee OA patients, and TUGT was shown to be reliable in the clinical settings. TUGT result is considered normal if <30

seconds.¹⁶ The SCT is usually used to assess overall knee function before and after an intervention that will affect the mobility of the lower extremities (e.g. surgery); its use is not limited in OA only. There is not yet normal range for SCT result.¹⁷

In this study we attempted to assess knee function according to TUGT and SCT as well as muscle strength after isometric exercise in patients with knee OA and the correlation between those variables.

METHODS

Patients

The study was conducted at the rheumatology and medical rehabilitation outpatient clinic at Cipto Mangunkusumo General Hospital, Jakarta between December 2005 and March 2006. We recruited female patients who were aged above 50 years old and diagnosed with knee OA based on the 1986 American College of Rheumatology (ACR) criteria¹⁸ for knee OA, had second or third degree joint damage according to the Kellgren-Lawrence scale, tibiofemoral angle of $\leq 15^\circ$, VAS of ≤ 4 (with or without the use of analgesics), preliminary TUGT score of < 30 seconds, Lequesne algofunctional score of ≥ 8 , and who were able to walk without the need for support. Patients with history of heart disease, stage 2 hypertension, neuromuscular disease, infection or abnormalities of the joints in the lower extremities, history of falling, knee trauma or surgery, and contracture of the knee joint (range of motion; ROM $\leq 135^\circ$) were excluded from the study.

Isometric exercise

The isometric exercises were performed 3 times a week for 6 weeks using N-K table (Enraf-Nonius, Rotterdam, The Netherlands). To determine the weight that was to be used for the exercise, first we measured the maximum weight that the patients were able to lift. Patients were seated on the N-K table with the knee flexed at 90° angle. Then they were asked to extend the knee and use the quadriceps muscles to raise a weight until the knee was at 30° flexion. The position was sustained for 6 seconds, before returning to the 90° angle flexion. After 5 seconds of rest, patients were asked to repeat the movement. The maximum weight that the patient was able to lift for 3 consecutive times was then recorded. In the isometric exercise, patients were asked to perform similar movement using 60% of the maximum weight. The movement was then repeated until fatigue occurred. For each week, a new maximum weight was determined.

Outcome measurements

Muscle strength (in kilograms) was measured by tensiometer cable attached to the N-K table. The TUGT (in seconds) was performed by calculating the time needed for the patient to stand up from a chair, walk through a 3-meter long path, turn around, walk back on the path, and resume the sitting position. The SCT (in seconds) was performed by calculating the time needed for the patient to walk up a 12-step stair (each step has a height of 18 cm and depth of 28 cm), turn around, and walk down the stair to return to the first position. Measurement of the quadriceps muscle strength, TUGT, and SCT were

performed before, at the beginning of week 4, and at the end of week 6 of the isometric exercise.

Statistical analysis

The comparison of quadriceps muscle strength and knee function before and at week 4 and 6 of isometric exercise were analyzed using the analysis of variance (ANOVA) or Friedman's test as appropriate. The correlation of quadriceps muscle strength with knee function was analyzed using Pearson's or Spearman's test as appropriate.

RESULTS

A total of 35 female patients were recruited in the study. The largest proportion of patients (45.7%) were aged 60 or older, followed by those aged 50–54 years old (40%), and 55–59 years old (14.3%). Most (62.86%) also had obesity (body mass index of ≥ 25 kg/m²). The majority of the patients were housewives (57.1%). Most (71.4%) had second degree joint damage according to Kellgren-Lawrence scale. Almost all of the patients did regular light exercise (91.4%) with the frequency of less than 3 times a week (94.3%). Table 1 further described the characteristics of the patients.

Table 1 Characteristics of the patients

Characteristics	n (%)*
Age, years, mean (SD)	57.57 (5.75)
Body mass index, kg/m ² , mean (SD)	
<18.5	1 (2.86)
18.5–22.9	9 (25.21)
23–24.9	3 (8.57)
25–29.9	8 (22.86)
≥ 30	14 (40)
Education	
Elementary school	1 (2.86)
Junior high school	6 (17.1)
Senior high school	18 (51.44)
Diploma or bachelor degree	10 (28.6)
Occupation	
Housewife	20 (57.1)
Employee	7 (20)
Nurse	3 (8.6)
Teacher	3 (8.6)
Other	2 (5.7)
Kellgren-Lawrence score	
2	25 (71.4)
3	10 (28.6)
Exercise	
Irregular	32 (91.4)
Regular	3 (8.6)
Frequency of exercise	
<3 times a week	33 (94.3)
≥ 3 times a week	2 (5.7)

*Unless otherwise specified.

At week 4, there was significant decrease in mean TUGT and SCT (by 27.5% and 30.5%, respectively; $p < 0.001$), and significant increase in mean right and left quadriceps muscles strength (by 29.1% and 22.0%, respectively; $p < 0.001$). At week 6, there was significant decrease in mean TUGT and SCT (by 39.0% and 45.6%, respectively; $p < 0.001$), and significant increase in mean right and left quadriceps muscles strength (by 47.9% and 36.7%, respectively; $p < 0.001$) compared with baseline. Figure 1 and 2 further describe the change in TUGT, SCT, and quadriceps muscles strength during the follow-ups.

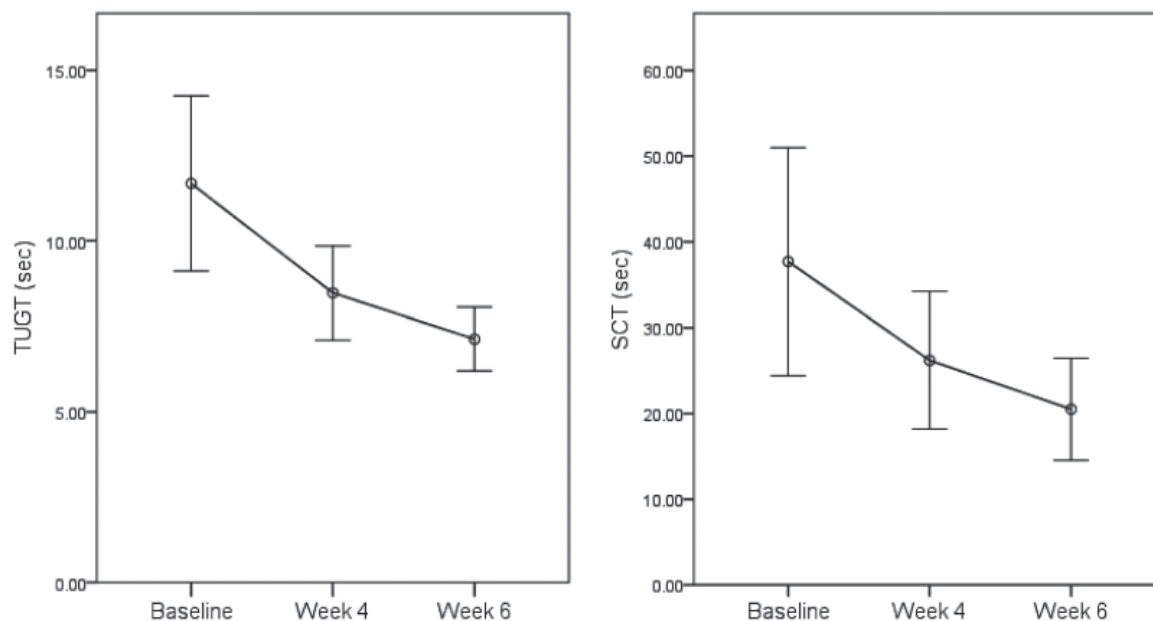


Figure 1 Timed up-and-go test (TUGT) and stair-climbing test (SCT) at baseline and at week 4 and 6 of the isometric exercise. Values shown are mean and standard deviation. TUGT at baseline, week 4, and week 6 were 11.68 ± 8.47 , 8.47 ± 1.37 , and 7.13 ± 0.93 sec, respectively. SCT at baseline, week 4, and week 6 were 37.70 ± 13.28 , 26.21 ± 8.02 , and 20.51 ± 5.95 sec, respectively. The decrease in TUGT and SCT at week 4 and 6 were all statistically significant ($p < 0.001$).

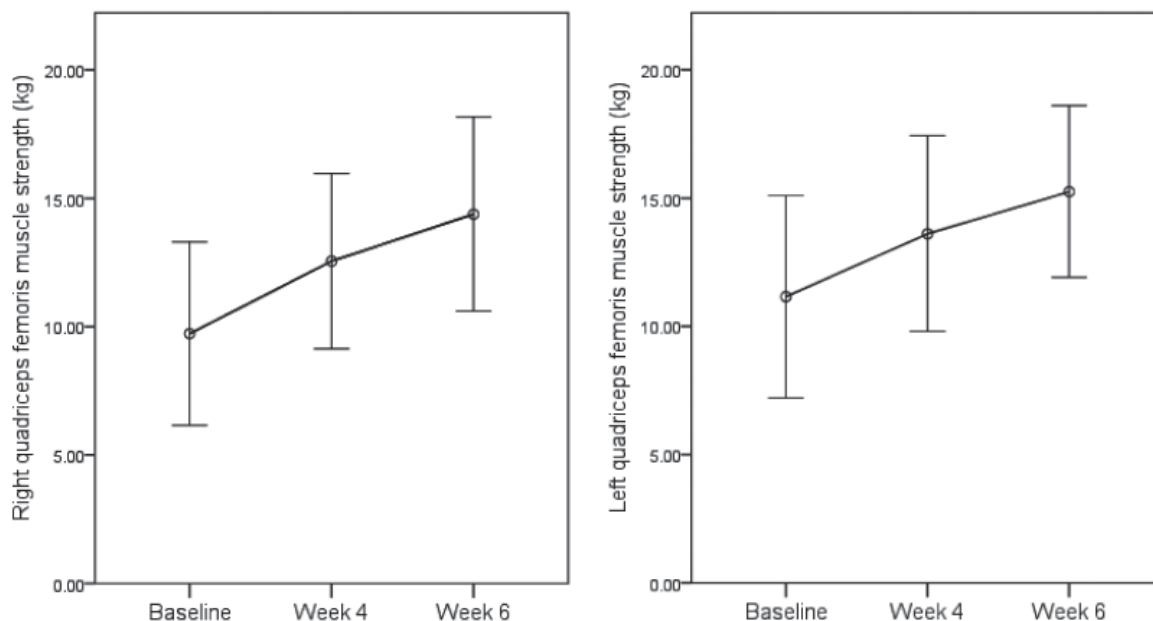


Figure 2 Quadriceps femoris muscle strength at baseline and at week 4 and 6 of the isometric exercise. Values shown are mean and standard deviation. The muscle strength of the right quadriceps at baseline, week 4, and week 6 were 9.73 ± 3.58 , 12.56 ± 3.42 , and 14.39 ± 3.78 kg, respectively. The muscle strength of the left quadriceps at baseline, week 4, and week 6 were 11.16 ± 3.95 , 13.61 ± 3.81 , and 15.26 ± 3.34 kg, respectively. The increase at week 4 and 6 was statistically significant for both legs ($p < 0.001$).

Statistical analysis showed no significant correlation of TUGT and SCT with muscle strength after isometric exercise (table 2). The coefficient of determination (r^2) was 0.0296–0.1018 for TUGT and 0.001–0.0034 for SCT.

Table 2 Correlation of timed up-and-go test (TUGT) and stair-climbing test (SCT) with quadriceps muscle strength at week 4 and 6 of the isometric exercise

	Quadriceps muscle strength	
	Right leg	Left leg
Week 4		
TUGT	–0.295 (0.086)	–0.319 (0.062)
SCT	–0.121 (0.490)	–0.055 (0.754)
Week 6		
TUGT	–0.172 (0.323)	–0.303 (0.077)
SCT	–0.031 (0.860)	–0.058 (0.742)

Data are presented as r (p value).

During the study, no adverse effects of the isometric exercise were reported by the patients.

DISCUSSION

The patients in our study showed significant decrease in the time needed to perform TUGT at week 4 and 6 of isometric exercise. Generally, TUGT and SCT are used to evaluate the functional performance and are not specific for knee function, and the improvement signified the progress of the overall physical functioning and vigor of the patients.^{15–17} TUGT and SCT provide a simpler and more easily applied alternative to measure knee function in the clinical settings. TUGT requires only minimal equipment, training, or expense. It also better isolates the functional deficits; so this test could be used to plan prevention strategies and in guiding further testings and treatments.¹⁶ Moreover, because TUGT result is also associated with cognitive function¹⁹ and could predict the risk of falling,²⁰ the use of this test may be beneficial in patients with OA, who are usually in the more advanced age.

In this study, isometric exercise was chosen over other type of exercises. In isometric exercise, muscle strength improves only at the joint angle at which the exercise takes place. This specificity of exercise principle may limit how much isometric exercise can affect performance of functional tasks that feature joint movement beyond the joint angle prescribed in the isometric exercise; however, it may have a possible advantage in that it does not stress the joint over a functional ROM. Dynamic resistance exercise improves strength and functioning over the exercise ROM, but the joint is being loaded while it is moved, which may result in pain among OA patients. In contrast, reduced joint movement in isometric exercise may result in less pain during and after the exercise.²¹

Significant increase in the quadriceps muscle strength was already shown at week 4 of the isometric exercise. Isometric exercise with the knee flexed at 30° angle, if done early in the course of the disease, will help maintain a better biomechanics of knee joint.^{22,23} Studies^{10–12} conducted previously at our institution also had shown similar results: a 6-week program of isometric exercise with the knee flexed at 30° angle increased the strength of quadriceps muscles and was safe for

knee OA patients with grade 2 and 3 Kellgren-Lawrence scale. Moreover, this exercise was also shown to decrease pain and improve knee function according to Lequesne index. Hettinger and Muller found that muscle contraction using 2/3 of the maximum strength in 5–6 seconds with interval of 20 seconds was able to increase muscle strength, a method known as brief repetitive isometric exercise (BRIME).²³ Isometric exercise of the quadriceps muscle could strengthen the supporting structures of the knee joint; thus it will decrease the effect of compression and intermittent relaxation to the patellar and tibiofemoral cartilage, meniscus, and ligament.^{19,24}

Statistical analysis did not show significant correlation of TUGT and SCT with muscle strength, which may be due to the limited sample size. The weak correlation signified that TUGT and SCT were also influenced by other factors that is important in mobility, such as biomechanical association between joint, strength of the supporting muscles, flexibility of the vertebrae and hip joints, range of motion of hip and joints of the lower extremities, postural control, and balance related to neuromusculoskeletal coordination.^{24–26}

Obesity was found in 62.86% of the patients. Previous studies^{10–13} conducted at our institution also reported that obesity was found in the majority of their subjects. Obesity has been known as a risk factor for the development of knee OA because of the change in the biomechanics of the knee joint.²⁷ In OA, there may be functional decline of the muscles that support the knee, i.e. the quadriceps and hamstrings.^{27,28} Besides, the decline is also physiologic as a part of aging, in which case exercise may help in improving muscle strength.^{29,30}

The limitations of this study that may affect the interpretation of the result includes recruitment of only female patients, lack of a control group, and the exclusion from analysis of factors that may affect the result of our study, such as BMI, age, degree of joint damage, size and direction of osteophytes, affected knee compartment, knee-stressing activities, and use of medications.

CONCLUSION

In female patients enrolled in this study, there was significant increase in quadriceps muscle strength and knee function according to TUGT and SCT at week 4 and 6 of isometric exercise. We found no significant correlation between muscle strength and knee function according to TUGT and SCT.

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