Original Article

ISSN: 2663-9491 e-ISSN: 2789-6897

Effectiveness of Quadriceps Strengthening Exercise in Patients with Knee Osteoarthritis

Imamur Rashid[1*], Mohammad Golam Nobi[2], Nadia Rahman[3], Abul Kalam Azad[4], Nadim Kamal[5]

Received: 21 June 2026
Accepted: 30 June 2026
Published Online: 3 July 2026

Published by:
Gopalganj Medical College, Gopalganj, Bangladesh

*Corresponding Author

DOI: 10.5281/zenodo.21148100

ABSTRACT

Background: *Knee osteoarthritis is a common degenerative joint disease and a major cause of pain and disability, particularly in older adults, with the knee being the most frequently affected joint. Quadriceps weakness is a key contributor to pain, instability, and functional limitation in knee OA, making quadriceps strengthening an essential part of its conservative management.* ***Objective:*** *The aim of the study was to evaluate the effectiveness of quadriceps strengthening exercise in improving pain, physical function, knee range of motion, and quadriceps muscle strength in patients with knee osteoarthritis.* ***Methods & Materials:*** *This quasi-experimental study was conducted at the Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Dhaka, Bangladesh, from January to December 2025 among 70 patients with knee osteoarthritis. Pain, functional status, knee range of motion, and quadriceps muscle strength were assessed before and after a quadriceps strengthening exercise program. Data were analyzed using SPSS version 26.0, with $p < 0.05$ considered statistically significant.* ***Results:*** *Among 70 patients with knee osteoarthritis (mean age 57.4 ± 8.7 years), most were female (62.9%) and had Kellgren-Lawrence grade II disease (51.4%). Following quadriceps strengthening exercise, significant improvements were observed in pain, WOMAC scores, knee range of motion, and quadriceps muscle strength (all $p < 0.001$). Overall, 57.1% of patients showed moderate improvement, 28.6% marked improvement, and 14.3% mild improvement, with no patient showing no improvement.* ***Conclusion:*** *Quadriceps strengthening exercise significantly improved pain, physical function, knee range of motion, and quadriceps muscle strength in patients with knee osteoarthritis, supporting its role as an effective non-pharmacological treatment modality.*

Keywords: *Quadriceps Strengthening Exercise, Knee Osteoarthritis, Rehabilitation*

(The Insight 2026; 9(2): 506-511)

1. *Associate Professor, Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Bangladesh (ORCID: 0009-0008-6452-4619)*
2. *Associate Professor, Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Bangladesh (ORCID: 0009-0006-8282-6819)*
3. *Associate Professor, Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Bangladesh (ORCID: 0009-0007-5305-0895)*
4. *Associate Professor, Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Dhaka, Bangladesh (ORCID: 0000-0003-4570-6202)*
5. *Associate Professor, Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Bangladesh (ORCID: 0009-0008-4959-1776)*

INTRODUCTION

Osteoarthritis (OA) is a common chronic musculoskeletal disorder and a degenerative joint disease characterized by progressive deterioration of joint structures, particularly the articular cartilage [1]. Among the various joints affected, the knee is the most commonly involved and represents the principal site responsible for pain, disability, and functional impairment in older adults [2]. Globally, OA affects approximately 250 million people, and knee OA is estimated to occur in 10–20% of individuals over 65 years of age [3,4,5]. The prevalence of OA increases steadily with advancing age and is further influenced by factors such as obesity and population ageing, making it an increasingly important public health concern. OA has been reported to affect nearly one-third of adults during their lifetime and imposes a considerable socioeconomic burden through healthcare expenditures, loss of productivity, and reduced quality of life [6]. In addition, the disease contributes substantially to mobility limitations and disability, particularly among older individuals and women, who are disproportionately affected.

Knee OA is associated with a wide spectrum of clinical manifestations, including pain, joint stiffness, proprioceptive deficits, reduced range of motion, muscle weakness, and progressive functional limitations [7]. Patients commonly experience difficulty performing activities of daily living such as walking, climbing stairs, standing from a seated position, and other weight-bearing activities, resulting in reduced independence and diminished quality of life [8]. As the disease progresses, pathological changes within the joint may lead to joint effusion, muscle atrophy, instability, contractures, and further restriction of movement [9,10]. Among these impairments, quadriceps muscle weakness is recognized as a key characteristic of knee OA and has been identified as both a risk factor for disease development and a contributor to disease progression [11,12]. Because the quadriceps muscle plays a crucial role in shock absorption and dynamic stabilization of the knee joint, weakness of this muscle

ISSN: 2663-9491 e-ISSN: 2789-6897

reduces joint protection, increases mechanical stress across the knee, and contributes to pain, instability, and functional disability [13].

The management of knee OA aims to reduce pain, improve physical function, minimize disability, and slow disease progression. Current treatment strategies include pharmacological therapy, weight reduction, rehabilitation interventions, bracing, and surgical procedures when conservative measures fail. Contemporary clinical practice guidelines consistently emphasize non-pharmacological approaches as a fundamental component of OA management, with exercise therapy being considered a cornerstone of treatment [14,15,16,17]. Exercise-based rehabilitation has been shown to improve symptoms, functional performance, and overall quality of life in individuals with knee OA [18]. In particular, the American College of Rheumatology recommends strength-training exercises as an important intervention for symptom management [19]. Among the various exercise modalities available, quadriceps strengthening exercises are among the most frequently prescribed interventions because of their ability to enhance muscle strength, improve joint stability, and reduce mechanical loading on the affected knee.

Several studies have demonstrated the beneficial effects of quadriceps strengthening exercises in patients with knee OA. Hospital-based and home-based exercise programs have been shown to increase muscle strength while reducing pain and stiffness and improving physical function [20]. Strength-training interventions have also been associated with improvements in pain, functional activities, and quality of life [21,22], findings that have been supported by systematic reviews [23]. Furthermore, quadriceps strengthening programs have been reported to enhance quadriceps muscle strength, improve sensorimotor function, reduce neural inhibition, and produce favorable clinical outcomes, including improvements in pain and physical function [24]. Notably, an eight-week quadriceps strengthening program was found to be as effective as nonsteroidal anti-inflammatory drug therapy in improving functional outcomes in patients with knee OA. However, previous studies have also reported variability in exercise protocols, methodological approaches, and treatment responses across different populations and healthcare settings [25]. Moreover, the relationship between gains in muscle strength and improvements in pain and function has not been consistently demonstrated in all studies. Therefore, further research is needed to evaluate the effectiveness of quadriceps strengthening exercises in specific patient populations and clinical settings.

Although quadriceps strengthening exercises are widely recommended for knee osteoarthritis and have shown beneficial effects on pain, function, and muscle strength in previous studies, the magnitude of improvement varies across populations, exercise protocols, and clinical settings, and findings are not always consistent regarding all functional outcomes. In particular, limited data are available from localized rehabilitation settings assessing combined changes in pain, WOMAC scores, knee range of motion, and quadriceps muscle strength following a structured supervised program. Therefore, this study was conducted to evaluate the effectiveness of quadriceps strengthening exercise in improving pain, physical function, knee range of motion, and quadriceps muscle strength in patients with knee osteoarthritis.

OBJECTIVE

To evaluate the effectiveness of quadriceps strengthening exercise in improving pain, physical function, knee range of motion, and quadriceps muscle strength in patients with knee osteoarthritis.

METHOD & MATERIALS

This quasi-experimental study was conducted at the Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Dhaka, Bangladesh, from January 2025 to December 2025. A total of 70 patients with knee osteoarthritis were included in the study, selected according to predefined inclusion and exclusion criteria. The study was undertaken to evaluate the effectiveness of quadriceps strengthening exercise on pain, physical function, knee range of motion, and quadriceps muscle strength in patients with knee osteoarthritis. Baseline and post-intervention assessments were performed to determine the clinical outcomes of the exercise program.

Inclusion Criteria

- Patients aged 40 years and above.
- Diagnosed with primary knee osteoarthritis according to the clinical and radiographic criteria of the American College of Rheumatology (ACR).
- Patients with Kellgren-Lawrence (KL) grade I–III knee osteoarthritis.
- Patients willing to participate and provide written informed consent.

Exclusion Criteria

- Patients with inflammatory arthritis (e.g., rheumatoid arthritis, gout, ankylosing spondylitis).
- History of previous knee surgery or significant knee trauma.
- Presence of severe knee deformity.
- Patients with neurological disorders affecting lower limb function.
- History of intra-articular injection within the preceding three months.
- Patients unable or unwilling to participate in the prescribed exercise program.
- Patients with Kellgren-Lawrence grade IV knee osteoarthritis.

Data Collection Procedure

Baseline demographic and clinical characteristics of the participants were recorded using a predesigned data collection sheet. Information regarding age, sex, and Kellgren-Lawrence (KL) radiographic grade was documented at enrollment.

Outcome Measures

Pain intensity was assessed using a 10-cm Visual Analog Scale (VAS). Functional status was evaluated using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), including its pain, stiffness, and physical function subscales. Knee range of motion (ROM) was measured using a standard universal goniometer, and quadriceps muscle strength was assessed by Manual Muscle Testing (MMT) according to the Medical Research Council grading system.

Intervention Protocol

All participants underwent a quadriceps strengthening exercise program as part of the study intervention. The exercise regimen included static quadriceps exercises, straight leg raising exercises, short arc knee extension exercises, and seated knee extension exercises. Participants were instructed to perform the prescribed exercises regularly and were monitored during follow-up visits to ensure adherence to the exercise program.

ISSN: 2663-9491 e-ISSN: 2789-6897

Follow-up Assessment

Clinical assessments, including VAS pain score, WOMAC score, knee range of motion, and quadriceps muscle strength, were performed at baseline and repeated after completion of the intervention period. Overall clinical improvement was categorized as marked, moderate, mild, or no improvement according to the overall clinical response observed following the intervention.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Quantitative variables were expressed as mean ± standard deviation (SD), while qualitative variables were presented as frequency and percentage. Comparisons between pre-intervention and post-intervention outcomes were performed using the paired t-test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Table I presents the baseline demographic and clinical characteristics of the study participants. The mean age of the participants was 57.4 ± 8.7 years, with the highest proportion belonging to the 50–59 years age group (33, 47.1%), followed by 60–69 years (18, 25.7%), 40–49 years (12, 17.1%), and ≥70 years (7, 10.1%). Females constituted the majority of the study population (44, 62.9%), while males accounted for 26 (37.1%). According to the Kellgren-Lawrence classification, Grade II osteoarthritis was the most prevalent grade (36, 51.4%), followed by Grade III (24, 34.3%) and Grade I (10, 14.3%).

Table I: Baseline Characteristics of the Study Participants (*n* = 70).

Variable		Frequency (n)	Percentage (%)
Age (years)	40–49	12	17.1
	50–59	33	47.1
	60–69	18	25.7
	≥70	7	10.1
	Mean ± SD	57.4 ± 8.7	
Sex	Male	26	37.1
	Female	44	62.9
Kellgren-Lawrence (KL) Grade	Grade I	10	14.3
	Grade II	36	51.4
	Grade III	24	34.3

Table II presents the comparison of Visual Analog Scale (VAS) pain scores before and after quadriceps strengthening exercise among the study participants. The mean VAS pain score decreased significantly from 7.1 ± 1.0 before intervention to 4.2 ± 1.1 after intervention, with a mean reduction of 2.9 points, which was statistically significant (p < 0.001).

Table II: Comparison of VAS Pain Scores Before and After Quadriceps Strengthening Exercise Among the Study Participants (*n* = 70)

Variable	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	Mean Difference	p-value
VAS Pain Score (0–10)	7.1 ± 1.0	4.2 ± 1.1	2.9	<0.001

Table III presents the comparison of Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores before and after quadriceps strengthening exercise. Significant reductions were observed in all WOMAC domains following intervention. The mean pain score decreased from 12.4 ± 2.3 to 8.1 ± 2.0, with a mean difference of 4.3 (p < 0.001). The mean stiffness score decreased from 4.9 ± 1.2 to 3.2 ± 1.0, with a mean difference of 1.7 (p < 0.001). Similarly, the mean physical function score decreased from 41.0 ± 7.8 to 28.3 ± 7.2, with a mean difference of 12.7 (p < 0.001). Consequently, the total WOMAC score decreased significantly from 58.3 ± 9.4 to 39.6 ± 8.7, with a mean difference of 18.7 (p < 0.001).

Table III: Comparison of WOMAC Scores Before and After Quadriceps Strengthening Exercise Among the Study Participants (*n* = 70)

WOMAC Subscale	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	Mean Difference	p-value
Pain (0–20)	12.4 ± 2.3	8.1 ± 2.0	4.3	<0.001
Stiffness (0–8)	4.9 ± 1.2	3.2 ± 1.0	1.7	<0.001
Physical Function (0–68)	41.0 ± 7.8	28.3 ± 7.2	12.7	<0.001
Total WOMAC (0–96)	58.3 ± 9.4	39.6 ± 8.7	18.7	<0.001

Table IV presents the comparison of knee range of motion before and after quadriceps strengthening exercise among the study participants. The mean knee range of motion increased significantly from 112.5° ± 8.6° before intervention to 123.8° ± 7.9° after intervention, with a mean increase of 11.3°, which was statistically significant (p < 0.001).

ISSN: 2663-9491 e-ISSN: 2789-6897

Table IV: Comparison of Knee Range of Motion Before and After Quadriceps Strengthening Exercise Among the Study Participants (*n* = 70)

Variable	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	Mean Difference	p-value
Knee Range of Motion (°)	112.5 ± 8.6	123.8 ± 7.9	11.3	<0.001

Table V presents the comparison of quadriceps muscle strength before and after quadriceps strengthening exercise among the study participants. The mean quadriceps muscle strength assessed by Manual Muscle Testing (MMT) improved significantly from 3.1 ± 0.6 before intervention to 4.0 ± 0.5 after intervention, with a mean increase of 0.9 points ($p < 0.001$).

Table V: Comparison of Quadriceps Muscle Strength Before and After Quadriceps Strengthening Exercise Among the Study Participants (*n* = 70)

Variable	Pre-intervention (Mean ± SD)	Post-intervention (Mean ± SD)	Mean Difference	p-value
Quadriceps Muscle Strength (MMT 0–5)	3.1 ± 0.6	4.0 ± 0.5	0.9	<0.001

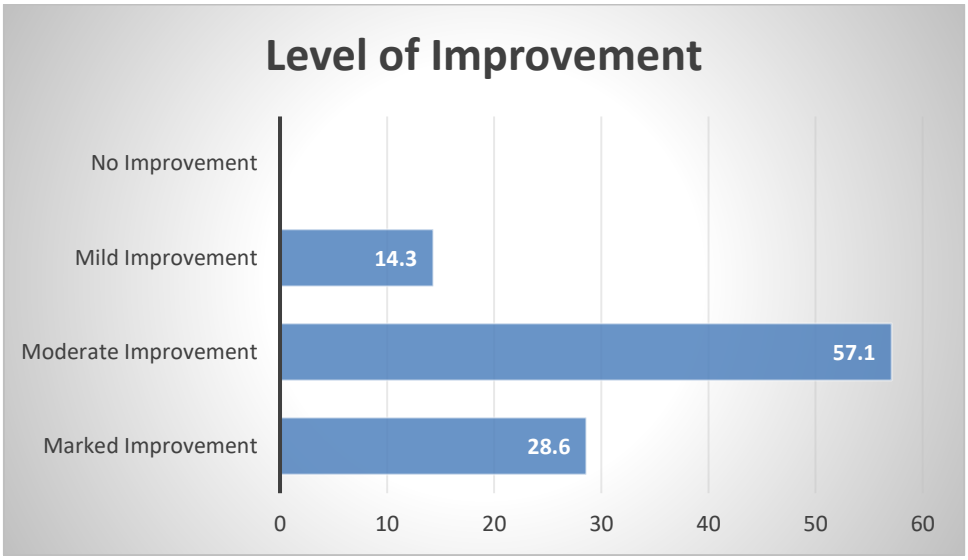

Figure 1: Distribution of Study Participants According to Overall Clinical Improvement Following Quadriceps Strengthening Exercise (*n* = 70)

Figure 1 presents the distribution of study participants according to the degree of overall clinical improvement following quadriceps strengthening exercise. Moderate improvement was observed in the majority of patients (40, 57.1%), followed by marked improvement in 20 (28.6%) patients and mild improvement in 10 (14.3%) patients. No participant showed no improvement following the intervention.

DISCUSSION

This quasi-experimental study was conducted at the Department of Physical Medicine and Rehabilitation, Bangladesh Medical University (BMU), Dhaka, Bangladesh. A total of 70 patients with knee osteoarthritis were enrolled based on predefined inclusion and exclusion criteria. The study aimed to evaluate the effectiveness of a structured quadriceps strengthening exercise program on pain, physical function, knee range of motion, and quadriceps muscle strength in patients with knee osteoarthritis, with pre- and post-intervention comparisons performed to assess clinical outcomes following the eight-week exercise intervention.

In the present study, the mean age of the participants was 57.4 ± 8.7 years, with the majority belonging to the 50–59 years age group (47.1%), and females constituted 62.9% of the study population. According to the Kellgren-Lawrence (KL) classification, Grade II osteoarthritis was the most prevalent radiographic grade (51.4%), followed by Grade III (34.3%) and Grade I (14.3%). These findings are in agreement with those reported by Zhou et al., who observed a mean age of 59.2 ± 10.2 years with marked female predominance (73.9%) and a substantial proportion of patients with KL grade II disease [26]. They further demonstrated that higher KL grades were associated with worsening symptoms and reduced joint mobility. Similarly, Sultan et al. reported a mean age of 59.6 ± 8.0 years, with 86.5% of participants being older than 50 years and most exhibiting moderate radiographic severity [27]. The close similarity between these studies and the present findings highlights the consistent demographic and radiographic profile of knee osteoarthritis across different populations.

ISSN: 2663-9491 e-ISSN: 2789-6897

In the present study, the mean Visual Analog Scale (VAS) pain score decreased significantly from 7.1 ± 1.0 before intervention to 4.2 ± 1.1 after quadriceps strengthening exercise, with a mean reduction of 2.9 points ($p < 0.001$), indicating substantial pain relief following the intervention. These findings are comparable to those reported by Imoto et al., who demonstrated significant improvement in pain and functional outcomes following quadriceps strengthening exercises in patients with knee osteoarthritis [28]. Likewise, DeVita et al. reported a significant reduction in pain intensity following an eight-week quadriceps strengthening program and concluded that strengthening exercises effectively improved pain and physical function [29]. The consistency between these findings and the present study further supports the beneficial role of quadriceps strengthening exercise in reducing pain in knee osteoarthritis.

The present study demonstrated significant improvements across all domains of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) following quadriceps strengthening exercise. These findings are consistent with those reported by Anwer et al., who demonstrated significant reductions in pain intensity and improvements in functional status and quality of life following an eight-week quadriceps strengthening program [30]. Similar observations were made by Imoto et al., who reported significant improvements in pain and physical function following quadriceps strengthening intervention [28]. Although WOMAC was not the primary outcome in all studies, the overall pattern of symptom and functional improvement closely parallels the findings of the present study, reinforcing the effectiveness of quadriceps strengthening in knee osteoarthritis.

In the present study, knee range of motion improved significantly following quadriceps strengthening exercise, with mean knee flexion increasing from 112.5 ± 8.6° before intervention to 123.8 ± 7.9° after intervention ($p < 0.001$). These findings are in agreement with those reported by Bokaeian et al., who demonstrated improvements in pain, function, and joint mobility following quadriceps strengthening exercises in knee osteoarthritis patients [31]. Further support is provided by Opara et al., who reported reduced knee range of motion in osteoarthritis patients compared to healthy individuals and emphasized the importance of rehabilitation strategies to restore joint mobility [32]. The present findings further highlight the role of quadriceps strengthening in improving knee mobility.

In the present study, quadriceps muscle strength improved significantly following the intervention, with the mean MMT score increasing from 3.1 ± 0.6 to 4.0 ± 0.5 ($p < 0.001$). These findings are consistent with those reported by Lall et al., who found significant improvements in quadriceps strength and functional performance following strengthening-based rehabilitation programs in knee osteoarthritis patients [33]. The similarity between these findings further supports the effectiveness of quadriceps strengthening exercises in improving muscle strength.

In the present study, the majority of patients demonstrated moderate to marked clinical improvement following quadriceps strengthening exercise, with no participant showing no improvement. These findings are comparable to those reported by Doi et al., who demonstrated that quadriceps strengthening exercise produced clinical improvements comparable to NSAID therapy in patients with knee osteoarthritis [34]. This highlights the effectiveness of quadriceps strengthening as a safe and effective non-pharmacological treatment modality.

LIMITATIONS

The study had several limitations:

- The study was conducted in a single tertiary care hospital; therefore, the findings may not be fully generalizable to the broader population of Bangladesh.
- The relatively small sample size may limit the statistical power of the study and the precision of the findings.

CONCLUSION

Quadriceps strengthening exercise was found to be an effective intervention for patients with knee osteoarthritis, resulting in significant reductions in pain and improvements in physical function, knee range of motion, and quadriceps muscle strength. The majority of patients demonstrated moderate to marked overall clinical improvement following the intervention. These findings support the incorporation of quadriceps strengthening exercise as a safe, cost-effective, and beneficial non-pharmacological approach in the management of knee osteoarthritis.

ACKNOWLEDGMENT

I would like to express my sincere gratitude for the invaluable support and cooperation provided by the staff, participants and my co-authors/colleagues who contributed to this study.

CONFLICTS OF INTEREST

There are no conflicts of interest.

REFERENCES

1. *Cesare, D., Abramson, P., & Samuels, S. (2009). Kelley's Textbook of th Rheumatology (Vol. 8). Saunders Elsevier.*
2. *Jordan KM, Arden NK, Doherty M, Bannwarth B, Bijlsma JW, Dieppe P, Gunther K, Hauselmann H, Herrero-Beaumont G, Kaklamanis P, Lohmander S. EULAR Recommendations 2003: an evidence based approach to the management of knee osteoarthritis: Report of a Task Force of the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCISIT). Annals of the rheumatic diseases. 2003 Dec 1;62(12):1145-55.*
3. *Chow YY, Chin KY. The role of inflammation in the pathogenesis of osteoarthritis. Mediators of inflammation. 2020;2020(1):8293921.*
4. *Sadeghi A, Rostami M, Khanlari Z, Zeraatchi A, Jalili N, Moghaddam AK, Moghaddam ZK, Fallah R, Sangtarash F. Effectiveness of muscle strengthening exercises on the clinical outcomes of patients with knee osteoarthritis: A randomized four-arm controlled trial. Caspian journal of internal medicine. 2023;14(3):433.*
5. *Liu Y, Ding W, Wang HL, Dai LL, Zong WH, Wang YZ, Bi J, Han W, Dong GJ. Gut microbiota and obesity-associated osteoarthritis. Osteoarthritis and cartilage. 2019 Sep 1;27(9):1257-65.*
6. *Jones G, Cahill A, McQuade J, Coleman S, Bennett J. Painful realities: the economic impact of arthritis in Australia in 2007. Sydney: Arthritis Australia; 2007. Available from: www.arthritisaustralia.com.au*
7. *Sekir U, Gür H. A multi-station proprioceptive exercise program in patients with bilateral knee osteoarthrosis: functional capacity, pain and sensoriomotor function. A randomized controlled trial. Journal of sports science & medicine. 2005 Dec 1;4(4):590.*
8. *de Oliveira DC, Barboza SD, da Costa FD, Cabral MP, Silva VM, Dionisio VC. Can pain influence the proprioception and the motor behavior in subjects with mild and moderate knee osteoarthritis?. BMC musculoskeletal disorders. 2014 Sep 27;15(1):321.*
9. *Sun, M. M.-G., Beier, F., & Pest, M. A. (2017). Recent developments in emerging therapeutic targets of osteoarthritis. Current Opinion in Rheumatology, 29(1), 96–102.*
10. *Mutlu EK, Mustafaoglu R, Birinci T, Ozdincler AR. Does Kinesio taping of the knee improve pain and functionality in patients with knee osteoarthritis?: a randomized controlled clinical trial.*

American journal of physical medicine & rehabilitation. 2017 Jan 1;96(1):25-33.

11. *Øiestad BE, Juhl CB, Eitzen I, Thorlund JB. Knee extensor muscle weakness is a risk factor for development of knee osteoarthritis. A systematic review and meta-analysis. Osteoarthritis and cartilage. 2015 Feb 1;23(2):171-7.*
12. *Serrão PR, Vasilceac FA, Gramani-Say K, Lessi GC, Oliveira AB, Reiff RB, Mattiello-Sverzut AC, Mattiello SM. Men with early degrees of knee osteoarthritis present functional and morphological impairments of the quadriceps femoris muscle. American Journal of Physical Medicine & Rehabilitation. 2015 Jan 1;94(1):70-81.*
13. *Mushtaq S, Choudhary R, Scanzello CR. Non-surgical treatment of osteoarthritis-related pain in the elderly. Current reviews in musculoskeletal medicine. 2011 Sep;4(3):113-22.*
14. *Yuenyongviwat V, Duangmanee S, Iamthanaporn K, Tuntarattanapong P, Hongnaparak T. Effect of hip abductor strengthening exercises in knee osteoarthritis: a randomized controlled trial. BMC musculoskeletal disorders. 2020 May 7;21(1):284.*
15. *Fernandes L, Hagen KB, Bijlsma JW, Andreassen O, Christensen P, Conaghan PG, Doherty M, Geenen R, Hammond A, Kjeken I, Lohmander LS. EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. Annals of the rheumatic diseases. 2013 Jul 1;72(7):1125-35.*
16. *Bannuru RR, Osani MC, Vaysbrot EE, Arden NK, Bennell K, Bierma-Zeinstra SM, Kraus VB, Lohmander LS, Abbott JH, Bhandari M, Blanco FJ. OARSI guidelines for the non-surgical management of knee, hip, and polyarticular osteoarthritis. Osteoarthritis and cartilage. 2019 Nov 1;27(11):1578-89.*
17. *McGrory BJ, Weber KL, Jevsevar DS, Sevarino K. Surgical management of osteoarthritis of the knee: evidence-based guideline. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2016 Aug 1;24(8):e87-93.*
18. *Hyldahl RD, Evans A, Kwon S, Ridge ST, Robinson E, Hopkins JT, Seeley MK. Running decreases knee intra-articular cytokine and cartilage oligomeric matrix concentrations: a pilot study. European journal of applied physiology. 2016 Dec;116(11):2305-14.*
19. *Hochberg MC, Altman RD, April KT, Benkhalti M, Guyatt G, McGowan J, Towheed T, Welch V, Wells G, Tugwell P. American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. Arthritis care & research. 2012 Apr;64(4):465-74.*
20. *Deyle GD, Henderson NE, Matekel RL, Ryder MG, Garber MB, Allison SC. Effectiveness of manual physical therapy and exercise in osteoarthritis of the knee: a randomized, controlled trial. Annals of internal medicine. 2000 Feb 1;132(3):173-81.*
21. *Bennell KL, Kyriakides M, Metcalf B, Egerton T, Wrigley TV, Hodges PW, Hunt MA, Roos EM, Forbes A, Ageberg E, Hinman RS. Neuromuscular versus quadriceps strengthening exercise in patients with medial knee osteoarthritis and varus malalignment: a randomized controlled trial. Arthritis & Rheumatology. 2014 Apr;66(4):950-9.*
22. *McQuade KJ, De Oliveira AS. Effects of progressive resistance strength training on knee biomechanics during single leg step-up in persons with mild knee osteoarthritis. Clinical biomechanics. 2011 Aug 1;26(7):741-8.*
23. *Lange AK, Vanwanseele B, Fiatarone singh MA. Strength training for treatment of osteoarthritis of the knee: a systematic review. Arthritis Care & Research: Official Journal of the American College of Rheumatology. 2008 Oct 15;59(10):1488-94.*
24. *McAlindon TE, Bannuru RR, Sullivan MC, Arden NK, Berenbaum F, Bierma-Zeinstra SM, Hawker GA, Henrotin Y, Hunter DJ, Kawaguchi H, Kwoh K. OARSI guidelines for the non-surgical management of knee osteoarthritis. Osteoarthritis and cartilage. 2014 Mar 1;22(3):363-88.*
25. *Fransen M, McConnell S, Harmer AR, Van der Esch M, Simic M, Bennell KL. Exercise for osteoarthritis of the knee. Cochrane database of systematic reviews. 2015(1).*
26. *Zhou G, Zhao M, Wang X, Geng X, Tian H. Demographic and radiographic factors for knee symptoms and range of motion in patients with knee osteoarthritis: a cross-sectional study in Beijing, China. BMC Musculoskeletal Disorders. 2023 May 12;24(1):378.*
27. *Sultan MI, Saiful Arif M, Dey P, Deb A, Islam MT, Bhattacharjee A, et al. Risk factors for medial and lateral compartment osteoarthritis of the knee: a cross-sectional analysis. Int J Res Med Sci. 2026;14(3):810–5.*
28. *Imoto AM, Peccin MS, Trevisani VF. Quadriceps strengthening exercises are effective in improving pain, function and quality of life in patients with osteoarthritis of the knee. Acta Ortop Bras. 2012;20(3):174-9.*
29. *DeVita P, Aaboe J, Bartholdy C, Leonardis JM, Bliddal H, Henriksen M. Quadriceps-strengthening exercise and quadriceps and knee biomechanics during walking in knee osteoarthritis: A two-centre randomized controlled trial. Clin Biomech (Bristol). 2018 Nov;59:199-206.*
30. *Anwer S, Alghadir A. Effect of isometric quadriceps exercise on muscle strength, pain, and function in patients with knee osteoarthritis: a randomized controlled study. J Phys Ther Sci. 2014 May;26(5):745-8.*
31. *Bokaeian HR, Bakhtiary AH, Mirmohammadkhani M, Moghimi J. Quadriceps strengthening exercises may not change pain and function in knee osteoarthritis. J Bodyw Mov Ther. 2018 Apr;22(2):528-533.*
32. *Opara Zupančič M, Šarabon N. Disease severity affects knee range of motion but not strength deficits in knee osteoarthritis: a systematic review and meta-analysis. Frontiers in medicine. 2026 Feb 13;13:1737973.*
33. *Lall S, Prem V, Karvannan H. Comparison of Neuromuscular Joint Facilitation and Quadriceps Strengthening Exercise in Knee Osteoarthritis: a Randomized Controlled Trial. Int J Ther Massage Bodywork. 2023 Sep 1;16(3):10-19.*
34. *Doi T, Akai M, Fujino K, Iwaya T, Kurosawa H, Hayashi K, Marui E. Effect of home exercise of quadriceps on knee osteoarthritis compared with nonsteroidal antiinflammatory drugs: a randomized controlled trial. Am J Phys Med Rehabil. 2008 Apr;87(4):258-69.*