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Efficacy of rectus femoris stretching on pain, range of motion and spatiotemporal gait parameters in patients with knee osteoarthritis: a randomised controlled trial

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ABSTRACT

Objective This study aimed to investigate the efficacy of rectus femoris stretching on pain intensity, knee range of motion (ROM), spatiotemporal gait parameters and function in patients with knee osteoarthritis (KOA).

Methods This parallel group, single-blinded randomised controlled trial was conducted in two outpatient physical therapy clinics. Study participants (n=60, with age>45 years) with mild-to-moderate bilateral KOA were randomised into the study group (SG) and control group (CG). SG received rectus femoris stretching exercises together with stretching exercises of the calf, hamstring and iliotibial band, strength exercises for the quadriceps, gluteus medius, gluteus maximus and calf muscles, whereas, the CG received all exercises mentioned for SG except rectus femoris stretching. Pain intensity, ROM, spatiotemporal gait parameters and function were measured before and after 4 weeks of treatment.

Results The SG showed a significant improvement in the visual analogue scale, Western Ontario and McMaster Universities measure and ROM ($p<0.001$). The SG also had a significantly greater step length and speed than CG ($p<0.001$). Extension ROM did not significant difference between the groups ($p>0.05$).

Conclusion Simple rectus femoris stretching exercises are easy to perform even at home and are beneficial for pain, flexion ROM, function and spatiotemporal gait parameters, such as step length and speed, in KOA patients if the compliance with the exercise regimen is good.

Trial registration number Pan African Clinical Trials Registry PACTR202003828737019.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Patients with knee osteoarthritis (KOA) experience a steady decrease in knee joint range of motion (ROM) over time and reduced knee ROM has been linked to the development of KOA, progression of pre-existing cartilage deficiencies and early joint arthroplasty.
⇒ To improve joint mobility, stability and physical function, various exercise therapies such as strengthening, ROM and stretching exercises have been performed.

WHAT THIS STUDY ADDS

⇒ For optimal knee osteoarthritis care, muscle-specific stretching exercises are recommended.
⇒ Rectus femoris stretching exercise improved pain, flexion ROM, function and spatiotemporal gait parameters, such as step length and speed, in KOA patients.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Rectus femoris stretching exercise can modify and normalise movement patterns in gait among the elderly to resemble healthy adults.
⇒ The study provides data that can serve as a basis for setting up controlled studies on other types of arthritis.

INTRODUCTION

Osteoarthritis (OA) is one of the most prevalent forms of debilitating joint illness that affects around 60% of those over the age of 50.[1 2] The common symptoms of knee osteoarthritis (KOA) include pain, muscular weakness, joint stiffness and limited range of motion (ROM), which make daily tasks difficult and impair functional capacity.[3] Evidence has shown that patients with KOA had worse spatiotemporal gait characteristics, such as slower walking speed and shorter steps, with the former being associated with an increased risk of mortality in KOA.[4 5]

KOA is caused by aberrant mechanical loads, which cause gradual articular cartilage degradation.[6] Muscle forces play a significant role in knee joint loading.[7] Although quadriceps and hamstring co-contraction improves knee joint stabilisation, it also increases knee loading, which has been linked to increased medial contact forces and cartilage volume loss on the medial side.[8] Loss of joint ROM

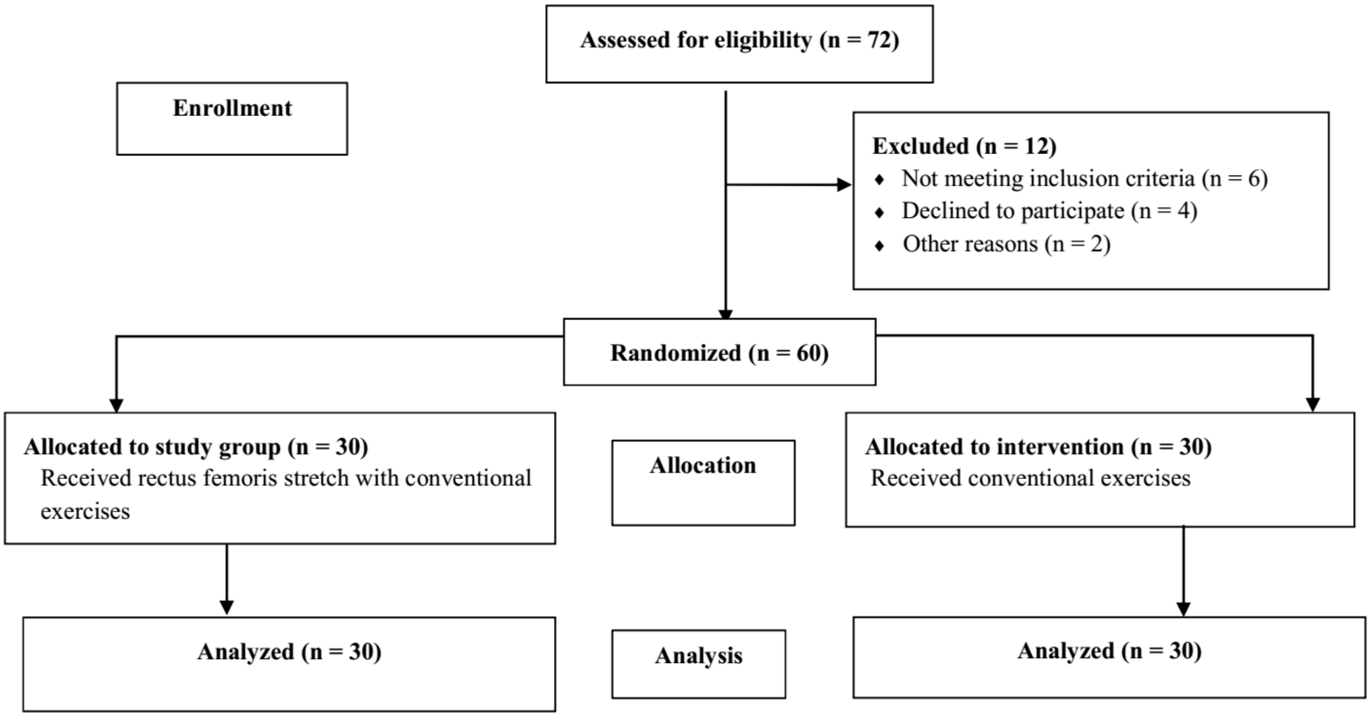

Figure 1 Participant recruitment flowchart.

can also hasten cartilage deterioration due to high hydrostatic pressures in the area, resulting in chondrocyte death and subsequent cartilage degradation.[9]

Previous research has found that unlike healthy people, those with KOA experience a steady decrease in knee joint ROM over time.[10] Reduced knee ROM has been linked to the development of KOA, progression of pre-existing cartilage deficiencies and early joint arthroplasty.[11 12]

Another study found that patients with KOA have lower muscular flexibility around the knee joint compared with healthy people, with quadriceps muscle flexibility being the most affected.[13] Reduced quadriceps flexibility could be a sign of reversible soft-tissue alterations linked to decreased knee flexion and extension, which could be improved by stretching exercises.[14]

To improve joint mobility, stability and physical function, various exercise therapies such as strengthening, ROM and stretching exercises have been performed.[15] A recent systematic review recommended specific muscles that should be stretched for optimal KOA care.[16]

Therefore, the current study aimed to investigate the efficacy of rectus femoris stretching exercises together with stretching exercises of the calf, hamstring and iliotibial band, strength exercises for the quadriceps, gluteus medius, gluteus maximus and calf muscles on pain intensity, ROM of the knee, spatiotemporal gait parameters and function in patients with KOA.

MATERIALS AND METHODS

Study design, setting and participants

Between January 2021 and August 2021, a single-blinded, pretest and post-test randomised controlled study was undertaken. It enrolled 60 patients with mild-to-moderate KOA from Elkasr El-ainy and the Faculty of Physical Therapy outpatient clinics in Egypt. G*POWER statistical software (V.3.1.9.2) was used to calculate the sample size based on visual analogue scale (VAS) data from pilot research with five patients per group. Accordingly, our calculation found that a sample size of 26 subjects for each group was needed for this investigation. Calculations were conducted using an α value of 0.05, power of 80% and effect size of 0.8. The actual number of individuals was increased to 30 for each group to account for probable dropouts.

Before enrolling in the study, the subjects were evaluated based on the established eligibility criteria and signed a written consent form. Patients over 45 years old with bilateral KOA and who satisfied the clinical standards of the American College of Rheumatology were

Table 1 Participants' characteristics

Variables		Group I	Group II	P value
Age (years)		53.63±6.04	53.13±5.94	0.74
Weight (kg)		91.16±4.1	91.66±4.27	0.64
Height (cm)		171.96±18.88	172.66±18.72	0.88
Body mass index (kg/m²)		32.13±0.84	32.06±0.69	0.74
Kellgren-Lawrence, median (IQR)		3 (3–2)	3 (3–2)	0.79
Sex, n (%)	Females	15 (50%)	15 (50%)	
	Males	15 (50%)	15 (50%)	

Values are presented as mean±SD; p value, probability value. *P<0.05.

Table 2 Mean VAS and WOMAC before and after treatment in groups I and II

Variables	Group I Mean±SD	Group II Mean±SD	MD	P value	ES
VAS of the right side					
Pretreatment	82.33±13.04	83.16±12.76	–0.83	0.800	0.032
Post-treatment	22.5±11.12	54.33±9.80	–31.83	0.001	0.835
MD (% of change)	59.83 (72.67%)	28.83 (34.67%)			
P value	*0.001*	*0.001*			
ES	*0.926*	*0.784*			
VAS of the left side					
Pre-treatment	78.66±15.69	77.83±12.43	0.83	0.82	*0.029*
Post-treatment	19.5±10.45	51.33±8.29	–31.83	0.001	*0.860*
MD(% of change)	59.16 (75.21%)	26.5 (34.05%)			
P value	***0.001***	***0.001***			
ES	*0.911*	*0.781*			
WOMAC					
Pre-treatment	66.5±6.14	66.3±4.66	0.2	0.88	*0.018*
Post-treatment	25.00±4.15	45.36±3.25	–20.36	0.001	*0.939*
MD(% of change)	41.5 (62.41%)	20.94 (31.58%)			
P value	***0.001***	***0.001***			
ES	*0.969*	*0.933*			

Values are presented as mean±SD. *P<0.05.
Statistically significant compared with baseline at p≤0.05.
ES, effect size; MD, mean difference; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster Universities.

eligible to participate.[17] Recent radiographs confirmed the presence of knee OA (Kellgren-Lawrence (KL) Scale grade II–III).[18] Their body mass index (BMI) was <33 kg/m^2, whereas their pain severity was at least 20 mm on a 100 mm VAS, along with a positive finding on Ely's test for rectus femoris tightness.[19] The exclusion criteria included severe OA, joint replacement surgery, systemic arthritic diseases, rheumatoid arthritis and lumbar radiculopathy.

Based on the eligibility criteria, 72 patients with KOA were identified and requested to participate in this study. We then excluded 12 patients, of whom 6 did not satisfy the inclusion criteria, 4 refused participation and 2 for other reasons. Thus, the 60 remaining patients were randomly divided into 2 groups: group I (the study group (SG)) and group II (the control group (CG)) (figure 1). To ensure concealment of allocation, eligibility was determined by a blinded physiotherapist not involved in the randomisation process. The randomisation sequence was drawn up and kept off-site by a statistician who was not aware of the study aims, using a random number generator. The sequence of subjects included in the SG or CG was mailed by the statistician to the recruiter.

Intervention

The participants underwent three exercise sessions per week for 4 weeks. Both groups perform warming up exercises and received a 15 min hot pack treatment first. The CG performed calf, hamstring and iliotibial band stretching exercises, as well as quadriceps, gluteus medius, gluteus maximus and calf muscular strength exercises. The SG performed rectus femoris stretching exercises, as well as the exercises performed in group CG.[20]

During rectus femoris stretching, participants were positioned on their side, with the stretched leg on top. The bottom leg's hip and knee were bent. One therapist's hand was placed across the anterior portion of the distal thigh of the leg being stretched, while another therapist's hand was placed over the iliac crest. The therapist performed hip hyperextension with full knee flexion until the subject felt a stretch in the anterior area of the thigh.[20]

In the course of calf stretching, participants were placed in the supine position. The therapist's forearm was positioned along the plantar surface of the foot, while the other hand held the subject's heel (calcaneus). The subject's ankle was dorsiflexed by the therapist, drawing the calcaneus in an inferior direction, with the thumb and fingers and exerting pressure and the forearm in a superior direction proximal to the heads of the metatarsals until the calf muscles were stretched.[20]

Table 3 Mean knee ROM before and after treatment between groups I and II

ROM (degrees)	Group I Mean±SD	Group II Mean±SD	MD	P value	ES
Extension of the right side					
Pretreatment	10.26±1.91	10.4±1.58	−0.140	0.770	*0.039*
Post-treatment	4.6±1.24	4.43±1.01	0.170	0.570	*0.074*
MD (% of change)	5.66 (55.17%)	5.97 (57.40%)			
P value	*0.001*	*0.001*			
ES	*0.874*	*0.913*			
Extension of the left side					
Pretreatment	10.1±1.76	10±1.72	0.100	0.820	*0.028*
Post-treatment	4.1±0.92	4.26±1.17	−0.160	0.540	*0.075*
MD (% of change)	6 (59.41%)	5.74 (57.4%)			
P value	*0.001*	*0.001*			
ES	***0.905***	***0.905***			
Flexion of the right side					
Pretreatment	96.86±7.98	95.1±6.39	1.76	0.340	*0.120*
Post-treatment	123.73±5.52	102.7±6.2	21.03	0.001	*0.873*
MD (% of change)	−26.87 (27.74%)	−7.6 (8%)			
P value	*0.001*	*0.001*			
ES	*0.890*	*0.516*			
Flexion of the left side					
Pretreatment	97.76±8.52	97.9±7.65	−0.14	0.94	*0.008*
Post-treatment	124.3±4.56	105.03±5.92	19.27	0.001	*0.876*
MD (% of change)	−26.54 (27.15%)	−7.13 (7.28%)			
P value	*0.001*	*0.001*			
ES	*0.930*	*0.462*			

Values are presented as mean±SD. *P<0.05.
Statistically significant compared with baseline at p≤0.05.
ES, effect size; MD, mean difference; ROM, range of motion.

Throughout hamstring stretching, the subjects were placed in the supine position. The distal half of the leg to be stretched was gripped by one therapist's hand, while the anterior side of the thigh was grasped by the second therapist's hand to keep the knee in the extended position. The hip was flexed in a straight leg lift position, while retaining the hip in a neutral position until the patient felt a stretch discomfort in the hamstrings.[20]

During iliotibial band stretching, the subjects were positioned lying on their side with their hip to be stretched uppermost. The subjects' hip was moved until slight hyperextension was achieved, after which the therapist's hand applied pressure over the lateral aspect of the distal thigh until the patient felt a slight stretch discomfort.[20]

At the time of hip abductor strengthening exercises, the subjects were positioned side laying with their bottom leg hip and knee in flexion. Their upper leg was actively abducted while in slight extension with no rotation at the hip.[20]

In the course of hip extensor strengthening, subjects were placed in the prone position with a pillow beneath their abdomen. With the knee extended, the leg was actively elevated.

Subjects were seated in a lengthy sitting position with their knee extended during static quadriceps contraction. They were told to statically contract their quadriceps and push their knees down without causing pain.[20]

At the time of straight leg rising, participants were lying down with one knee extended and the other flexed, they were requested to contract their quadriceps first and then lift their leg to 45°–60° of hip flexion with their knee extended.[2]

For short arc knee extension, subjects were placed in the supine position with the exercising leg resting on a roll with the knee flexed up to 45°. They were then instructed to extend the knee.[20] Participants were instructed to keep their leg in place for 5–10 s before lowering it to the resting position. The exercise was then

Table 4 Mean STGP before and after treatment in groups I and II

STGP	Group I Mean±SD	Group II Mean±SD	MD	P value	ES
Right step length (m)					
Pretreatment	0.499±0.026	0.502±0.029	−0.003	0.670	0.054
Post-treatment	0.566±0.022	0.550±0.023	0.016	0.009	0.334
MD (% of change)	−0.067 (13.43%)	−0.048 (9.56%)			
P value	*0.001*	*0.001*			
ES	*0.811*	*0.675*			
Left step length (m)					
Pretreatment	0.486±0.031	0.483±0.025	0.003	0.680	0.053
Post-treatment	0.558±0.025	0.535±0.022	0.023	0.001	0.438
MD (% of change)	−0.072 (14.81%)	−0.052 (10.77%)			
P value	*0.001*	*0.001*			
ES	*0.787*	*0.741*			
Speed (m/s)					
Pretreatment	0.780±0.110	0.750±0.060	0.030	0.220	0.166
Post-treatment	1.190±0.130	0.910±0.060	0.280	0.001	0.810
MD (% of change)	−0.41 (52.56%)	−0.16 (21.33%)			
P value	*0.260*	*0.150*			
ES	*0.862*	*0.800*			

Values are presented as mean±SD. *P<0.05.
Statistically significant compared with baseline at p≤0.05.
ES, effects size; MD, mean difference; STGP, spatiotemporal gait parameters.

repeated with a weight cuff affixed to the leg above the ankle joint.

Subjects were requested to do a partial squat by tightening the quadriceps and gluteal muscles while maintaining the knees centred over their feet and returning to the standing posture thereafter.[21]

Outcome measurements

All outcomes were assessed by independent assessors who were blinded to participant allocation. Pain intensity assessment was measured by using a VAS. The score was based on the intensity of pain, with 0 mm representing no discomfort and 100 mm representing the highest degree of pain intensity. This current study used the VAS to determine the exact intensity of pain that participants experienced in their daily lives.[22] Bijur *et al* and Boonstra *et al* confirmed the validity and reliability of the scale to study pain intensity.[23 24]

Knee ROM assessment was assessed by using a standard Universal goniometer. An independent outcome assessor was recruited to assess knee ROM of the patients. During ROM of extension, the Universal goniometer was positioned so that the goniometer axis rested over the lateral epicondyle of the femur. The stationary goniometer arm was aligned parallel to the longitudinal axis of the femur, aligned with the greater trochanter, while the mobile arm was placed parallel to the longitudinal axis of the fibula, aligned with the lateral malleolus. When the examiner was satisfied, they had completed the measurement, the therapist documented the results.[25] While, during ROM of flexion, patients were requested to lie prone, with extended knee; patients were asked to bring the heel of the tested leg as close as possible to the buttock while the other foot remained in contact with the plinth. The fulcrum of the goniometry on the lateral epicondyle of the femur of the tested knee with one arm in line with the lateral malleolus and the other arm in line with the greater trochanter, after which the therapist documented the results.[25]

The Western Ontario and McMaster Universities (WOMAC) Scale was used to measure physical function assessment. The Arabic WOMAC Index has been confirmed to be a valid and accurate tool for assessing knee OA function. The 24-item questionnaire is divided into three subdimensions, namely pain, stiffness and physical function. By summing the points from the three subscales, the overall score can be determined. WOMAC scores were based on the severity of symptoms and varied from 0 to 96 points (best to worst).[26]

Salaffi *et al* confirmed the validity and reliability of WOMAC Scale to measure physical function assessment.[27]

During the Spatiotemporal gait parameters assessment (6 m walk test), each person was given 10 m to walk at a normal speed. From the second to the eighth metre, the time spent walking was counted by stopwatch in seconds because the initial 2 m (acceleration) and last 2 m (deceleration) were not calculated.[28]

Finally, step length (cm) was estimated using a standard Biodex Gait Trainer 2 (Model 950-380, software V.2.6x, New York, USA). This is a specially built treadmill that includes a screen for evaluating and training walking abilities in people with gait disabilities. The velocity was gradually increased to a suitable level for every patient to begin the evaluation process. Individuals were given 3 min to walk continuously before the assessment concluded, with the treadmill gradually slowing until completely stopping, after which the results were recorded.[29]

Data analysis

All data were tested for normality using the Shapiro-Wilk test. The independent sample t-test was used to analyse the participants' characteristics between the groups. To ensure that the groups were homogeneous, Levene's test for homogeneity of variances was used. Pain, ROM, function and spatiotemporal gait characteristics were compared within and between groups using multivariate analysis of variance (MANOVA). For multiple comparisons, the Bonferroni correction was used for post-hoc testing. Data were analysed using statistical software for social sciences (SPSS) V.25 for Windows. The significance level was set at p<0.05 for all statistical analyses.

RESULTS

This study included 60 participants with KOA. The age, weight, height, BMI, KL Classification and sex distribution of the participants did not significantly differ between groups (p>0.05; table 1), so the groups were well matched at entry level.

Within group comparisons

A significant treatment and time interaction was found on pain, ROM and spatiotemporal gait parameters after the intervention (p<0.001). In both groups, the post-treatment VAS and WOMAC scores were significantly higher than the pretreatment (p<0.001; table 2). Similarly, both groups' post-treatment flexion and extension ROM showed significantly higher scores than the pretreatment (p>0.001; table 3). Moreover, groups I and II displayed significant greater step length and speed after than before treatment (p<0.001; table 4).

Between-group comparisons

Before treatment, no significant difference in any of the measures was observed between the two groups (p>0.05). After the treatment, however, group I had significantly lower VAS and WOMAC scores compared with group II (VAS; MD=59.16, 95% CI, p>0.001, ES=0.91 (91%); WOMAC; MD=41.5, 95% CI, p<0.001, ES=0.96 (96%); table 2).

Group I had a significantly higher flexion ROM compared with group II (flexion of right side; MD = −26.87, 95% CI, p>0.001, ES=0.89 (89%); flexion of left side; MD=−26.54, 95% CI, p<0.001, ES=0.93 (93%). However, no significant difference in extension ROM was observed between both groups (p>0.05; table 3). A significant difference in step length and speed was noted between groups I and II (p<0.001; table 4).

DISCUSSION

The purpose of this study was to investigate the efficacy of rectus femoris stretching on pain intensity, knee ROM, spatiotemporal gait parameters and function in patients with KOA. The main findings of the study confirm that the SG (those who performed rectus femoris stretching) show significantly better improvement in VAS, WOMAC, flexion ROM, step length and speed in comparison to CG. However, no significant difference in the extension ROM was observed between the two groups.

Previous study on patients with early symptomatic KOA found a link between limited knee ROM and osteophyte growth, crepitus and discomfort.[30] Another study found a link between pain and knee flexion.[31] Meanwhile, the current study found that rectus femoris stretching improved pain and function in KOA. Previous research has shown that stretching exercises can help reduce pain among people with musculoskeletal problems by lowering muscle tension and improving joint metabolism.[32]

The current study supports a recent systematic review, which showed that stretching exercises on their own could adequately reduce pain in KOA patients.[16] The findings of obtained herein may support a previous study's notion that stretching exercise reduces discomfort experienced during passive extension or flexion, which could indicate reversible soft-tissue changes rather than bone alterations.[33]

To avoid pain, patients with KOA prefer to avoid physical activity, which leads to periarticular connective tissue fibrosis due to immobilisation or inactivity.[34] Mobility requires various degrees of knee flexion. Accordingly, walking on a flat surface requires a minimum of 70° of knee flexion, whereas climbing stairs, rising from a seated position and squatting required 83°, 93° and 120° of knee flexion, respectively. A previous study established an association between ROM and impairment, with their findings showing that reduced mobility within joints, particularly flexion of the knee, was an integral key part of disability in KOA.[35]

Our findings showed that rectus femoris stretching increased flexion ROM. Stretching exercises may increase ROM by raising the pain threshold, stretch tolerance and sarcomere numbers.[36–38] The current results support the findings of Suzuki's research, which showed that improving joint flexibility and multiple muscle strength was more important than increasing quadriceps strength alone.[39] The current study also supports Chow *et al*'s study, which showed that 2 weeks of stretching, was beneficial for total knee arthroplasty patients given that it improved ROM and postoperative outcomes.[40]

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Evidence has shown that a walking speed increase exceeding 0.1 m/s can be considered clinically significant.[41] In the current study, rectus femoris stretching increased walking speed by 0.28 m/s. Step length and cadence are the factors that determine walking speed.[42] As expected, the experimental group displayed an increase in walking speed considering that stretching may reduce hip flexor muscle tightness, which limits hip joint extension and causes anterior pelvic tilt.[43]

The increase in step length may be attributed to the increased ROM during knee flexion, hip and pelvic motion, which has been considered the key for increasing walking velocity after stretching.[37] Given the increased ROM around the pelvis, the swinging leg may be able to contact the ground with the heel further in front of the body.[37] The findings obtained in the current study agree with those presented in a previous study, which showed that stretching exercises can modify and normalise movement patterns in gait among the elderly to resemble healthy adults.[44]

In conclusion, simple rectus femoris stretching exercises are easy to perform even at home and are beneficial for pain, flexion ROM, function and spatiotemporal gait parameters, such as step length and speed, in KOA patients if the compliance with the exercise regimen is good.

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Ethics approval This study involves human participants and was approved by the faculty of physical therapy's ethical committee, Cairo University, Egypt. Participants gave informed consent to participate in the study before taking part.

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