Original Article

Effectiveness of Plantar Flexor and Intrinsic Foot Muscle Exercises in Knee Osteoarthritis: A Randomized Controlled Trial

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Abstract

Background*:* Knee osteoarthritis (KOA) is a common degenerative disorder, often aggravated by obesity, malalignment, and inactivity. While most rehabilitation targets proximal muscles, foot and ankle function—essential for shock absorption, postural control, and gait—remains overlooked. This gap highlights the need for a more integrated approach addressing both proximal and distal components of the lower limb.

Objectives*:* To evaluate the added benefit of foot and ankle exercises in KOA rehabilitation.

Methods*:* Eighty participants were randomized into two groups. Group A received exercises for foot intrinsic and plantar flexors along with quadriceps, hamstrings, and hip abductors. Group B performed only proximal muscle exercises. Knee Osteoarthritis Outcome Scores were recorded at baseline and after six weeks.

Results*:* Both groups improved significantly (overall posttest Mean = 48.42, SD = 12.45; $p < 0.05$). Group A achieved greater gains across all KOOS subscales (Mean = 59.86, SD = 12.58; $p < 0.05$).

Conclusion*:* Incorporating foot and ankle exercises enhances KOA rehabilitation, supporting a kinetic-chain approach.

Keywords*:* Exercise therapy, foot intrinsic, osteoarthritis, plantar flexors, toe intrinsics

Introduction

Knee osteoarthritis (KOA) is the most common and rapidly progressing form of arthritis [1], marked by cartilage degeneration, subchondral bone changes, and inflammation causing pain, stiffness, muscle weakness, reduced mobility, and functional decline [2,3]

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Osteoarthritis (OA), affecting the tibiofemoral and patellofemoral joints, is classified as primary (systemic/local factors) or secondary (identifiable causes)[3,4]. Key risk factors include age, genetics, obesity, trauma, repetitive stress, lifestyle, structural abnormalities, and systemic diseases [4,5]

A systematic review and meta-analysis reported thatknee OA is more common in women and increases with age, affecting 22.9% of people over 40 years. In 2020, there were 654 million cases worldwide, with 19.2% prevalence in Asia. [6]

According to the Kellgren-Lawrence classification, the prevalence of OA in India is 28.7%, higher in women (31.6%) than men (28.1%). Elevated BMI, sedentary lifestyle, and use of Western toilets are key contributing factors [7]

Subchondral bone changes may precede cartilage loss in OA. Reduced blood supply triggers osteoblasts to send signals that harm cartilage, and exosomes promote cartilage breakdown.Senescent chondrocytes release pro-inflammatory SASP factors (TGF-β,IL-6), promoting chronic inflammation and degradation [8-10]

Kinematic changes KOA increase peak knee adduction moments (KAM) and reduce knee flexion moments (KFM), indicating greater medial joint loading and OA progression [9]. Cartilage damage disrupts smooth motion, and repetitive loading worsens pain, inflammation, and discomfort [10,11]

Conventional OA management encompasses medications, surgery, and non-pharmacological approaches. Among the latter, exercises are widely used as it is safer than medication and enhances both function and overall health [11]

Conventional KOA rehabilitation targets hip abductors, quadriceps, and hamstrings [12,13], but often overlooks the foot and ankle's role in the kinetic chain.

Recent research emphasizes the importance of plantar flexors and intrinsic foot muscles in shock absorption, posture, and gait. Weakness in these muscles can disrupt mechanics, increase knee joint stress, and limit the effectiveness of proximal-focused rehab alone [14]

This gap in current clinical practice underscores the need for a comprehensive, integrated approach that addresses both proximal and distal components of the lower limb. Hence, this study aims to compare the effectiveness of two exercise regimens: one combining exercises for the hip abductors, quadriceps, and hamstrings with plantar flexors and intrinsic foot muscles, and another using conventional proximal-focused exercises alone. Outcomes will be assessed with KOOS to evaluate added benefits of foot and ankle training.

Methodology

This single-blinded randomized controlled trial was conducted at a tertiary care center in Dharwad, Karnataka, India, from April 2024 to May 2025. Ethical approval was obtained (SDMIEC/2024/715), and the trial was preregistered (CTRI/2024/10/075245). The study followed CONSORT 2025 guidelines.

A total of 93 patients presenting with knee pain were screened. Inclusion criteria were individuals aged ≥40 years [15], of any gender, with clinical and radiographic evidence of medial tibiofemoral OA in unilateral or bilateral knee/s [11, 16], Kellgren–Lawrence grades 1–3[14]. Exclusion criteria included inflammatory or infective arthritis, OA of the hip, ankle, or foot, prior knee or hip surgery, taken intra-articular injections within the past 6 months, neurological disorders affecting the lower limbs, or deformities of the affected limb(s). Written informed consent was obtained from all participants after they were fully informed about the study.

Sample size

The prevalence of osteoarthritis in India is approximately 39%, with 83% attributed to knee osteoarthritis (KOA). Using the formula $4pq/L^2$ ($p = 83\%$, $q = 17\%$, $L = 10\%$), and a 5% alpha error, the calculated sample size was 80, divided equally into two groups of 40 participants each.

Randomization and Blinding

The participants' demographic data were taken and assessed. Of 93 participants, 80 met the criteria and were randomized (1:1) into Group A (experimental, n = 40) and Group B (control, n = 40) using a concealed envelope method by an independent third party, ensuring allocation blinding (Figure 1).

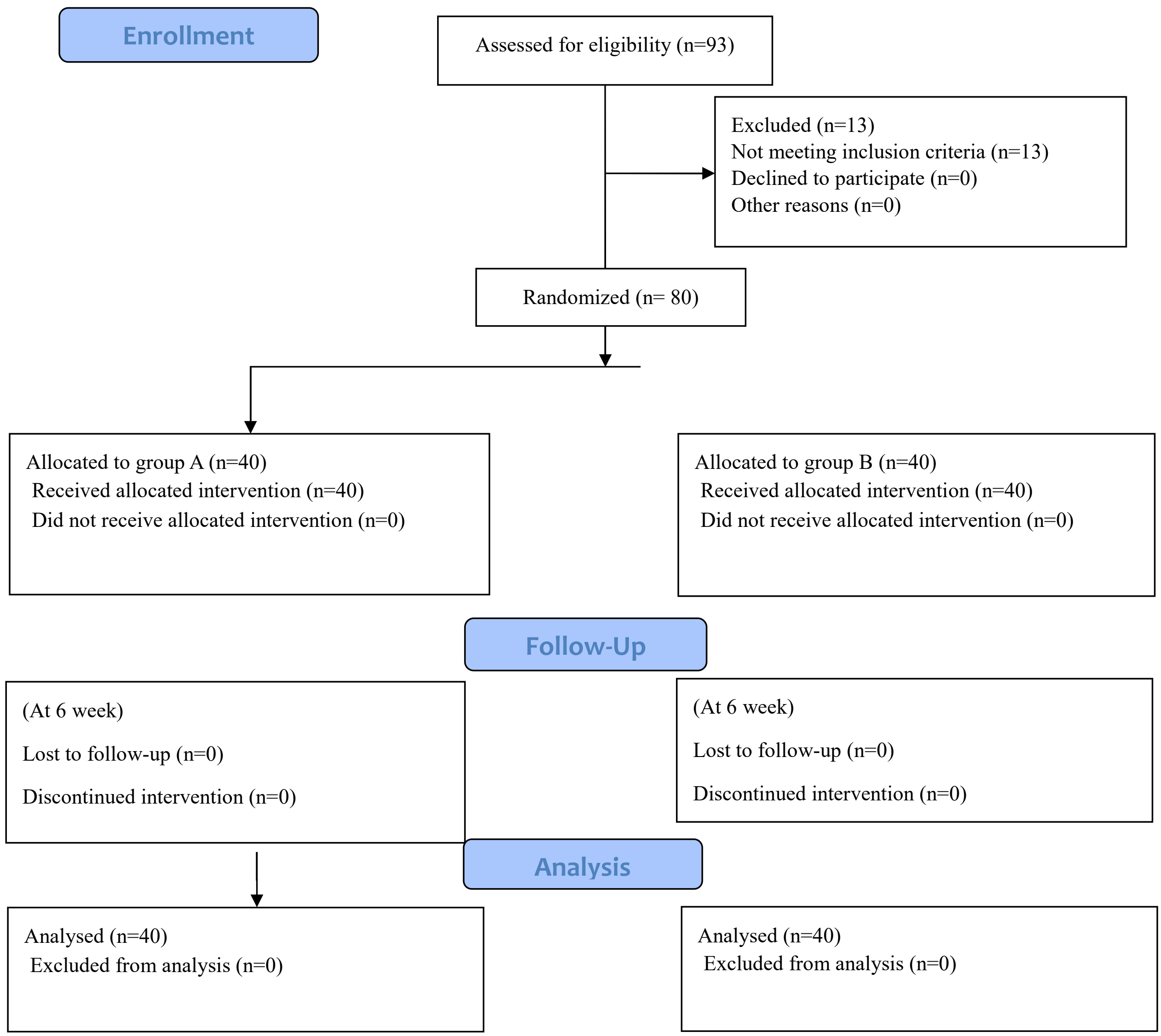

Figure 1. CONSORT flowchart

Interventions

Group A: - plantar flexors and intrinsic muscles of the foot exercise training along with hamstrings, quadriceps, and hip abductors.

Group B: - hip abductors, quadriceps, hamstrings training.

Exercise Protocol for Group A (Figures 2 to 6)

The exercise regimen was customized, with distinct sets and repetitions for every muscle that were increased weekly with a 1-minute rest between sets.

Figure 2: Hip Abductor Training Exercise

Figure 3: Quadriceps Training Exercise

Figure 4: Hamstring Training Exercise

Figure 5: Plantar Flexors Training Exercise (5a, 5b)

Figure 6: Foot Intrinsics Exercise Training

1st week:

Hip abductors- 10x2

Quadriceps- 20x2

Hamstrings- 20x2

Plantar flexors- 20x2

Intrinsics- 30secs x2 (curling and releasing the toes for 30 secs into 2 sets)

2nd week:

Hip abductors- 15x2

Quadriceps- 30x2

Hamstrings- 30x2

Plantar flexors- 30x2

Intrinsics- 45secs x2

3rd week:

Hip abductors- 15x2

Quadriceps- 40x2

Hamstrings- 40x2

Plantar flexors- 40x2

Intrinsics- 1 min x2

4th week:

Hip abductors- 20x2

Quadriceps- 50x2

Hamstrings- 50x2

Plantar flexors- 50x2

Intrinsics- 1 min x3

5th week: Half kg of external resistance was added for hip abductors, quadriceps, hamstrings and 100 grams was added for intrinsics

Hip abductors- 10x2

Quadriceps- 20x2

Hamstrings- 20x2

Plantar flexors- 20x2

Intrinsics- 1 min x3

6th week: 1 kg of external resistance was added for hip abductors, quadriceps, hamstrings and 200 grams was added for intrinsics

Hip abductors- 10x2

Quadriceps- 20x2

Hamstrings- 20x2

Plantar flexors- 20x2

Intrinsics-1 min x3

Exercise Protocol for Group B (Figures 2 to 4)

The protocol is the same as experimental group for the Hip abductors, quadriceps, and hamstrings.

A compliance sheet was given to every subject, where he/she had to tick, as they performed the exercises. Patients were followed once a week.

Each muscle group was performed 5 days a week. Hence, a total of 90 sessions were carried out for 30 minutes. A minimum of 45 sessions was considered for evaluating the participant.

Outcomes

The KOOS is a self-administered questionnaire consisting of 42 items; five domains. Scores for each domain are transformed to a 0–100 scale, with 100 indicating no problems [17]. Participants completed all domains at baseline and at the end of the 6th week.

Statistical Analysis

All analyses were conducted using SPSS version 23 (IBM, Armonk, NY, USA). Descriptive statistics included mean, standard deviation, frequencies, and percentages. Chi-square and independent t-tests assessed demographic differences. Normality was tested using the Shapiro-Wilk test, revealing a non-normal distribution. Therefore, Wilcoxon matched pairs test and Mann-Whitney U test were used for within- and between-group comparisons, respectively. A p-value <0.05 was considered statistically significant.

Results

Baseline data showed no significant differences between groups (Tables 1and 2). After 6 weeks of intervention, both groups showed significant improvements across all KOOS domains (p=0.0001*) [Table 3], with Group A demonstrating significantly greater improvement than Group B (p=0.0001*) [Table 4]. MCID values are Pain: 14.3- 15.3, Symptoms: 14.1-15.6, ADL: 15.2-16.0, Sp/rec: 11.7-11.8 and QOL: 13.6[18]

Table 1. Comparison of gender distribution in both groups.

Gender	Group A	%	Group B	%	Total	%	P-value
Male	13	32.50	14	35.00	27	33.75	0.8131
Female	27	67.50	26	65.00	53	66.25	
Total	40	100.00	40	100.00	80	100.00	

Chi-square test, Group A- experimental group, Group B- control group

Table 2. Comparison of Group A and Group B with mean age by

Group	n	Mean	SD	SE	t-value	P-value
Group A	40	59.38	10.56	1.67	0.2397	0.8112
Group B	40	58.88	7.91	1.25		

Independent t test, Group A- experimental group, Group B-control group, SD- standard deviation, SE- standard error

Table 3. Within-Group Comparison of Pre-Test and Post-Test Scores of KOOS in Group A and Group B

KOOS Domains	Group	Time	Mean	SD	Mean Diff.	Effect Size	% of Effect	Z-value	p-value
Pain	A	Pretest	22.40	12.09					
		Posttest	68.78	12.15	46.37	3.84	207.02	5.43	0.0001*
	B	Pretest	21.63	8.97					

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		Posttest	38.73	11.50	17.09	1.91	79.01	5.44	0.0001*
Symptoms	A	Pretest	26.08	10.53					
		Posttest	57.42	11.50	31.34	2.98	120.19	5.51	0.0001*
	B	Pretest	24.59	7.74					
		Posttest	38.60	10.77	14.01	1.81	56.95	4.97	0.0001*
ADL	A	Pretest	18.80	7.68					
		Posttest	63.22	12.68	44.43	5.79	236.37	5.51	0.0000*
	B	Pretest	16.53	5.11					
		Posttest	35.35	11.73	18.82	3.68	113.87	4.81	0.0000*
SP/REC	A	Pretest	16.12	8.21					
		Posttest	49.06	15.19	32.93	4.01	204.24	5.44	0.0001*
	B	Pretest	15.30	10.86					
		Posttest	29.93	12.89	14.63	1.35	95.59	5.37	0.0001*
QOL	A	Pretest	32.69	10.13					
		Posttest	59.84	12.08	27.15	2.68	83.04	5.44	0.0001*
	B	Pretest	35.39	11.17					
		Posttest	43.28	14.04	7.89	0.71	22.29	4.56	0.0001*

Wilcoxon Matched Pairs Test, ADL = Activities of Daily Living, SP/REC = Sports/Recreation, QOL = Quality of Life, SD = standard deviation, Diff = difference, KOOS = Knee Injury and Osteoarthritis Outcome Score $p < 0.05$*

Table 4. Between-Group Comparison of Pre-Test and Post-Test Scores of KOOS in Group A and Group B

KOOS Domains	Time Point	Group A Mean ± SD	Mean Rank A	Group B Mean ± SD	Mean Rank B	Effect Size	Z-value	p-value
Pain	Pretest	22.40 ± 12.09	40.44	21.63 ± 8.97	40.56	0.07	0.0192	0.9846
	Posttest	69.78 ± 11.47	58.93	38.73 ± 11.50	22.08	2.70	7.0870	0.0001*
	Difference	47.37 ± 16.29	58.08	17.09 ± 9.03	22.93	2.39	6.7598	0.0001*

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Symptoms	Pretest	26.08 ± 10.53	40.93	24.59 ± 7.74	40.08	0.16	0.1588	0.8738
	Posttest	57.42 ± 11.50	54.93	38.60 ± 10.77	26.08	1.69	5.5474	0.0001*
	Difference	31.34 ± 12.86	55.16	14.01 ± 7.64	25.84	1.69	5.6388	0.0001*
ADL	Pretest	18.80 ± 7.68	42.23	16.53 ± 5.11	38.78	0.35	0.6591	0.5098
	Posttest	63.22 ± 12.68	57.69	35.35 ± 11.73	23.31	2.28	6.6107	0.0001*
	Difference	44.43 ± 14.75	57.01	18.82 ± 9.98	23.99	2.07	6.3509	0.0001*
SP/REC	Pretest	16.12 ± 8.21	40.73	15.30 ± 10.86	40.28	0.09	0.0818	0.9348
	Posttest	49.06 ± 15.19	53.24	29.93 ± 12.89	27.76	1.36	4.8979	0.0001*
	Difference	32.93 ± 15.24	54.28	14.63 ± 8.40	26.73	1.55	5.2972	0.0001*
QOL	Pretest	32.69 ± 10.13	40.14	35.39 ± 11.17	40.86	0.25	0.1347	0.8928
	Posttest	59.84 ± 12.08	52.85	43.28 ± 14.04	28.15	1.27	4.7487	0.0001*
	Difference	27.15 ± 12.80	56.65	7.89 ± 7.97	24.35	1.85	6.2113	0.0001*

Mann Witney U Test, ADL = Activities of Daily Living, SP/REC = Sports/Recreation, QOL = Quality of Life, SD = standard deviation, KOOS = Knee Injury and Osteoarthritis Outcome Score $p< 0.05$*

Discussion

The objective of the current study was to assess how a thorough lower limb training program affected people with KOA. The study consisted of 80 participants, randomly divided into two groups: the experimental and control group. Results demonstrated statistically significant improvements in both groups through within-group analysis, while between-group analysis favored the experimental group.

Frontal plane pelvic control during gait depends on the hip abductors, which prevent contralateral pelvic drop and trunk sway. In KOA, weak abductors cause pelvic instability, trunk lean, higher knee adduction moments, and medial knee overload [19] Training them improves lateral stability, reduces dynamic valgus, and enhances gait symmetry and confidence.

The quadriceps femoris stabilizes the knee during gait, working isometrically at heel strike, eccentrically to foot flat, and concentrically in mid-stance, with peak activity again in deceleration. In KOA, quadriceps weakness reduces shock absorption, stability, and eccentric control, impairing function. Dynamic quadriceps training improves knee control, load distribution, pain and mobility. [12,13].

The hamstrings stabilize the knee by acting eccentrically at heel strike, concentrically at toe-off and mid-swing, and eccentrically in deceleration. In KOA, weakness impairs tibial control, swing initiation, and stability, increasing anterior knee load. Eccentric training restores support, balance, gait stability, and efficiency [11,13].

The gastrocnemius, stabilizes the ankle during the foot flat and controls anterior tibial translation eccentrically in mid-stance. Its peak activity occurs during heel off, where it contracts concentrically, providing plantarflexion power for propulsion, and continues through toe-off before becoming inactive in swing phases. Originating from the femur, its activation also helps control anterior tibial glide, reducing shear forces in the tibiofemoral joint. In KOA, weak plantar flexors diminish eccentric control and push-off strength, contributing to poor gait mechanics and joint stress.[20]

The experimental group showed better dynamic knee stability in mid-to-terminal stance due to gastrocnemius training, which improved push-off timing and magnitude, reduced gait asymmetry, minimized compensatory hip/trunk movements, and absorbed impact after initial contact, lowering knee joint loads.

The soleus originates from the posterior fibular head and upper shaft, the tibialsoleal line, and the middle third of the medial tibial border, narrowing to join the calcaneal tendon. While its main role is ankle plantarflexion, it also influences knee biomechanics by modulating tibial rotation during gait.Its inferior part is deeply indented in the shape of a horseshoe with a medial and lateral border[21,22].

1. **Heel strike to mid-stance**: Soleus eccentrically controls tibial forward translation and internal rotation, preventing excess dorsiflexion and prolonged pronation that increase KAM and medial knee stress.
2. **Mid-stance to toe-off**: Soleus maintains eccentric control until heel-off, then switches to concentric action to drive plantarflexion, subtalar supination, and tibial external rotation.

The toe intrinsics, originating from the calcaneus and plantar fascia and inserting into the proximal phalanges and extensor hoods, play key roles in gait:

1. **Arch Support**: Maintain medial arch, limit pronation, and control tibial/femoral rotation. Weakness causes arch collapse, poor force transfer, longer stance, and medial knee overload.
2. **Midstance to Toe-off**: Stabilize MTPJs and activate the windlass mechanism, stiffening the arch for efficient push-off, better propulsion, and reduced hip/quadriceps strain.[14,20]

Knee OA reduces knee extension and propulsion, altering gait with weaker toe-off. Shortened stance time lowers toe intrinsic activation, leading to poor proprioception and balance. Training toe intrinsics improved toe clearance, reduced tripping risk, enhanced gait coordination, and lowered abnormal OA limb loading.

- A bottom-up biomechanical improvement throughout the lower leg is produced by the coordinated participation of these muscles:
- Initial Contact to Mid-Stance: Reduced excessive dorsiflexion due to improved soleus function minimizes knee overloading.
- From mid-stance to terminal stance, the gastrocnemius muscle helps stabilize the knee and facilitates effective forward propulsion
- Terminal Stance to Pre-Swing: The limb is ready for swing due to the toe intrinsics, which also provide final propulsion and strengthen arch mechanics.

The experimental group improved KOOS scores by enhancing gait mechanics and redistributing load, reducing knee stress. Gastro-soleus training boosted plantarflexion for smoother weight transfer and stronger push-off, while stronger toe intrinsics improved terminal stance stability, stride symmetry, and reduced fall risk[24,25]

In future longitudinal studies to evaluate the sustained effects of this expanded protocol over six months to one year can be conducted, biomechanical analysis techniques (such as EMG and gait analysis) can be used to clarify the physiological processes behind the noted functional gains.

The limitations of the study was theshort-term duration of the intervention limits the ability to assess the prolonged sustainability of the selected parameters. The study was conducted in a single-center setting, which may restrict the generalizability of findings to broader or more diverse populations.

Conclusion

The findings of this study provide compelling evidence for a holistic, kinetic-chain-focused rehabilitation strategy in managing KOA. The experimental group, which received additional foot and ankle exercises, outperformed the control group across all KOOS subscales. These benefits likely stem from improved gait mechanics, enhanced neuromuscular control, and reduced joint stress. This study advocates for shifting rehabilitation paradigms toward full-limb, multi-joint interventions that reflect the functional complexity of human movement.

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Name of the registry- Clinical Trials Registry-India (CTRI)

https://ctri.nic.in/Clinicaltrials/login.php (ctri.nic.in)

Conflicts of Interest- The authors declare no conflicts of interest related to this study.

References

1. Geng R, Li J, Yu C, Zhang C, Chen F, Chen J, Ni H, Wang J, Kang K, Wei Z, Xu Y, Jin T. Knee osteoarthritis: Current status and research progress in treatment (Review). ExpTher Med. 2023 Aug 25; 26(4):481. doi: 10.3892/etm.2023.12180. PMID: 37745043; PMCID: PMC10515111.
2. Jang S, Lee K, Ju JH. Recent Updates of Diagnosis, Pathophysiology, and Treatment on Osteoarthritis of the Knee. Int J Mol Sci. 2021 Mar 5; 22(5):2619. doi: 10.3390/ijms22052619. PMID: 33807695; PMCID: PMC7961389.
3. Hame SL, Alexander RA. Knee osteoarthritis in women. Curr Rev Musculoskelet Med. 2013 Jun; 6(2):182-7. doi: 10.1007/s12178-013-9164-0. PMID: 23471773; PMCID: PMC3702776.
4. Allen KD, Thoma LM, Golightly YM. Epidemiology of osteoarthritis. Osteoarthritis Cartilage. 2022 Feb; 30(2):184-195. doi: 10.1016/j.joca.2021.04.020. Epub 2021 Sep 14. PMID: 34534661; PMCID: PMC10735233.
5. Driban JB, Harkey MS, Barbe MF, Ward RJ, MacKay JW, Davis JE, Lu B, Price LL, Eaton CB, Lo GH, McAlindon TE. Risk factors and the natural history of accelerated knee osteoarthritis: a narrative review. BMC MusculoskeletDisord. 2020 May 29; 21(1):332. doi: 10.1186/s12891-020-03367-2. PMID: 32471412; PMCID: PMC7260785.
6. Cui A, Li H, Wang D, Zhong J, Chen Y, Lu H. Global, regional prevalence, incidence and risk factors of knee osteoarthritis in population-based studies. EClinicalMedicine. 2020 Nov 26; 29-30:100587. doi: 10.1016/j.eclinm.2020.100587. PMID: 34505846; PMCID: PMC7704420.
7. Kumar H, Pal CP, Sharma YK, Kumar S, Uppal A. Epidemiology of knee osteoarthritis using Kellgren and Lawrence scale in Indian population. J ClinOrthop Trauma. 2020 Feb; 11(Suppl 1):S125-S129. doi: 10.1016/j.jcot.2019.05.019. Epub 2019 May 24. PMID: 31992932; PMCID: PMC6977151.
8. Mora JC, Przkora R, Cruz-Almeida Y. Knee osteoarthritis: pathophysiology and current treatment modalities. J Pain Res. 2018 Oct 5; 11:2189-2196. doi: 10.2147/JPR.S154002. PMID: 30323653; PMCID: PMC6179584.
9. Yunus MHM, Nordin A, Kamal H. Pathophysiological Perspective of Osteoarthritis. Medicina (Kaunas). 2020 Nov 16; 56(11):614.

10. Vincent KR, Conrad BP, Fregly BJ, Vincent HK. The pathophysiology of osteoarthritis: a mechanical perspective on the knee joint. PM R. 2012 May; 4(5 Suppl):S3-9. doi: 10.1016/j.pmrj.2012.01.020. PMID: 22632700; PMCID: PMC3635670.
11. Shamsi S, Al-Shehri A, Al Amoudi KO, Khan S. Effectiveness of physiotherapy management in knee osteoarthritis: A systematic review. Indian J Med Spec 2020; 11(4):185-91. doi:10.4103/INJMS.INJMS_96_20
12. Raposo F, Ramos M, Lúcia Cruz A. Effects of exercise on knee osteoarthritis: A systematic review. Musculoskeletal Care. 2021 Dec; 19(4):399-435. doi: 10.1002/msc.1538. Epub 2021 Mar 5. PMID: 33666347.
13. Khan SA, Parasher P, Ansari MA, Parvez S, Fatima N, Alam I. Effect of an Integrated Physiotherapy Protocol on Knee Osteoarthritis Patients: A Preliminary Study. Healthcare (Basel). 2023 Feb 14; 11(4):564. doi: 10.3390/healthcare11040564. PMID: 36833098; PMCID: PMC9956031.
14. Dantas G, Sacco ICN, Dos Santos AF, Watari R, Matias AB, Serrao PRMS, Pott-Junior H, Salvini TF. Effects of a foot-ankle strengthening programme on clinical aspects and gait biomechanics in people with knee osteoarthritis: protocol for a randomised controlled trial. BMJ Open. 2020 Sep 25; 10(9):e039279. doi: 10.1136/bmjopen-2020-039279. PMID: 32978204; PMCID: PMC7520828.
15. Pal CP, Singh P, Chaturvedi S, Pruthi KK, Vij A. Epidemiology of knee osteoarthritis in India and related factors. Indian J Orthop. 2016 Sep; 50(5):518-522. doi: 10.4103/0019-5413.189608. PMID: 27746495; PMCID: PMC5017174.
16. Rocha TC, Ramos PDS, Dias AG, Martins EA. The Effects of Physical Exercise on Pain Management in Patients with Knee Osteoarthritis: A Systematic Review with Metanalysis. Rev Bras Ortop (Sao Paulo). 2020 Oct; 55(5):509-517. doi: 10.1055/s-0039-1696681. Epub 2019 Sep 23. PMID: 33093712; PMCID: PMC7575366.
17. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. J Orthop Sports PhysTher. 1998 Aug; 28(2):88-96. doi: 10.2519/jospt.1998.28.2.88. PMID: 9699158.
18. Watabe T, Sengoku T, Kubota M, Sakurai G, Yoshida S, Taniguchi Y. Knee injury and osteoarthritis outcome score and knee society score for the minimal clinically important differences after cruciate-retaining total knee arthroplasty: Two-year follow-up. Knee. 2025;53:176-82. doi:10.1016/j.knee.2024.12.015
19. Hinman RS, Hunt MA, Creaby MW, Wrigley TV, McManus FJ, Bennell KL. Hip muscle weakness in individuals with medial knee osteoarthritis. Arthritis Care Res (Hoboken). 2010 Aug; 62(8):1190-3. doi: 10.1002/acr.20199. PMID: 20704005.
20. Sylvester AD, Lautzenheiser SG, Kramer PA. Muscle forces and the demands of human walking. Biol Open. 2021 Jul 15; 10(7):bio058595. doi: 10.1242/bio.058595. Epub 2021 Jul 19. PMID: 34279576; PMCID: PMC8325943.
21. Neumann DA, Kelly ER. Kinesiology of the musculoskeletal system: foundations for rehabilitation. 3rd ed. St. Louis (MO): Elsevier; 2017.
22. Whittle MW. Gait analysis: an introduction. 5th ed. Edinburgh: Butterworth-Heinemann; 2014.
23. Menz HB, Morris ME, Lord SR. Foot and ankle characteristics associated with impaired balance and functional ability in older people. J Gerontol A BiolSci Med Sci. 2005 Dec; 60(12):1546-52. doi: 10.1093/gerona/60.12.1546. PMID: 16424286.
24. Khan M, Memon M, Ramachandran M, Bhandari M, Simunovic N. Efficacy of hip strengthening in knee osteoarthritis: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2020; 101(1):79-92.
25. Perry J, Burnfield JM. Gait analysis: normal and pathological function. 2nd ed. Thorofare (NJ): SLACK Incorporated; 2010