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Assessment of Foot Deformities in Patient with Knee Osteoarthritis

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Abstract

Foot morphology evaluation techniques are commonly used to evaluate foot abnormalities. The foot is essential for keeping the biomechanical performance of the lower extremities. Knee osteoarthritis is a pathological condition that could lead to foot deformities. The major goal of this study was to investigate the prevalence of foot deformity in patients with Knee osteoarthritis. Another goal was to quantify the impact of pain and the severity of osteoarthritis foot morphological changes in Knee osteoarthritis patients.A total of seventy-eight participants took part in this study, including forty-six non-pathological subjects and thirty-two subjects diagnosed with knee osteoarthritis. Foot characteristics were assessed by a podoscope that can automatically estimate foot morphological parameters including Arch Index, Chippaux-Smirak Index, Staheli Index, Weisflog's index, Clarke's angle and Hallux valgus angle. Numerous foot-related variables have been connected in a direct manner to knee osteoarthritis. Particularly, those who had knee osteoarthritis had substantially higher values for the Arch index (0.29±0.018; P=0.00), Chippaux-Smirak index (0.55±0.5; P=0.00), Staheli index (0.77±0.7; P=0.00), and Weisflog's index (2.7±0.25; P=0.00) than those who did not have this disease. Furthermore, their Clarke's angle and Hallux valgus angle exhibited high values of (30.27±2.7) and (13±1.8), respectively. There were also significant correlations found within the knee osteoarthritis group. There was, for example, a substantial positive correlation between the Arch Index and the Chippaux-Smirak Index (0.767; p=0.00), the Arch Index and the Staheli Index (r=0.35; p=0.04), and the Chippaux-Smirak Index and the Staheli Index (r=0.44; p=0.01). In terms of foot abnormalities, the Midfoot (333.528.6; p=0.00) was more significant than the Rearfoot (604.25±31.2; p=0.85) and Hindfoot (433.3±35.2; p=1.66). With association values of (r=0.4; p=0.02) and (r=0.4; p=0.04), the Arch Index and Chippaux-Smirak Index were both significantly linked with the severity of knee osteoarthritis.Foot abnormalities are substantially more prevalent in persons with Knee osteoarthritis. Collapsed medial longitudinal arch, transverse arch, and hallux valgus are all variables to consider in the management of Knee osteoarthritis. Healthcare providers may target Knee osteoarthritis effects on midfoot morphology with focused therapies. Custom orthotic devices, footwear adjustments, and particular workouts may enhance midfoot stability and alignment. Assessing foot morphology allows healthcare providers to enhance knee osteoarthritis therapy and patient results.

Keywords: *Foot deformation; Osteoarthritis; Arch Index; Chippaux-Smirak Index; Staheli Index*

1. Introduction

Knee osteoarthritis (KOA) is a degenerative joint ailment that gradually becomes worse over time. It is characterised by chronic joint pain and stiffness, which can severely impede a person's physical function and ability to do everyday tasks. KOA is a primary source of functional impairment and is expected to impact roughly 18% of those aged 45 and over.

This disorder may have larger implications on the lower limb. It has the ability to change the alignment of the whole lower leg, including the knee, hip, and ankle joints. This altered alignment places additional stress on the ankle joint, this can lead to degeneration and the development of ankle joint disorders. Individuals with KOA should seek appropriate medical care and management measures to relieve pain, enhance function, and limit the course of the illness. Treatment options may include pain management strategies, physical therapy, exercise, assistive equipment, and, in certain situations, surgical proceduresConsulting with a healthcare expert, such as an orthopaedic specialist or rheumatologist, can lead the most suited treatment method for each individual's unique circumstance [1]. Flatfoot, a disorder defined by a collapsed or low arch in the foot, can contribute to the increased severity of disability in patients with KOA. Specifically, flatfoot can result in excessive rotation of the knee joint [2]. It is still unknown if abnormalities such as flatfoot are a direct cause or a risk factor for the development of KOA.

Traditionally, osteoarthritis (OA) was diagnosed based on the radiological appearance of the afflicted joints. In 1957, Kellgren and Lawrence established radiographic criteria for OA [3], They were eventually approved by the World Health Organisation during a 1961 session in Milan[4]. Kellgren and Lawrence's categorization approach categorises OA into five phases.

A healthy knee (stage 0) does not have osteoarthriti. The severity increases as the medical condition worsens. Severe OA is categorised as stage 4, indicating significant joint degeneration. Stage 4 is the most severe variety of OA, with each stage signifying a more advanced condition of the disease. This grading system offers a standardised framework for characterising the radiological appearance and severity of OA.

Traumatic injury, genetic susceptibility, obesity, and poor joint biomechanics can all play a role in the development of KOA. Poor joint biomechanics is thought to play a role in primary progressive KOA, in which the disease steadily worsens over time [5]. KOA is commonly associated with clinical symptoms such as slow-onset knee pain that worsens with movement, knee stiffness and edoema, discomfort after long periods of sitting or sleeping, and growing pain with time.
Foot characteristics and mechanics, such as static foot posture (e.g., flatfoot or high arch) and dynamic foot function (e.g., how the foot moves when walking or running), may contribute to musculoskeletal diseases in the lower limbs. However, the specific relationships between foot features, foot mechanics, and the development or progression of KOA have not been extensively studied and are not well understood.

The research has two primary goals. The study intended to analyse the variations in foot features between persons with KOA and those without the disease. By comparing the foot features of these two groups, the researchers attempted to understand if specific foot traits are more widespread or distinct in persons with KOA.

Furthermore, the study focused primarily on investigating midfoot abnormalities in persons with advanced KOA and tried to acquire a better understanding of how midfoot deformities may be associated to the progression or severity of KOA.

1.2 literature Review

Foot posture has a substantial impact on the development of lower limb musculoskeletal problems because it effects mechanical alignment and dynamic function. Foot abnormalities can result from a variety of clinical disorders, including osteoarthritis and rheumatoid arthritis. These disorders not only have an impact on one's quality of life, but they can also cause immobilisation and functional limits. The most common foot deformity related with KOA is flatfoot. Flatfoot is defined as a collapsed or low arch of the foot, which might change the biomechanics of the lower limb and contribute to the development or symptoms of KOA [6-8].

Footprint measurements, such as the arch index (AI) and the Chippaux-Smirak Index (CSI), are often used to assess foot alignment. These measurements are used because they are simple and easy to calculate, and they give a means to categorise foot arches, particularly those with lower arches [9]. These measurements can help physicians and researchers categorise people based on their foot arch types and investigate the link between foot alignment and other foot-related illnesses or pathologies P. Levinger et al [10] Significant differences in the arch index were detected between a control group and people with KOA. This implies that foot posture, as measured by the arch index, differs between these two populations.
Furthermore, an increased AI has been identified as a contributing factor to lower muscle strength in the hamstring muscles on both the same side (ipsilateral) and the opposite side (contralateral), as well as in the contralateral quadriceps muscles in KOA patients with flatfoot deformity in their dominant leg [11]. This suggests that flatfeet deformity, as evidenced by an elevated arch index,

may have ramifications for muscular strength in persons with KOA.

There is a substantial relationship between the severity of the flattening of the foot arch and the symptoms of KOA, as measured by Clarke's angle (CA). This implies that the degree of flattening of the foot arch is directly associated to the prevalence and severity of symptoms reported by patients with KOA [12].

Daman K. Jha et al [13] found that hallux valgus deformities, pes planus (flatfoot), and hindfoot varus were the most prevalent foot deformities associated with KOA. The study indicates that these specific foot abnormalities are typically reported in persons with KOA.

In a study conducted by H. Guler et al [6], Foot abnormalities were analysed in 115 women with KOA, and there was a significant link between the existence of foot deformities and greater degrees of impairment in women with KOA. This indicates that the presence of foot abnormalities is connected with higher impairment in women affected with KOA.

A. Priya et al [14] indicate that the Staheli Index (STI) and CSI are more sensitive in diagnosing flatfoot in teenagers than the CA. The enhanced sensitivity of the STI and CSI demonstrates their efficacy in reliably identifying patients with flatfoot in this age range. Furthermore, the CSI and STI have a positive association, indicating that they measure comparable characteristics of foot arch deformity.

Individuals with KOA may develop a variety of foot malformations, including rearfoot, midfoot, and hindfoot deformities. Hindfoot varus deformity, in particular, has been discovered in around 30% of patients with end-stage varus KOA, demonstrating a considerable relationship between these two disorders [15, 16].

Furthermore, data suggests that patients with KOA may have altered rearfoot posture, particularly pronation, as a compensatory response to the knee's varus alignment. The foot can keep its plantigrade posture, which is necessary for walking and weight distribution, according to this compensating mechanism [17].

Kuryliszyn-Moskal discovered that the impact of rheumatoid arthritis (RA) and OA on women's Weisflog's index (W) index is more significant compared to the control group. Also, the prevalence rate of α, indicated by the angle value, was significantly higher in the RA group compared to both the OA and control groups. However, no significant differences were observed between the groups in terms of CA or the prevalence rate of longitudinal arch pathology based on the angle value [18].

In older individuals, having a flat foot (high AI) is associated with recurring knee pain and the degeneration of cartilage in the medial tibiofemoral joint. This indicates that the shape of the foot, specifically a planus foot or flat arch, is linked to both the presence of chronic knee discomfort and the deterioration of the cartilage in the inner part of the knee joint [7].

C. P. Ojukwu et al examined the AI of pregnant women and found that those with low foot arches, indicative of pes planus or flat feet, experienced more frequent foot and knee discomfort [19].

Additionally, S. M. Shariff et al [20] revealed a significant correlation between different categories of body mass index (BMI) and foot arches, as assessed by five different footprint parameters. The results, obtained through CSI, CA, AI, and STI, indicated that increased BMI does have an impact on foot arches. Therefore, individuals who are overweight or obese should take measures to effectively manage their body weight and utilize appropriate footwear to prevent foot disorders.

According to M. Adamczyk *et al* [21], there is an inverse relationship between the W index and increasing body mass index (BMI). In other words, as BMI rises, the W tends to decrease.

Subsequent research [22] suggests that different assessment methods for foot arch disorders may yield varying results and levels of agreement. CA, in particular, may have limitations in accurately detecting flat feet compared to the CSI index. However, as BMI increases, the discrepancy between these measurements becomes less pronounced, implying a potential association between BMI and the accuracy of foot arch evaluations.

The aforementioned literature reveals the planter footprint is a typical technique for assessing the integrity of the foot arches. Numerous scientific study articles have been published regarding the significance of OA and flatfoot, although a few findings have been proven to be contentious by others. Researchers and physicians using AI to measure the arches of the foot are unable to capture the degree of foot deformation. There is no considerable study to illustrate the classification of flat and high arch feet. These obstacles are met by the development of computer techniques based on image processing to enable better detection of variations in foot morphology, allowing the expert to make a prompt diagnosis. To address this issue and fill gaps, the current study aims to use a tool capable of measuring plantar foot indices to identify changes in foot morphology in individuals with KOA using simple and useful parameters, and to analyse the relationships between these changes and the grade of OA affected knee.

2. Materials and Methods

2.1 Participants

The inclusion criteria were as follows: age range > 55 years, healthy and physically active, without a history of major lower-extremity or lumbar-region injuries or surgery (for the control group) and subjects with KOA for the case group. Seventy-eight subjects (46 NP and 32 subjects with KOA) participated in this study; the demographic characteristics of all participants are presented in Table 1, which displays the average values of age, height, weight, and BMI of non-pathological (NP) and KOA subjects who participated in this study. The average age and BMI of all participants were 61.4 and 63.5 years and 32 and 32.6 Kg/m2, for NP and OA groups, respectively. This means that participants were consistent in their group age, and they both had overweight where the normal BMI ranges from 18.5 to 25 kg/m2 [100]. Age, weight, and BMI were compared between the NP and OA groups using the t-test. The height and weight of NP and OA subjects were found to vary significantly ($p<0.05$) as shown in Table 1. The NP subjects were found to be taller and heavier than the OA subjects. No significant differences between groups on their age. Also, there was a significant difference in BMI between the two groups.

Kellergen's classification for grading the KOA of each subject is illustrated in Table 1. The KOA subjects who participated in this study are classified as severe KOA.
The NRS rating for pain in KOA participants is presented in Table 1, this revealed high pain in patients with severe KOA.

Table 1,
Participants' demographic characteristics.

Parameters	NP (n =46)	OA (n =32)	P value
Age (year)	61.4 ±4.8	63.5±5	0.569
Height (cm)	174.6±4.3	163.1±5.5	0.00
Body weight (kg)	98.5±18.9	86.8±10.7	0.009
Body mass index (kg/m2)	32±5.5	32.6±3.9	0.00
KL grade	NA	Grade (3), n=17 Grade (4), n=15	
NRS rate	NA	NRS rate (5), n=7 NRS rate (6), n=10 NRS rate (7), n=2 NRS rate (8), n=5 NRS rate (9), n=6 NRS rate (10), n=2	

n: number of subjects.

2.2 Experimental Protocol

1. Knee Pain Assessment: Participants were surveyed using a questionnaire to determine if they experienced any pain in their knees. They were specifically asked if they had pain in either the right, left, or both knees.
2. Age, Gender, and BMI Evaluation: The study collected data on age, gender, and BMI from all participants. BMI was calculated by dividing the weight in kilograms by the square of the height in meters. To ensure accuracy, participants were weighed without shoes and heavy clothing using a balance beam scale.
3. Safe Staircase Setup: A staircase was positioned alongside a Podoscope device to facilitate the safe ascent of participants, as depicted in Fig. 1 The purpose of this arrangement was to ensure the safety and comfort of individuals during their interaction with the device.
4. Ethical Approval Documentation: The study involved obtaining ethical approval from the relevant authorities. The required ethical approval documents were completed and submitted, ensuring compliance with ethical guidelines and regulations regarding human participant research. These materials described the study's design, protocols, possible risks and benefits, informed consent process, and protection of participant confidentiality and privacy. The ethical approval procedure was designed to guarantee that the study

followed ethical standards and protected the rights and well-being of the persons participating.

Fig. 1. Podoscope with a small staircase.

5. Participants' feet were uniformly wetted using water and then dried meticulously using a towel. Subsequently, participants were instructed to stand upright and face forward while positioning their feet on the podoscope instrument. A podoscope instrument was used to assess the plantar footprint and enable accurate estimation of clinical indexes of foot deformities based on image processing techniques [23]. After a few attempts to ensure proper positioning, images captured by the camera and calculations for six distinct footprint parameters, namely AI, CSI, STI, W, CA, and α, were successfully employed to determine foot morphology as shown in Fig. 2.
6.

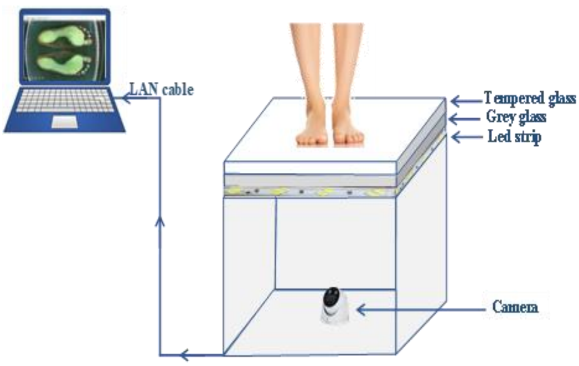


Fig. 2. Podoscope structure with a protocol of the test [23].

2.3 Numerical rating scale (NRS) for pain

The Numeric Rating Scale (NRS) is a commonly utilized self-report measure for assessing pain intensity. It is widely used due to its simplicity (requiring no specialized equipment) and the preference of healthcare professionals for its 0 to 10 metric, which allows for quantifying patient discomfort. Individuals are typically asked to rate their pain intensity on a scale from 0 to 10, with 0 representing no pain and 10 representing the strongest or worst pain imaginable [24].In this study, the NRS was used to classify the level of pain experienced by each participant with KOA.

2.4 Receiver operating characteristic (ROC) curve

The receiver operating characteristic (ROC) curve is a graphical representation that assesses the diagnostic accuracy of a test. In this work, the ROC curves for three gold parameters, AI, CSI, and STI, were shown, and they showed good accuracy in recognising the presence or absence of a certain condition. The ROC curve is often presented in the top left triangle above the reference line, indicating no discriminating ability (y=x line). The area under the ROC curve (AUC) is a quantitative measure of the test's ability to discriminate. An AUC of 0.5 indicates no discrimination, while an AUC of 1.0 indicates perfect discrimination [25].

2.5 Statistical Analysis

Statistical analysis was done in the Statistical Packages for Social Science (SPSS, Version 26, IBM). The descriptive statistics were computed and provided as mean ± standard deviation for tables and as mean ± standard error of the mean for figures of the NP and KOA groups.

For AI, CSI, STI, age, BMI, height and CA parameters: parametric tests were used to identify the significant differences between the control and KOA groups. The normality of the data distribution was assessed by using the Kolmogorov-Smirnov test with Lilliefors correction and the Shapiro-Wilk test ($p \geq 0.05$). The analysed quantitative variables did exhibit normality of distribution. The parametric t-test was applied in two groups to compare quantitative variables.

For the W index and α angle: non-parametric tests were used to identify the significant

differences between the control and KOA groups. The normality of the data distribution was assessed by Mann-Whitney between the two groups. All results were considered to be statistically significant ($p < 0.05$). The results of AI, CSI and STI were compared with the clinical diagnosis of the foot as a gold standard and displayed on a receiver operating characteristic (ROC) curve. Also, the ROC area under the curve (AUC) was computed.

The correlation between KOA foot parameters was calculated using Pearson's correlation coefficient.

3. Results

Table 2,
Differences in foot posture measurements between the two groups.

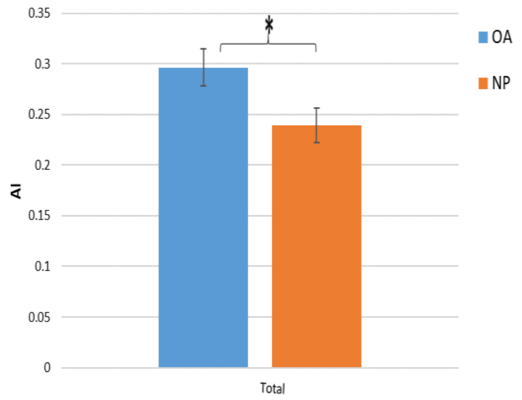
AI= Arch index; CSI= Chippaux-Smirak index; STI= Staheli arch index; W= Weisflog's index; CA= Clarke's angle;

Measure	NP (n = 46)	KOA (n = 32)	p-value
AI	(0.238 ± 0.017)	(0.29± 0.018)	p = 0.00
CSI	(0.39 ± 0.5)	(0.55± 0.5)	p = 0.00
STI	(0.58 ± 0.9)	(0.77±0.7)	p = 0.00
W	(2.9 ± 0.20)	(2.7 ±0.25)	p = 0.00
CA	(31.2± 2.199)	(30.27 ± 2.7)	p = 0.109
A	(14 ±2.7)	(13 ± 1.8)	p = 0.50

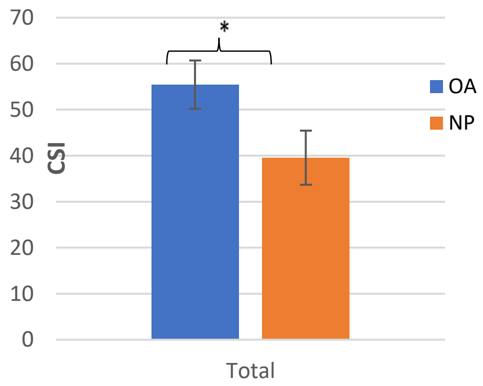
α= Hallux valgus angle;n=number of subjects.

3.1 Foot Characteristic

The associations between these variables were looked at in terms of the effect of KOA on foot morphology, and the results are shown in Table 2. KOA foot group had significantly higher AI, CSI and ST than usual, as shown in Fig. 3 (a,b,c,e), AI (0.29± 0.018, vs. 0.238 ± 0.017.), CSI(0.55.4±0.5., vs.0.39.09±0.5), STI (0.77±0.7 vs. 0.58 ± 0.9), and the W index reduced significantly in OA compared to the NP group (2.7 ±0.25vs. 2.9 ± 0.20), whereas the CA and α did not show a significant difference between two groups as shown in Fig. 3 (d,f), respectively.



(a)



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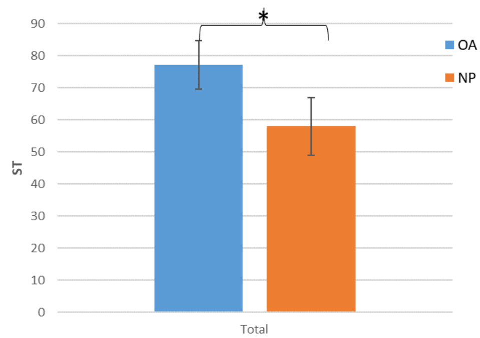

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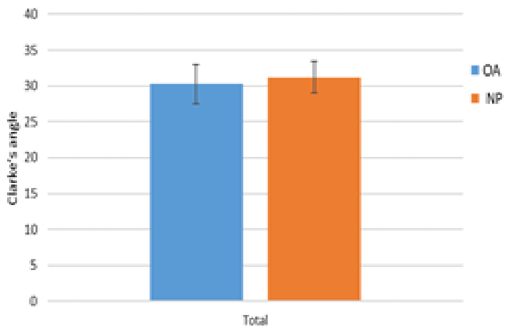

(d)

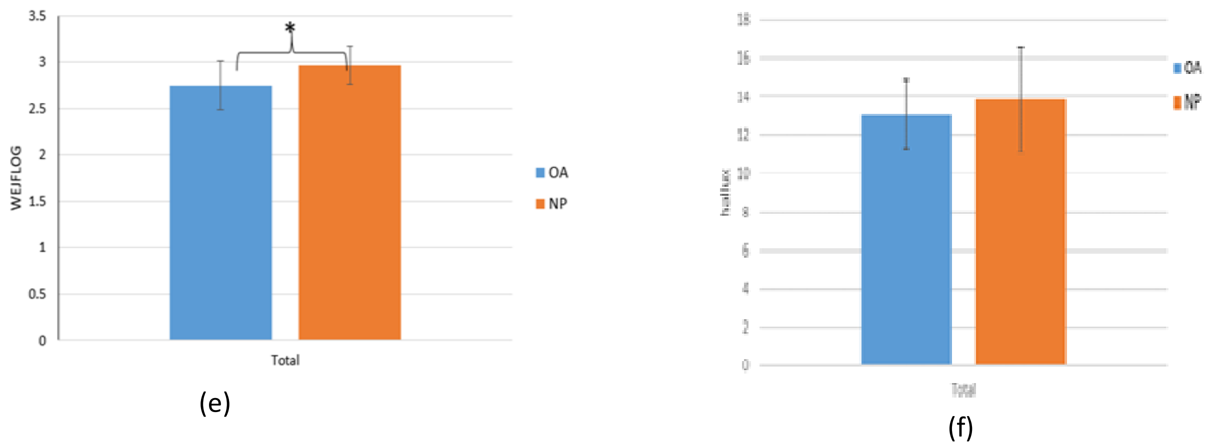

Fig. 2. Relation between NP and KOA groups (a) AI= Arch index; (b) CSI= Chippaux-Smirak index ; (c) STI= Staheli arch index; (d) CA= Clarke's angle; (e) W= Wejsflog's index; (f) α= hallux valgus angle.

Pearson correlation between the parameters of KOA was calculated. As shown in Table 3, among the six parameters analyzed, AI, CSI and SIT showed the strongest correlation between them.

Rearfoot, midfoot and hindfoot areas were calculated for both groups. Midfoot deformities have a significant difference in the subject with the OA group (p=0.00) rather than other areas of the foot as shown in Table 4.

The results of AI, CSI and STI of the KOA group were compared with a clinical diagnosis of foot deformities as a gold standard and displayed on a receiver operating characteristic (ROC) curve. The methodology used in this study followed that described by Chen et al [26].

The ROC curves for the methods of footprint analysis are displayed in Fig. 4. The area under the curve (AUC) shows that AI had high accuracy for predicting KOA (AUC 0.74), followed by the CSI (AUC 0.7) and the SI (AUC 0.64). The AUC of the AI and CSI have a significant effect from that of the STI as shown in Table 5.

Table 3,
Significant correlation of parameters in the KOA group.

Parameters	r-value	P-value
AI&STI	0.35	0.04*
CSI&STI	0.445	0.011*
CSI&AI	0.767	0.00*

* Correlation is significant at the 0.05 level (2-tail).
AI= Arch index; CSI= Chippaux-Smirak index; STI= Staheli arch index; W= Weisflog's index; CA= Clarke's angle; α= hallux valgus angle.

Table 4,
Participants' foot part demographic characteristics.

Part of foot	NP	KOA	P value
Rearfoot	605.7±39.6	604.25±31.2	0.85
Midfoot	242.4±32.2	333.5±28.6	0.00*
Hindfoot	430±37.1	433.3±35.2	1.66

*significant at the 0.05 level

Table 5,
The area under the curve.

kOA parameters	The area under the curve	P value
AI	0.714	*0.04
CSI	0.7	*0.04
STI	0.443	0.50

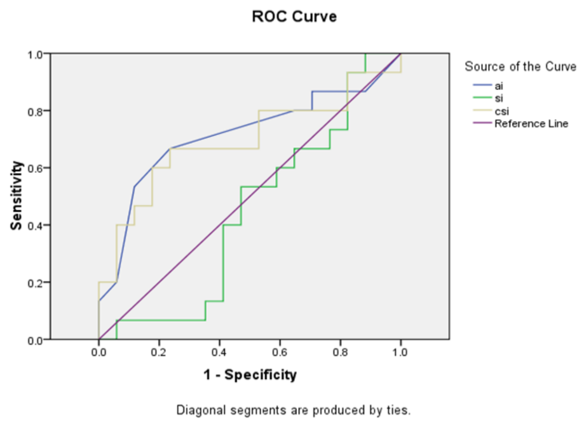

Fig 3.ROC curve between gold standard parameters (AI, CSI, and STI).

To assess the foot deformation based on pain and OA grade, the correlation was calculated respectively. Table 6 shows that pain and OA grade have a significant correlation between them with (r=0.9), also AI and CSI have a significant correlation with OA grade with (p=0.029) and (p=0.04) respectively. In contrast, there was no correlation between foot deformation and pain in the knee.

Table 5,
The correlation between pain and OA grade on foot morphology.

KOA	Pain		OA grad	
parameters	r-value	P-value	r-value	P-value
AI	0.3	0.6	0.4	0.029*
CSI	0.2	0.1	0.4	0.04*
SI	-0.12	0.53	-0.118	0.519
W	0.299	0.9	0.155	0.039*
CA	-0.09	0.6	-0.149	0.04*
A	0.29	0.1	0.15	0.03*
Pain	1	-	0.9**	0.00
OA grade	0.9**	0.00	1	-

*significant at the 0.05 level.** significant at the 0.01 level. AI= Arch index; CSI= Chippaux-Smirak index; STI= Staheli arch index; W= Weisflog's index; CA= Clarke’s angle; α= hallux valgus angle.

4. Discussion

This study assessed the association between KOA and foot deformities. Additionally, more severe flatfoot was significantly associated with a greater risk of severe OA symptoms. Six distinct footprint parameters, namely AI, CSI, STI, W, CA, and α, were successfully employed to determine foot morphology. The key findings of the study were as follows:

(i) The increase of AI was significant with OA symptoms. (ii) The high CSI and STI were associated with a significantly increased risk of having OA. (iii) No significant differences were captured in the α and CA between the NP and KOA groups. (iv) Transverse arch was significantly different between the two groups this was identified by the W index.

The recent findings of this study have significant implications for the management and treatment of KOA. When deciding on conservative treatment options like as surgery or orthotics, it is critical to consider the individual's foot morphology. Healthcare providers can personalise treatment approaches to patients with KOA by taking into account the particular qualities of their foot. Understanding the association between foot shape and KOA can result in more personalised and successful treatment regimens.

A prior study shown that KOA had a stronger affect on the back [27] and hindfoot [13] demonstrated changes in subjects with OAHowever, to our knowledge, the particular influence of KOA on the midfoot has not been extensively identified. One significant finding from this study is that KOA has a greater impact on the anatomy of the midfoot. This research emphasises the need of identifying and correcting midfoot alterations in persons with KOA, which may have repercussions for their overall biomechanics and functional outcomes.

Recognising the effect of KOA on midfoot morphology allows healthcare providers to plan tailored therapies that address these particular abnormalities. Interventions for improving midfoot stability and alignment may include bespoke orthotic devices, footwear adjustments, or particular exercises. By combining foot morphology assessments into KOA management, healthcare professionals may optimise treatment regimens and perhaps enhance patient results.

Table 1 shows that there was no significant difference in average age between those with symptomatic KOA (63.5±5) and those with NP (61.4 ±4.8). The age category between (55-80) was chosen. The basis for this decision is based on past study linked to this, symptomatic KOA increasing with each decade of life, with the annual incidence of KOA being highest between the ages of 55 and 64 [28]. This finding further justifies the chosen age range for the study.

AI has developed as a reliable and effective way for reliably computing foot characteristics from static footprints [29]. This technique has substantial therapeutic relevance, especially in the evaluation of persons suffering from KOA [10]. Notably, a comprehensive investigation done in this area found significant differences in foot features between the KOA group and the normal population (NP) group. These disparities were substantiated by the mean and standard deviation of AI values, which were determined to be (0.238 ± 0.017) and (0.29 ± 0.018), respectively, and demonstrated statistical significance with a p-value lower than 0.05.

Specifically, individuals with KOA displayed a pronounced tendency towards longitudinal flattening and deformity in their feet when compared to the feet of those in the normal population. This observation can be attributed to excessive midfoot loading, which potentially leads to heightened compressive stresses on the dorsal aspect of the foot [30]. This study sought to acquire a better knowledge of the interaction between AI and midfoot loads, as well as their influence on KOA, by analysing the related deformities and their exact locations. The current study conducted computations for the rearfoot, midfoot, and hindfoot regions to identify the major regions of foot deformation in individuals with KOA. The analysis aimed to determine the specific locations where these deformations occurred as a response to the KOA condition. Additionally, this study tried to agree or disagree with a prior study that connected greater AI values to more midfoot [31] and peak pressure at the midfoot [32].

Table 4 indicated that there was no significant difference observed between the rearfoot and hindfoot regions in either the KOA or NP groups. Thus, these regions cannot be utilized to distinguish between the two groups. However, the midfoot region exhibited a significant difference (p=0.00), making it the reference landmark for identifying foot deformations in individuals with KOA. This finding aligns with the previous studies mentioned earlier regarding midfoot loading [31] and pressure [32].

The association between increased midfoot loading and two additional parameters, namely CSI and STI, is of considerable importance.

The study findings demonstrated a significant difference (p=0.00*) in CSI values between the KOA and NP groups. The NP group had CSI values of (0.39 ± 0.5), whereas the KOA group had CSI values of (0.55 ± 0.5). This discrepancy can be attributed to the CSI (midfoot/forefoot) rule, indicating that the midfoot morphology of individuals with KOA experienced notable changes, resulting in higher CSI values. In contrast, the NP group, which did not experience knee discomfort, displayed no significant alterations in midfoot morphology, as evidenced by CSI values remaining within the normal range of 0.25 to 0.45.

Likewise, the STI index exhibited a similar trend to CSI, calculated as the ratio of midfoot to hindfoot. It is directly proportional to the midfoot condition. The study also observed a significant difference (p=0.00*) in STI values between the KOA and NP groups. The NP group had mean STI values of (0.58 ± 0.9), while the KOA group had mean STI values of (0.77 ± 0.7). The NP group fell within the normal STI range of 0.50 to 0.70, indicating a normal midfoot condition. Conversely, the KOA group displayed higher STI values, suggesting abnormalities in the midfoot region. So, these three parameters served as a gold standard for distinguishing between NP and OA groups.

Foot deformities, particularly hallux valgus and pes planus (flat feet), are frequently observed in individuals with KOA. These deformities contribute to abnormal excessive stress on the medial compartment of the knee joint and medial rotation of the tibia [6, 33]. One potential compensatory motion or posture is subtalar joint pronation, which generates a valgus force and leads to the development of pes planus and hallux valgus [34].

Hallux valgus (α) is a foot deformity characterized by abnormal angulation, rotation, and lateral deviation of the first metatarsophalangeal joint of the big toe [35]. The typical range of this angle is 0-9 degrees, and values exceeding 9 degrees indicate the presence of Hallux valgus [18]. In the present study, participants in the NP group, who were aged up to 50 years, exhibited a higher range of hallux valgus angle (14 ± 2.7) due to age-related changes. As a result, both the NP and KOA groups had higher indices, and there were no significant differences between the two groups when considering the influence of age. These findings align with the predictions made by Pita-Fernandez et al [36], who reported a higher prevalence of hallux valgus with increasing age, with 38% of the individuals in their study exhibiting this deformity.

Similarly, CA was used to assess foot morphology. In the present study, the mean CA value in KOA patients was approximately 30.27 ± 2.7, while the mean CA value in the NP group was 31.2 ± 2.199, and the difference was not statistically significant (p = 0.109). The evaluation of longitudinal arch pathology based on CA also showed no significant differences between the two groups. These findings are consistent with a previous study [37].

The current study revealed that the prevalence of hallux valgus increases with age, but there were no significant differences in hallux valgus angle and longitudinal arch pathology between the KOA and NP groups when accounting for age-related changes. Therefore, these angles cannot be used as fundamental diagnostic parameters to distinguish between NP and those with KOA. Additionally, the presence of foot deformity based on these angles cannot reliably predict the occurrence of KOA.

The W index is a widely used indicator for evaluating the transverse arch of the foot [38]. In the present study, significant differences (p=0.00) were observed in the transverse arch between the KOA and control groups. This suggests that individuals with KOA display alterations not only in the longitudinal arch (as measured by AI, CSI, and STI) but also in the transverse arch. These findings are consistent with another study that reported significant differences in the W index values between a control group and individuals with KOA [18].

The KOA group exhibited severe OA grades and reported high levels of knee pain, which were confirmed by a consultant using Kellgren's classification for grading KOA and a Numeric Rating Scale (NRS) for pain assessment, as shown in Table 1, respectively. Interestingly, no significant impact of knee pain on foot deformities was observed. The presence of severe KOA was the primary factor contributing to the high levels of knee pain, as demonstrated by the strong correlation (r=0.9, p=0.00), as shown in Table 6. However, it remains unknown whether foot deformities directly cause knee pain. These findings are consistent with a previous study [39], which suggests that symptomatic KOA itself leads to knee pain and functional impairment [40].

Moreover, a notable association was found between the grade of KOA and both AI and CSI, as presented in Table 6. This correlation finding aligns with the outcomes of the ROC curve analysis, which revealed significant area under the curve (AUC) values for AI and CSI with OA grade as shown in Fig. 4 and Table 5. These results indicate that individuals with more severe KOA tend to have greater foot deformities, as indicated by higher AI and CSI values. Hence, when assessing the severity of KOA, it is crucial to consider the existence of foot deformities.

It is worth noting that further research is needed to fully understand the relationship between KOA, foot morphology, and the effectiveness of different treatments of KOA approaches. However, these recent findings shed light on an important aspect of foot management that had not been well-documented previously, paving the way for future investigations and potentially enhancing the care provided to individuals with KOA.

5. Conclusion

- The prevalence of foot deformities is significantly higher in KOA.
- Assessing the association between KOA features and foot characteristics may aid with accurate diagnosis and KOA treatment.
- KOA was most often related to mid-foot abnormalities.
- Among the six parameters that were used to identify changes in foot morphology, AI, CSI, STI and Weisflog's index acted as indicators for the incidence of foot deformities in the KOA group. However, there is no significant difference in CA and α angles between KOA and foot deformity.
- AI and CSI were linked to KOA grade. This association matches the ROC curve study, which showed substantial AUC values for AI and CSI about OA grade. These findings suggest that severe KOA patients have more foot abnormalities, as seen by higher AI and CSI values.
- KOA pain was caused by knee deformities and did not seem to be linked to foot abnormalities.
- Healthcare providers may target KOA's effects on midfoot morphology with focused therapies. Custom orthotic devices, footwear adjustments, and particular workouts may enhance midfoot stability and alignment. Healthcare professionals may optimise KOA therapy and patient outcomes by assessing foot morphology.

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تقييم تشوهات القدم للمرضى المصابين بسوفان العظام في مفصل الركبة

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المستخلص

تستخدم تقنيات تقييم مورفولوجيا القدم بشكل شائع لتقييم تشوهات القدم. القدم ضرورية للحفاظ على الأداء الميكانيكي الحيوي للأطراف السفلية. سوفان الركبة هي حالة مرضية يمكن أن تؤدي إلى تشوهات القدم. كان الهدف الرئيسي من هذه الدراسة هو التحقيق في انتشار تشوه القدم في المرضى الذين يعانون من سوفان العظام في الركبة.و الهدف الآخر هو تحديد تأثير الألم وشدة سوفان العظام على التغيرات المورفولوجية للقدم الخاص بمرضى سوفان العظام في الركبة.ثمانية وسبعون مشارك ساهم في هذا البحث وقسموا الى قسمين, 46 شخص غير مصابين,32 مصابين بسوفان العظام في الركبة.جهاز بودوسكوب المطور يعطي النتائج بشكل اوتوماتيكي لتشخيص تشوهات القدم عن طريق المؤشرات الاتية:

Arch Index (AI), Chippaux-Smirak Index (CSI), Staheli Index (SI), Wejsflog's index, Clarke’s angle (CA) and hallux valgus angle (α).

تم ربط العديد من المتغيرات المتعلقة بالقدم بطريقة مباشرة بالتهاب مفاصل الركبة. على وجه الخصوص، كان و أولئك الذين أصيبوا بالتهاب مفاصل الركبة قيم أعلى بكثيرللمؤشرات مقارنة بمن لم يصابوا بهذا المرض

Arch index (0.29±0.018; P=0.00), Chippaux-Smirak index (0.55±0.5; P=0.00), Staheli index (0.77±0.7; P=0.00), and Weisflog's index (2.7±0.25; P=0.00(.

علاوة على ذلك، أظهرت زاوية كلارك وزاوية إبهام القدم الأروح قيمًا عالية تبلغ (30.27±2.7) و(13±1.8) على التوالي. كانت هناك أيضًا ارتباطات مهمة موجودة داخل مجموعة التهاب مفاصل الركبة. كان هناك، على سبيل المثال، ارتباط إيجابي كبير بين مؤشر Arch ومؤشر Chippaux-Smirak (0.767; p=0.00)، ومؤشر Arch ومؤشر(Staheli (r=0.35; p=0.04 ، ومؤشر Chippaux-Smirak ومؤشر Staheli بارتباط يساوي (r=0.44; p=0.01) .من حيث تشوهات القدم، كان منتصف القدم (333.528.6; p=0.00) أكثر أهمية من مقدمة القدم (604.2531.2; p=0.85) ومؤخر القدم.(433.335.2; p=1.66) مع قيم الارتباط (r = 0.4; p = 0.02) و(r = 0.4; p = 0.04) ، تم ربط كل من مؤشر Arch ومؤشر-Chippaux Smirakبشكل كبير مع شدة التهاب مفاصل الركبة.النتائج المخرجة من الجهاز اوضحت اختلاف واضح بين الاشخاص المصابين بسوفان العظام في الركبة والغير مصابين.اكثر الاصابات بلتشوه كانت واضحة جدا في المؤشرات التالية:

AI, CSI, SI, and W index.اضافة لذلك النتائج بينت تشوه القدم في المنطقة الوسطى هو اكثر من بقية اجزاء القدم لاصحاب الاشخاص المصابيين بسوفان العظام في الركبة. تشوهات القدم واضحة لاصحاب مرض سوفان العظام في الركبة حيث تتضمن تشوهات في الاقواس الطولية والعرضية اضافة لذلك,انحراف ابهام القدم.لذلك وجب اخذ بعين الاعتبر هذه التشوهات عند تشخيص الاشخاص المصابين بسوفان العظام في الركبة.قد يستهدف مقدمو الرعاية الصحية تأثيرات سوفان العظام في الركبة على مورفولوجيا منتصف القدم بعلاجات مركزة. وقد تعمل أجهزة تقويم العظام المخصصة وتعديلات الأحذية والتدريبات الخاصة على تعزيز استقرار منتصف القدم . ايضا ويمكن لأخصائيي الرعاية الصحية تحسين علاج سوفان العظام في الركبة ونتائج المرضى من خلال تقييم مورفولوجيا القدم.