


# Association of eccentric quadriceps torque with pain, physical function, and extension lag in women with grade $\leq$ II knee osteoarthritis

## An observational study

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### Abstract

Knee osteoarthritis (OA) is a prevalent disabling disease among women and quadriceps weakness is attributed to one of the causes of knee pain (KP) and disability. The study aimed to test the correlation of eccentric quadriceps torque (EQT) with 2 subscales of the reduced WOMAC questionnaire (KP and physical function) and extension lag range of motion (ROM) at the knee joint in osteoarthritic women.

A cross-sectional design was used. A total of 70 patients (mean age 41.1 years) who had grade I or II knee OA participated in the study. The Pearson correlation coefficient was used to test the correlation between the EQT and 2 subscales of the reduced WOMAC questionnaire and extension lag ROM.

EQT presented a significant moderate negative correlation with pain ( $r = -0.489$ ,  $P < .001$ ) and physical function ( $r = -0.425$ ,  $P < .001$ ), and low positive correlation with available ROM ( $R = 0.349$ ,  $P < .001$ ).

KP, physical function, and extension lag in the early stages of knee OA in women are associated with EQT. Therefore, designing a rehabilitation program that has eccentric quadriceps strengthening exercises may improve KP and physical activities, but more randomized controlled trials are needed to verify this.

**Abbreviations:** BMI = body mass index, EQT = eccentric quadriceps torque, KP = knee pain, OA = osteoarthritis, ROM = range of motion.

**Keywords:** eccentric strength, osteoarthritis, pain, quadriceps, WOMAC

## 1. Introduction

Osteoarthritis (OA) is the most common form of arthritis.<sup>[1]</sup> As it is related to the aging process, it has caused a great burden on the economic and social condition of our aging society<sup>[1]</sup> and has caused a considerable impact on the quality of life of aging people.<sup>[2,3]</sup> Up to 41%, 30% and 19% of limb arthritis were located in the knees, hands, and hip joints respectively, making the knee joint the most commonly affected joint by OA.<sup>[4]</sup> In individuals suffering from knee OA symptoms vary from physical dysfunction to joint pain and stiffness.<sup>[5,6]</sup> Several risk factors have been attributed to causing OA such as age, gender, genetics, ethnicity, occupation, physical activity,

trauma, obesity, joint structure, and alignment.<sup>[7]</sup> Worldwide, knee OA is found to be more common in women than in men.<sup>8-10</sup> Women also differ from men in the presentation of knee OA as they are usually presented in more advanced stages, have different gait patterns, and also in terms of the anatomic area affected in the knee joint.<sup>[11]</sup> Women also report more pain and disability.<sup>[12,13]</sup>

Many studies have been performed to find the association of quadriceps muscle strength with knee pain (KP) and functional status. For example, 1 study performed by Riann M Palmieri-Smith et al<sup>[14]</sup> reported that quadriceps strength (Nm/kg) was 22% greater in women without radiographic OA than in women with radiographic OA. Another study by MC Hall et

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al reported that the presence of pain-free radiological OA has a significant negative influence on relative quadriceps strength and disability. However, in both of these studies, the isometric strength of the quadriceps muscle was measured. Serrão PR et al examined knee eccentric extensor torque in male osteoarthritic patients and reported a moderate and negative correlation between eccentric extensor torque and three subscales of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) ( $r = -0.40$  to  $0.69$ ,  $P < .05$ ).<sup>[15]</sup>

Most of the studies conducted on this matter examined the concentric or isometric strengths of the quadriceps muscle. Not enough studies have been conducted in women that tested the correlation of eccentric quadriceps torque (EQT) with 2 subscales of the reduced WOMAC questionnaire (KP and physical function), and extension lag range of motion (ROM) in the early stages of knee OA. Therefore, this study aimed to determine whether KP, physical function, and extension lag ROM correlate with EQT in women with grade I or II knee OA. Patients with grades III and IV were excluded so that the results of this study are deduced from patients with early stages of knee OA only. If the correlation is found in the early stages of the disease, then we may be able to modify the progression of this disease by designing an appropriate rehabilitation program. Therefore, we hypothesized that EQT has a significant correlation with KP, physical function, and extension lag ROM.

## 2. Methods

### 2.1. Study design

It was a cross-sectional study. KP, physical function, and extension lag ROM were dependent variables. EQT was the independent variable. KP and physical functions were measured using the reduced WOMAC questionnaire<sup>[16,17]</sup> and extension lag ROM and eccentric quadriceps strength were measured using the Biodex Isokinetic Dynamometer.<sup>[18]</sup>

### 2.2. Participants

Before conducting the study, the sample size was calculated using software G\*Power 3.1.9.4. Eighty-four participants were shown to be necessary based on an alpha level of 0.05 and power ( $1-\beta$ ) of 0.80; therefore, 90 female patients between the age group 30 and 50 years having OA of grade I or II as per Kellgren and Lawrence system, of unilateral/bilateral knees, were selected for participation in the study. Patients were referred from the orthopedics department of University Medical Centre to the rehabilitation department for occasional knee pain and diagnosed with knee osteoarthritis. However, of 90 participants, 15 participants had grade  $\geq$  III OA, therefore they did not meet the inclusion criteria and 5 participants reported pain on their isokinetic strength measurement test and therefore were not recruited into the study. Therefore, a total of 70 participants (mean age  $41.1 \pm 7.1$  years) successfully participated and completed the study (Table 1). The study started in December 2019 and was completed in August 2020. Each participant visited the rehabilitation department only once. OA was diagnosed with X-rays (AP and lateral views in standing position) of the knee by a radiologist and in the case of bilateral OA, the more affected knee was chosen for the study. If both knees had similar radiological findings, then the knee with more severe clinical symptoms was chosen for the study. The Kellgren and Lawrence grading system for OA classification was used to grade the severity of OA (grades 0 to 4).<sup>[19]</sup> The Kellgren and Lawrence grading system is a valid and reliable measurement of knee osteoarthritis status.<sup>[19-22]</sup> All participants gave their informed consent to include them before participating in the study. The

study conforms to “The Code of Ethics of the World Medical Association (Declaration of Helsinki).” The ethical subcommittee of the institutional review board (Rehabilitation Research Chair, King Saud University; File ID: RRC-2019-23 and date of approval 21/11/2019) approved this study.

Individuals who had a deformity in the ipsilateral lower extremity, previous ipsilateral lower extremity surgery, corticosteroid injection into the ipsilateral knee joint in the last 6 months, and other diseases of the musculoskeletal, cardiovascular, neurological, and/or respiratory systems were excluded from the study. Sixty-eight participants presented with both anteroposterior and lateral x-rays of the affected knee and 12 presented with anteroposterior x-rays only. The study protocol has been deposited on protocols.io (DOI: [dx.doi.org/10.17504/protocols.io.bqxwmxpe](https://doi.org/10.17504/protocols.io.bqxwmxpe)).

### 2.3. Questionnaire

Participants read and completed the reduced WOMAC questionnaire which is a valid and reliable instrument to assess pain and physical functions in individuals with knee osteoarthritis.<sup>[16,17]</sup> The test questions were scored on a scale of 0–4, which correspond to None (0), Mild (1), Moderate (2), Severe (3), and Extreme (4). Then the scores for each subscale are summed up, with a possible score range of 0–20 for pain and 0–28 for physical function. Higher scores on the reduced WOMAC questionnaire indicate worse pain and functional limitations.

### 2.4. Participants' preparation and isokinetic evaluation

An isokinetic dynamometer (Biodex Multi-Joint System 4, Biodex Medical Inc., NY) was used to measure eccentric quadriceps strength.<sup>[18]</sup> Before data collection, the isokinetic dynamometer was calibrated according to the manufacturer instructions. The participants were then asked to sit (with the hip and knee joints bent at  $90^\circ$ ) on the dynamometer chair according to the manufacturer's recommendations with the trunk and thighs stabilized by a belt. The resistance was applied by knee attachments of the dynamometer at 5 cm above the medial malleolus and the rotational axis was aligned 5 cm away from the lateral epicondyle of the femur. Then EQT was evaluated at a speed of  $90^\circ/s$  using “The Reactive Eccentric Mode.”<sup>[15]</sup> Speed of  $90^\circ/s$  was chosen to facilitate a comparison of the results of this study with a previous study performed by Serrão PR et al in males with early knee OA.

### 2.5. Extension lag ROM measurement

The extension lag ROM was measured using the isokinetic dynamometer by asking the participants to fully extend the knee, then the lag in full extension (to achieve  $0^\circ$  knee flexion) was measured. A negative ROM score meant the subject could not bring his leg to the position defined as horizontal by the protocol for ROM measurements.

**Table 1**  
Demographic properties of participants with Knee Osteoarthritis, n = 70.

Characteristics	Mean $\pm$ SD
Age (years)	41.1 $\pm$ 7.1
Height (cm)	157.8 $\pm$ 19.7
Weight (kg)	69.2 $\pm$ 13.9
BMI (kg/cm <sup>2</sup> )	27.33 $\pm$ 5.5

BMI = Body mass index, SD = Standard deviation.

### 2.6. Eccentric strength measurement

Afterward, participants were familiarized with the test by performing 1 bout of three submaximal eccentric isokinetic contractions with a ROM from 20 to 90° (being 0° meaning full knee extension). After that, they performed 1 bout of 3 maximal contractions with their best possible effort. The rest between each contraction was 30 seconds. For statistical analysis, the average of the peak torques of the three maximal contractions was taken. No subject complained of pain during the test. Verbal commands were used to encourage participants to produce maximum torque during the procedure. Torque was measured in Nm, then this data was normalized by body weight (in kg) using the formula: (Nm torque/kg body weight) × 100.<sup>[15]</sup>

### 2.7. Data Analysis

Data were analyzed using SPSS statistical software version 26 (SPSS Inc., Chicago, IL). Data collected for dependent variables (reduced WOMAC subscales for pain and physical function, and extension lag) and independent variable (normalized mean EQT) showed a normal distribution ( $P > .05$ ) therefore the parametric test was chosen. The Pearson correlation coefficient was used to analyze the correlation between the independent and dependent variables. The correlation was considered significant at the  $P$  value  $< 0.05$ . Following categories were used to interpret the  $r$  values: none/mild = 0.00 to 0.19; low = 0.20 to 0.39; moderate = 0.40 to 0.69; strong = 0.70 to 0.89; and very strong = 0.9 to 1.00.<sup>[23]</sup>

## 3. Results

Data from a total of 70 participants were analyzed. The descriptive statistics for the dependent and independent variables are presented in Table 2. The data analysis of the study showed a significant correlation between EQT and the reduced WOMAC questionnaire subscales (pain and physical function) and the extension lag in the knee joint, in women with grade I or II knee OA (Table 3). EQT presented a significant moderate negative correlation with both the reduced WOMAC subscales [pain  $r = -0.489$  ( $P < .001$ ) and physical function  $r = -0.425$  ( $P < .001$ )] and a significant low positive correlation with available ROM [ $R = 0.349$  ( $P < .001$ )]. Additionally, EQT also presented a significant moderate negative correlation with BMI [ $r = -0.480$  ( $P < .001$ )] and a significant moderate negative correlation with the complete WOMAC score [ $r = -0.507$  ( $P < .001$ )].

### 3.1. Discussion

The present study aimed to find out how EQT is associated with KP, physical functions, and extension lag in women with grade I or II knee OA. Data analysis revealed a correlation of

EQT with KP as moderate negative ( $r = -0.489$ ,  $P < .001$ ), with physical function as moderate negative ( $r = -0.425$ ,  $P < .001$ ), and with available knee ROM as low positive ( $R = 0.349$ ,  $P < .001$ ). Additionally, the correlation of EQT with BMI was revealed as moderate negative ( $r = -0.480$ ,  $P < .001$ ) and with comprehensive WOMAC score also as moderate negative ( $r = -0.507$ ,  $P < .001$ ). The negative correlations indicated that the individuals having higher EQT, had lower KP, physical dysfunction, and BMI. Positive correlations indicated that those who had higher EQT had higher available ROM at the knee joint. Results of the present study showed that the eccentric strength of the quadriceps muscle may have important roles to play in the knee joint.

The findings of the present study are also supported by earlier research. One of the studies performed on American women reported that women having radiographic knee OA have 22% lesser quadriceps strength (Nm/kg) than women without knee OA ( $P < .05$ ).<sup>[14]</sup> Another study performed by Serrão PR et al on volunteers having grade I or II knee OA, reported that there is a moderate negative correlation of EQT with 3 subscales of WOMAC ( $r = -0.40$  to  $0.69$ ,  $P < .05$ ).<sup>[15]</sup> Similarly, Hortobágyi et al<sup>[24]</sup> reported the correlation between time spent by the patients with knee OA (grade  $\geq$  II), to perform certain functional tasks and quadriceps muscle strength (sum of maximum eccentric, concentric and isometric contractions) as moderate negative.

Many previous studies have highlighted the contribution of the quadriceps muscle to knee joint stability, such as studies by Winby CR et al and Mikesky AE et al reported that for both the functional knee joint stability<sup>[25]</sup> and knee joint loading,<sup>[26,27]</sup> the primary contribution comes from quadriceps muscles. The quadriceps muscles also provide dynamic knee joint stability by controlling tibial translation during ambulation, thus if quadriceps muscles are weak, the risk of damage to joint structures will increase.

The pathomechanics behind the association of an increase in KP, functional disability, and extension lag in knee OA patients with decreased eccentric strength of the quadriceps muscle could be explained as follows: During ambulation, the eccentric function of the quadriceps muscle is to absorb body weight while landing the foot on the ground or lowering the body to the ground. It also provides dynamic stability to the lower quadrant of the body during ambulation. The ability of the quadriceps muscle to generate force in OA patients is significantly affected especially during lengthening (when it contracts eccentrically) than the force generation during concentric or isometric contractions.<sup>[24]</sup> This shows why the eccentric function of the quadriceps is important for the knee joint. Thus, the neuromuscular functions around the knee joint are impaired in the form of decreased quadriceps recruitment and increased hamstring muscle activity (during late stance and early swing

**Table 2**  
Descriptive statistics, mean, and Standard Deviation, for dependent and independent variables, n = 70.

	Mean	SD
EQT (Nm/kg × 100)	105.50	46.837
BMI (kg/cm <sup>2</sup> )	27.37	5.554
Pain (points)	8.74	3.586
Physical function (points)	11.80	4.793
Extension Lag ROM (degrees)	-6.128	3.03
WOMAC (points)	23.81	8.850

BMI = Body mass index, EQT = Eccentric quadriceps torque, ROM = Range of motion, SD = Standard deviation, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

**Table 3**  
Pearson's Correlation Coefficient (r) between Eccentric Quadriceps Torque and BMI, pain, physical function, available ROM, WOMAC score.

	Eccentric Quadriceps Torque (EQT)	
	r	P value
BMI (kg/cm <sup>2</sup> )	-0.480	$P \leq .001^*$
Pain (points)	-0.489	$P \leq .001^*$
Physical function (points)	-0.425	$P \leq .001^*$
Available ROM at knee (degrees)	0.349	$P \leq .001^*$
WOMAC (points)	-0.507	$P \leq .001^*$

BMI = Body mass index, ROM = Range of motion, WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

\*Significant ( $P < .01$ ).

phase) during ambulation due to osteoarthritic changes. This results in impaired load distribution in the joint and thus further facilitates disease progression.<sup>[28]</sup> The increased joint loading and decreased shock absorption due to cartilage erosion lead to more stress on the static stabilizers of the joint causing excessive stretching of ligaments and capsules which could further contribute to increased KP, decreased ROM, and more disability.<sup>[29]</sup>

However, some studies do not support the findings of the present study, such as a study performed by Zacaron KAM et al on elderly people with knee OA reported no correlation between the pain variable and the total work of quadriceps muscle.<sup>[30]</sup> The possible reason might be that they used a visual analog scale for pain assessment, which does not actually represent the pain perception during the patient's usual daily activities.

The present study also has some limitations and scope for future studies. This study well highlighted the fact that self-reported symptoms of KP, physical function, and extension lag ROM in the early stages of knee OA are associated with EQT. However, the cross-sectional design of the present study precludes it from making a definite inference that the increase in KP, physical dysfunctions, and extension lag are due to a decrease in eccentric quadriceps strength or vice versa. Thus, we can only infer from this study that if a rehabilitation program involving eccentric quadriceps strengthening exercises is started early in the initial stages of the disease, then we may be able to reduce KP and improve the activities of daily living in those individuals. But to make a definite clinical recommendation a separate proper randomized controlled trial is needed that involves eccentric quadriceps strengthening exercises as an intervention in such patients. The sample size in the present study also fell short by 14 participants as the minimum sample size calculated was 84. Therefore, further studies are needed on larger sample size. The inclusion criteria in the present study did not take into account the occupation, previous and current activity levels of the participants. Therefore, if some patients with grade I or II knee OA have a high level of physical activity, then they may have more eccentric quadriceps strength than those patients who have low levels of physical activity. Therefore, future research is needed that includes participants having equivalent occupation and physical activity. In addition, the use of assistive devices such as canes or walkers and psychological factors were not taken into account when recruiting participants. These factors may influence the association examined in the present study. Further research is also needed to compare correlation results between different ethnic groups to know any geographical, cultural, genetic, or economic variations.

#### 4. Conclusions

To conclude, the self-reported symptoms of KP, physical function, and extension lag in the early stages of knee OA in women are associated with EQT. Thus including eccentric quadriceps strengthening exercises in the rehabilitation program for patients with early stages of knee OA may improve KP, physical functions, and extension lag, but further randomized controlled trials are needed to confirm this hypothesis.

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#### Author contributions

FA, NQ, SAK, AHA, and MK conceptualized the study and its methodology. FA and MK were involved in data collection

and curation also. FA and MK did the data analysis, wrote and edited the manuscript. NQ, SAK, and AHA were involved in supervision. All authors read and approved the final version of the manuscript.

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