https://doi.org/10.46351/jas.v32i2pp53-65

JAS Journal of Anatomical Sciences (U.P. Chapter of Anatomical Society of India)

Original Article

Pedographic and radiographic analysis of foot and its clinical implication

Puneet Chaudhary[1], Swati Saxena[1], Rajesh Kumar Maurya[1], Mahendra Kumar Pant[1]

1. Department of Anatomy, Government Doon Medical College, Dehradun, India

ABSTRACT

Introduction: Foot posture plays a crucial role in musculoskeletal health by influencing the dynamic function and alignment of the lower limbs. Alterations in foot biomechanics, such as flatfoot, have been linked to the development and progression of medial compartment knee osteoarthritis (OA). Pedography, a non-invasive technique to assess foot posture, provides detailed visualization of footprints and may serve as an effective screening tool for early identification and management of foot malalignment using orthotics.

Materials and Methods: This case-control study assessed pedographic parameters (Arch index and Arch angle) and radiographic parameters (calcaneal pitch angle and cuboid abduction angle) in 45 patients with clinically and radiologically confirmed medial knee OA and 33 age-matched healthy controls from the Dehradun district. Additional radiographic angles measured included Meary's angle, talo-calcaneal angle, and talo-navicular coverage angle. The correlation between pedographic and radiographic parameters was analyzed, along with demographic factors such as BMI, age, and gender.

Results: Significant differences were found in both pedographic and radiographic measurements between individuals with and without knee OA. Pronated foot posture (elevated Arch index and reduced Arch angle) was more prevalent in the OA group. The cuboid abduction angle (CAA) and calcaneal pitch angle (CPA) also showed significant associations with OA status ($p = 0.000$ and 0.035, respectively). BMI was significantly associated with OA presence.

Conclusions: Pronated flatfoot was more common in individuals with medial knee OA, suggesting a biomechanical link. Pedographic assessment offers a useful, radiation-free alternative for early screening and prevention strategies, especially in rural settings where radiographic resources are limited.

Keywords: Arch index, Calcaneal pitch, Foot health, BMI, Foot alignment

Address for Correspondence:
Dr. Swati Saxena, Assistant Professor, Department of Anatomy, Government Doon Medical College, Dehradun, India
Email: 21swatidocsaxena@gmail.com

Date of Receiving: 19 Aug 2024
Date of Acceptance: 23 Sep 2024

INTRODUCTION

Osteoarthritis (OA) of the knee is a painful joint condition that damages the articular cartilage and bone structure. There has been evidence linking the symptoms of osteoarthritis (OA) to abnormal mechanical stress of the lower limbs [1,2]. The foot serves as essential for maintaining proper joint motion, absorbing ground reaction stresses, and creating the pattern of postural alignment within the lower extremities [3]. While doing weight-bearing tasks, the foot and knee move in a closed kinematic chain, which can cause excessive knee rotation in those who have flat feet [4]. thereby increasing the prevalence of OA [5,6]. It has been proposed that the conservative treatment of lower limb OA may benefit from orthoses that modify the features of the hindfoot.

For OA of the knee's medial compartment, lateral wedged insoles have been suggested. Given that the leading cause of pain and impairment in the elderly is osteoarthritis (OA) of the knee [6-11]. The aim of this study was to analyse the pedographic (arch angle and the arch index) and radiographic parameters (calcaneal pitch angle and cuboid abduction angle) of foot with and without medial knee osteoarthritis among the population in Dehradun district. The objectives of this study were:

1. To assess the correlation between the pedography parameters (arch index and arch angle) and socio-demographic factors such as age, gender, and BMI.
2. To estimate the frequency of MKOA related to age, gender and BMI.
3. To examine the correlation between the pedography parameters (arch index and arch angle) of foot and radiographic measurements in clinically diagnosed medial knee osteoarthritis.

MATERIAL AND METHODS

The present study was designed as a case control study and was carried out in Orthopaedics, Physical medicine and rehabilitation and Radiology departments of Government Doon hospital. Ethical clearance was obtained from Institutional Ethics Committee (IEC), GDMC, Dehradun via reference number: GDMC/ IEC/ 2023/ 28. This study included, 45 subjects (30 females and 15 males) with clinically diagnose medial knee osteoarthritis and 33 people without knee osteoarthritis (20 males and 13 females) to assess pedographic parameters, radiographic parameters and demographic parameters.

Samples were taken from patients who visited in departments of orthopaedics and PMR of government doon Hospital, Dehradun. Footprint were taken from Harris mat and x-ray foot were collected from department of radiology in Government Doon hospital, Dehradun.

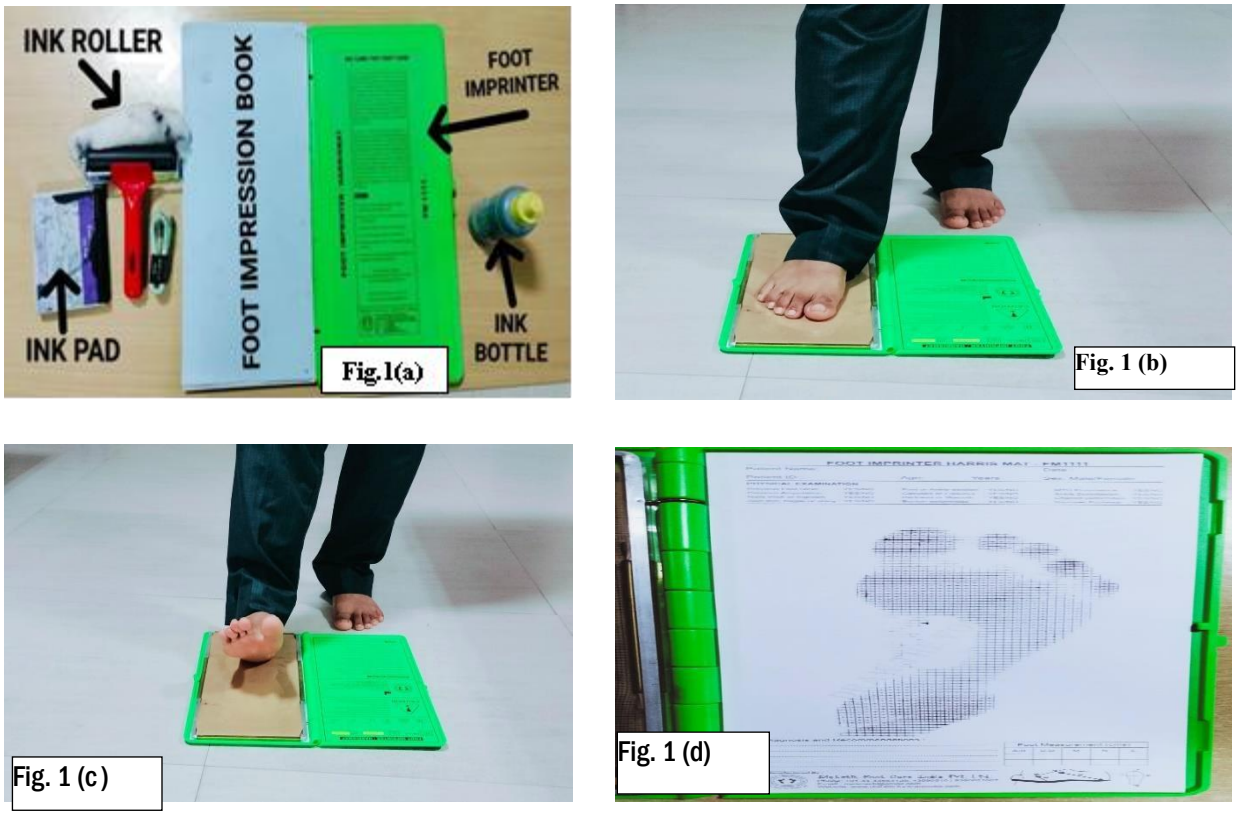

Fig. 1. Estimation of patients' footprint using Harris mat.

Inclusion criteria – Patients with previously or freshly diagnosed knee osteoarthritis, without having previous history of foot or ankle injury or walking deformity/gait with age 30-70 years.

Exclusion criteria - Patients with previous injury of foot or ankle, age <30 and >70 years, previous ankle or foot surgery, with foot prosthesis or orthosis, congenital deformity of foot and patients suffering from neurological disease eg -: hypotonia, cerebral palsy with muscular disease eg-: muscular dystrophy.

Procedure

Samples of cases were collected from patients who visited the PMR and Orthopaedics out patient departments. Participants' body mass index (BMI), height and footprint from Harris mat (Fig.1) were recorded.

Foot posture measurements:

Arch index: Using computer graphics, it was computed as the ratio of the middle portion to the total footprint area (Fig. 2(a)). A flatter (more pronated) foot was indicated by higher arch index values. flat foot= >0.26, normal=0.21-0.26, high arched=<0.26 [12].

Arch angle/Clarke's angle: It was measured as the angle formed by the line joining the metatarsal region's most medial point and the footprint's medial boundary line Fig. 2(b) [12].

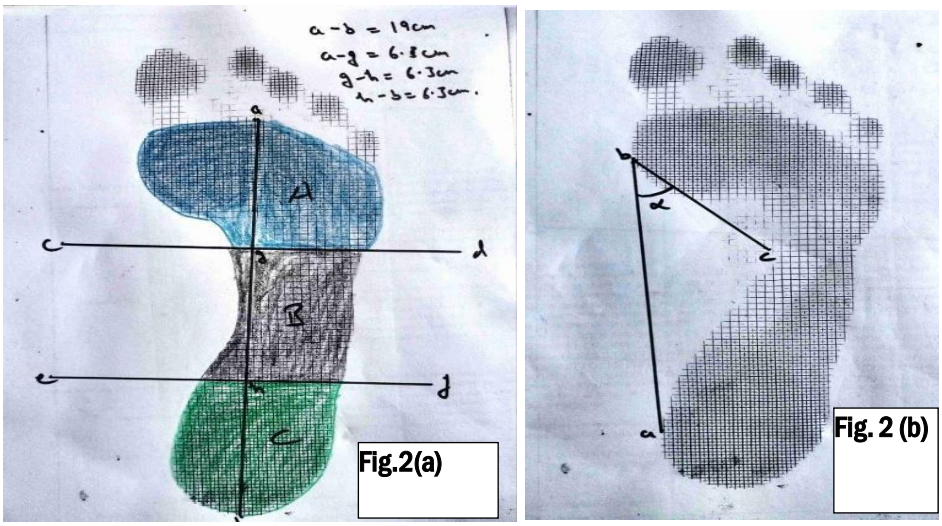

Fig. 2. Measurement of (a) Arch index and (b) Arch angle/Clarke's angle.

Radiographic Measurements:-

Calcaneal pitch angle: A line drawn on the plantar surface from the calcaneus and a segment joining the inferior border of the calcaneus and the inferior margin of the fifth metatarsal head constituted the calcaneal pitch angle (β). Fig. 3(a) [13].

Meary's angle(α): Created by the talus's long axis and the first metatarsal axis Fig. 3(b) [13].

Talo-navicular angle: The line that connects the medial and lateral edges of the talus and the line that connects the medial and lateral borders of the navicular bone are perpendicular enough to create (Y). Fig. 3(c) [13].

Cuboid abduction angle (CAA): Angle between the rearfoot's longitudinal axis and a line perpendicular to the cuboid's lateral surface (Fig. 2) (normal: 0°-5°). With the mid-tarsal joint pronating, this angle rises above 5°, and with supination and adduction, it falls below 0°. Fig. 3(d) [14].

Statical analysis: A Microsoft Excel sheet was used to tabulate and statistically analyze the data. The mean and standard deviation were used to express the findings with their p-value and correlation was calculated with the help of Pearson's coefficient.

RESULTS

A total of 78 participants were included in the study, with 45 individuals clinically diagnosed with medial knee osteoarthritis (MKOA) and 33 controls without MKOA. The mean age was higher in the OA group, and a greater proportion of females (30 out of 45) were affected compared to males (15 out of 45). Body Mass Index (BMI) was significantly higher in participants with MKOA (30.47±4.02) than in controls (22.96±2.7), with a highly significant p-value of 0.000.

Pedographic measurements revealed a significantly elevated arch index in the MKOA group (0.2813±0.045) compared to controls (0.2427±.023), indicating a flatter foot profile in OA participants (p = 0.000). Correspondingly, the arch angle (Clarke's angle) was significantly lower in the OA group (30.94±7.85°) than in controls (45.35±3.9°), further supporting the prevalence of flatfoot (p = 0.000).

Radiographic analysis showed a markedly higher cuboid abduction angle (CAA) in the OA group (16.56±8.23°) versus controls (3.96±1.10°, p = 0.000), indicating midfoot pronation. However, the calcaneal pitch angle (CPA) did not show significant differences between the two groups (26.45±6.69° in OA vs. 23.61±4.09° in controls, p = 0.35).

Flatfoot prevalence was notably higher in the OA group, with 80% showing pronated foot based on arch index and 89% based on arch angle. A significant association was found between BMI and flatfoot status (χ^2 = 8.372, p = 0.004), while age and gender showed no statistically significant associations.

Correlation analysis indicated a significant negative correlation between arch index and truncated arch (r = -0.565, p < 0.001), Foot Posture Index (FPI) (r = -0.539, p < 0.001), and calcaneal pitch (r = -0.352, p = 0.018), whereas correlations involving arch angle were weak and non-significant.

Table 1. Characteristics of participants with and without medial knee osteoarthritis

Parameters	Without OA (n=33)	With OA (n=45)	p-value
Arch index	0.2427±.023	0.2813±.045	0.000
Arch angle	45.3515±3.9	30.9378±7.85	0.000
BMI	22.9697±2.7	30.4689±4.02	0.000
CP angle	23.6182±4.09	26.4467±6.69	0.35
CAA angle	3.9606±1.10	16.5578±8.23	0.000

Table 2. Distribution of characteristics by Arch Index and arch angle

Foot characterstics	Parameters	Frequency	Percent(%)
Pronated	Arh index	36	80
	Arch angle	40	89
Normal	Arh index	9	20
	Arch angle	5	11
Total	Arh index	45	100
	Arch angle	45	100

Table 3. Association of Arch Index with age, gender and BMI

Age	Arch Index		Chi square, p value
	Pronated	Normal	
less than 50	14(77.8)	4(22.2)	0.093, 0.761
≥50	22(81.5)	5(18.5)	
Gender			
Male	12(80.0)	3(20.0)	2.314, 0.789
Female	24(80.0)	6(20.0)	
BMI			
Normal	0(0.0)	2(100.0)	8.372, 0.004
Overweight	36(83.7)	7(16.3)	

Table 4. Association of Arch angle with age, gender and BMI

Age	Arch Angle		Chi square, p value
	Normal	Flat foot	
less than 50	3(16.7)	15(83.4)	1.228, 0.746
≥50	2(7.4)	25(92.6)	
Gender			
Male	1(6.7)	14(93.3)	0.750, 0.369
Female	2(6.7)	28(93.3)	
BMI			
Normal	0(0.0)	2(100.0)	0.742, 0.863
Overweight	5(11.6)	38(88.4)	

DISCUSSION

The present study aimed to investigate the relationship between pedographic (Arch index and Arch angle) and radiographic parameters (calcaneal pitch angle and cuboid abduction angle) of the foot in individuals with and without medial knee osteoarthritis (MKOA) in the Dehradun district. The results reveal significant differences in both arch index and arch angle between individuals with MKOA and those without, supporting the hypothesis that alterations in foot biomechanics—particularly a pronated foot posture—may be associated with knee osteoarthritis.

The arch index was significantly higher in participants with MKOA (0.2813±0.045) compared to those without (0.2427±.023), indicating flatter feet in the OA group. Correspondingly, the arch angle was significantly lower in the OA group (30.93±7.85°), further confirming the presence of foot pronation. These findings strongly suggest that the altered foot posture and reduced medial arch integrity may play a contributory role in the pathogenesis or progression of MKOA.

The study's outcomes align with the established understanding that foot biomechanics significantly impact the loading and kinematics of the knee joint. In the kinetic chain of the lower limb, the foot and knee function in tandem; excessive foot pronation has been shown to increase internal tibial rotation and medial knee compartment loading, both of which are implicated in the development and progression of MKOA.

This biomechanical interrelationship is consistent with earlier research by Guler et al. [3], Riskowski et al. [5], and Iijima et al. [11], all of whom identified a link between altered foot posture and increased knee pain and disability in OA patients. Moreover, the statistically significant association of BMI with both flatfoot prevalence and MKOA incidence ($p < 0.001$) in our study echoes findings by Menz et al. [15] and Rothrauff et al. [17], reinforcing the idea that obesity exacerbates mechanical loading on both the foot arch and knee joint, thus amplifying degenerative processes.

A further notable observation is the significant positive correlation between the arch index and cuboid abduction angle (CAA), which was markedly elevated in MKOA patients (16.55±8.23°) compared to controls (3.96±1.10°, $p < 0.001$). The CAA reflects midfoot abduction, which is a feature of excessive pronation. Increased CAA is indicative of midtarsal joint instability and transverse plane foot deformities—conditions that can alter the gait cycle and affect proximal joints like the knee. This observation aligns with Inui et al. [13], who documented a relationship between midfoot deformities and radiographic signs of knee OA, and supports the growing body of evidence suggesting that

foot abnormalities may not be mere consequences of OA-related disuse or aging but active contributors to pathological biomechanics.

The arch index was significantly higher in participants with MKOA (0.2813±0.045) compared to those without (0.2427±.023), indicating flatter feet in the OA group. Correspondingly, the arch angle was significantly lower in the OA group (30.93±7.85°), further confirming the presence of foot pronation. These findings strongly suggest that the altered foot posture and reduced medial arch integrity may play a contributory role in the pathogenesis or progression of MKOA.

The study's outcomes align with the established understanding that foot biomechanics significantly impact the loading and kinematics of the knee joint. In the kinetic chain of the lower limb, the foot and knee function in tandem; excessive foot pronation has been shown to increase internal tibial rotation and medial knee compartment loading, both of which are implicated in the development and progression of MKOA. This biomechanical interrelationship is consistent with earlier research by Guler et al. [3], Riskowski et al. [5], and Iijima et al. [11], all of whom identified a link between altered foot posture and increased knee pain and disability in OA patients. Moreover, the statistically significant association of BMI with both flatfoot prevalence and MKOA incidence ($p < 0.001$) in our study echoes findings by Menz et al. [15] and Rothrauff et al. [17], reinforcing the idea that obesity exacerbates mechanical loading on both the foot arch and knee joint, thus amplifying degenerative processes.

A further notable observation is the significant positive correlation between the arch index and cuboid abduction angle (CAA), which was markedly elevated in MKOA patients (16.55±8.23°) compared to controls (3.96±1.10°, $p < 0.001$). The CAA reflects midfoot abduction, which is a feature of excessive pronation. Increased CAA is indicative of midtarsal joint instability and transverse plane foot deformities—conditions that can alter the gait cycle and affect proximal joints like the knee. This observation aligns with Inui et al. [13], who documented a relationship between midfoot deformities and radiographic signs of knee OA, and supports the growing body of evidence suggesting that foot abnormalities may not be mere consequences of OA-related disuse or aging but active contributors to pathological biomechanics.

While the calcaneal pitch angle (CPA) was slightly elevated in the OA group (26.44±6.69°) compared to controls (23.61±4.09°), the difference was not statistically significant ($p = 0.35$). Interestingly, despite CPA being traditionally considered a marker of medial arch height, its variability in our sample may reflect compensatory

mechanisms, anatomical variations, or postural adaptations over time. These inconsistencies are not uncommon; Tayashiki et al. [16] and Kobayashi et al. [17] also reported varying levels of correlation between arch index and calcaneal pitch, suggesting that dynamic and static measurements of foot posture may not always align due to differences in weight-bearing status, muscular control, and joint laxity.

The findings on demographic associations are also instructive. The prevalence of flat feet and MKOA was found to be higher among individuals aged over 50 years, in females, and in overweight participants, although statistical significance was reached only in the BMI category ($p = 0.004$). These results are consistent with prior epidemiological studies such as those by Felson et al. [6] and Lawrence et al. [8], who documented a higher incidence of OA in older adults and females, attributing it to hormonal influences, reduced muscle mass, and joint alignment differences. The lack of statistically significant associations for age and gender in the current study may be due to sample size constraints, but the trends remain in agreement with broader literature and indicate the need for targeted screening in these high-risk groups.

Table 5. Arch index of pronated foot

S. No	Author	Population	Year	Mean ±sd
1	George S Murley et al[18]	Australian	2009	0.30 ± 0.07
2	Menz et al[15]	Australian	2010	028±0..05
3	Dwi Basuki Wibowo et al[19]	Indonesian	2017	0.543±0.057
4	Gunawan Dwi Haryadi et al[20]	Indonesian	2018	0.319 ± 0.040
5	Mr. Chandan Kumar Yadav et al[21]	Indian	2022	1.03 ± 0.1058
6	Present study	Indian	2024	0.2813±0.045

Table 6. Arch angle of pronated foot

S. No.	Author	Sample size	Population	Year	Mean±Sd
1	Patel M et al22	284	Indian	2021	29.00±3.87
2	Hegazy F et al23	460	UAE	2020	36.71±3.20
3	Pauk J et al24	42	USA	2014	24.1 ± 4.0
4	Zhang M et al 25	95	Chinese	2022	28.47±13.24
5	Present study	45	Indian	2024	30.9378±7.85

The clinical implication of this study is profound. Given the strong correlation between pedographic indicators and MKOA, particularly in resource-limited settings where radiography may not be readily available, pedography offers a viable, cost-effective screening tool. Arch index and arch angle measurements using the Harris mat provide rapid, non-invasive insights into foot biomechanics.

Their correlation with radiographic markers like cuboid abduction angle and, to a lesser extent, calcaneal pitch angle, enhances their utility in community-level screening programs. Furthermore, the ability to detect early foot malalignment and pronation can inform timely interventions, such as prescribing orthoses, footwear modifications, and physical therapy, thereby possibly delaying or mitigating the progression of MKOA.

In particular, the application of pedography could be pivotal in screening obese individuals, elderly populations, and pregnant women—all of whom are prone to altered gait mechanics and foot posture changes. Pregnancy, in particular, introduces ligamentous laxity and weight gain, both of which could contribute to medial arch collapse and subsequent knee malalignment. Although not directly studied here, extrapolating these findings to such populations opens avenues for preventive care strategies and targeted interventions.

Despite the strengths of the study, including its use of both pedographic and radiographic data and the relevance of its findings to an Indian population (where flatfoot prevalence and OA risk factors may be underdiagnosed), there are several limitations. The sample size, though adequate for preliminary conclusions, limits the statistical power to detect more subtle correlations, particularly in subgroup analyses. A larger, multicentric cohort study would be beneficial to confirm the associations observed. Moreover, the cross-sectional design restricts causal inference; while foot posture is associated with MKOA, it remains unclear whether the altered biomechanics precede the onset of osteoarthritis or are adaptive consequences thereof. Longitudinal studies would be instrumental in resolving this temporal ambiguity.

Another limitation pertains to the use of 2D pedography and plain radiography, which, although practical and economical, lack the depth and detail of 3D imaging or dynamic gait analysis. This restricts the ability to capture real-time changes in joint mechanics and muscular coordination, which are critical in comprehensively understanding the pathophysiology of MKOA. Future studies could incorporate plantar pressure mapping, motion capture systems, or weight-bearing CT/MRI for a more nuanced analysis. Additionally, while our study did not assess functional outcomes such as pain severity, walking speed, or quality of life, including

such parameters could strengthen the clinical relevance of biomechanical measurements.

In light of these findings, it is recommended that clinicians and public health practitioners consider integrating routine foot assessments—particularly arch index and arch angle evaluations—into OA screening protocols, especially in high-risk groups. Educational programs on proper footwear and the role of orthotic supports should be promoted in community health settings. Finally, future research should aim to explore the effectiveness of targeted foot interventions (such as custom orthotics or strength training for foot muscles) in reducing pain and improving function in MKOA patients.

Hence, this study highlights a significant association between flatfoot as characterized by elevated arch index and reduced arch angle, and the presence of medial knee osteoarthritis. These pedographic parameters, particularly when corroborated by radiographic features like increased cuboid abduction angle, offer valuable insight into the biomechanical factors contributing to MKOA. Pedography emerges as an accessible and effective tool in the early identification and potential prevention of knee osteoarthritis, particularly in resource-constrained environments. Further investigation with larger cohorts, dynamic biomechanical assessments, and interventional follow-up will be critical in fully harnessing the potential of foot-based screening and management strategies for knee osteoarthritis.

CONCLUSION

Arch index and arch angle in the Dehradun region were found to be 0.2813±0.045 and 30.9378±7.85. Regular assessments of pedographic parameters (arch index,arch and angle) can be beneficial in monitoring changes in foot structure, especially in populations at risk, specially in obese individuals. In remote areas where facility of x ray radiography is not available, measurement of the progression of osteoarthritis can be done with the help of pedographic parameters along with the progression of MKOA in pregnant women. The relationship between arch index, calcaneal pitch angle, and BMI underscores the importance of these parameters in understanding foot health and biomechanics. Pedography provides excellent visualization of the footprint and can be used as screening procedure for early identification of flat foot and other foot malalignment and its effective management by using orthotics.

REFERENCES

1. Poole AR, Guilak F, Abramson SB. Etiopathogenesis of osteoarthritis. In: Moskowitz RW, Altman RD, Buckwalter JA, Goldberg VM, editors. Osteoarthritis: Diagnosis and Medical/Surgical

Management. 4th ed. Philadelphia: WB Saunders; 2007. p. 27–49.

2. Kumar H, Pal CP, Sharma YK, Kumar S, Uppal A. Epidemiology of knee osteoarthritis using Kellgren and Lawrence scale in Indian population. J Clin Orthop Trauma. 2020 Feb;11(Suppl 1):S125–9.
3. Guler H, Karazincir S, Turhanoglu AD, Sahin G, Balci A, Ozer C. Effect of coexisting foot deformity on disability in women with knee osteoarthritis. J Am Podiatr Med Assoc. 2009 Jan;99(1):23–7.
4. Toda Y, Tsukimura N, Kato A. The effects of different elevations of laterally wedged insoles with subtalar strapping on medial compartment osteoarthritis of the knee. Arch Phys Med Rehabil. 2004 Apr;85(4):673–7.
5. Riskowski JL, Dufour AB, Hagedorn TJ, Hillstrom HJ, Casey VA, Hannan MT. Associations of foot posture and function to lower extremity pain: results from a population-based foot study. Arthritis Care Res (Hoboken). 2013 Nov;65(11):1804–12.
6. Felson DT, Lawrence RC, Dieppe PA, Hirsch R, Helmick CG, Jordan JM, et al. Osteoarthritis: new insights. Part 1: the disease and its risk factors. Ann Intern Med. 2000 Oct 17;133(8):635–46.
7. Kim JS, Lee MY. The effect of short foot exercise using visual feedback on the balance and accuracy of knee joint movement in subjects with flexible flatfoot. Medicine (Baltimore). 2020 Mar;99(13):e19260.
8. Lawrence RC, Helmick CG, Arnett FC, Deyo RA, Felson DT, Giannini EH, et al. Estimates of the prevalence of arthritis and selected musculoskeletal disorders in the United States. Arthritis Rheum. 1998 May;41(5):778–99.
9. Goodman SM, Springer B, Guyatt G, Abdel MP, Dasa V, George M. American College of Rheumatology/American Association of Hip and Knee Surgeons guideline for the perioperative management of antirheumatic medication in patients with rheumatic diseases undergoing elective total hip or total knee arthroplasty. Arthritis Rheumatol. 2017 Sep;69(8):1538–51.
10. Mochizuki T, Omori G, Nishino K, Tanaka M, Tanifuji O, Koga H, et al. The medial inclination of the proximal tibia is associated with the external knee adduction moment in advanced varus knee osteoarthritis. Knee Surg Sports Traumatol Arthrosc. 2022 Feb;30(2):574–83.
11. Iijima H, Ohi H, Isho T, Aoyama T, Fukutani N, Kaneda E, et al. Association of bilateral flat feet with knee pain and disability in patients with knee osteoarthritis: a cross-sectional study. J Orthop Res. 2017 Nov;35(11):2490–8.
12. Hawes MR, Nachbauer W, Sovak D, Nigg BM. Footprint parameters as a measure

of arch height. Foot Ankle. 1992 Jan;13(1):22–6.

13. Inui K, Ikoma K, Imai K, Ohashi S, Maki M, Kido M, et al. Examination of the correlation between foot morphology measurements using pedography and radiographic measurements. J Foot Ankle Surg. 2017 Mar;56(2):298–303.
14. Gentili A, Masih S, Yao L, Seeger LL. Foot axes and angles. Br J Radiol. 1996 Oct;69(826):968–74.
15. Menz HB, Sherrington C. Foot posture and foot function in older people: a review of the literature. J Aging Res. 2006;2006:35884.
16. Tayashiki K, Yamada K, Yamamoto S. Correlation between arch index and calcaneal pitch angle in healthy adults. J Phys Ther Sci. 2014 Mar;26(3):433–6.
17. Kobayashi K, Yamada K, Yoshimoto H. The relationship between foot arch index and calcaneal pitch angle in various foot types. J Foot Ankle Res. 2018 Jan;11(1):5.
18. Rothrauff BB, Miller MC, de Meireles SM, et al. The influence of obesity on foot biomechanics: a systematic review. J Foot Ankle Surg. 2016 Jul–Aug;55(4):855–64.
19. Wibowo DB, Haryadi GD, Widodo A, Rahayu SP. Correlation of loaded and unloaded foot area with arch index in younger flatfoot. MATEC Web Conf. 2017;135:00060.
20. Haryadi GD, Wibowo DB, Widodo A, Suprihanto A. Comparison of ratio loaded and unloaded foot area of flat foot and healthy foot in younger adults. MATEC Web Conf. 2018;159:02019.
21. Yadav CK, Modi V, Rani A, Rajput K, Mishra R, Srivastava S. A study on prevalence of flat foot among children 5–10 years and adults above 18 years in Lucknow population: a cross-sectional study. NeuroQuantology. 2022;20(15):3127.
22. Patel M, Shah P, Ravaliya S, Patel M. Relationship of anterior knee pain and flat foot: a cross-sectional study. Int J Health Sci Res. 2021;11(3):86–92.
23. Hegazy F, Aboelnasr E, Abuzaid M, Kim IJ, Salem Y. Comparing validity and diagnostic accuracy of Clarke's angle and foot posture index-6 to determine flexible flatfoot in adolescents: a cross-sectional investigation. J Multidiscip Healthc. 2021 Sep 27;14:2705–17.
24. Pauk J, Ihnatouski M, Najafi B. Assessing plantar pressure distribution in children with flatfoot arch: application of the Clarke angle. J Am Podiatr Med Assoc. 2014 Nov;104(6):622–32.
25. Zhang M, Nie MD, Qi XZ, Ke S, Li JW, Shui YY, et al. A strong correlation between the severity of flatfoot and symptoms of knee osteoarthritis in 95 patients. Front Surg. 2022 Jun 30;9:936720.