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# Sagittal Pelvic inclination, Frontal Knee Alignment, and Foot Posture in Patients with Mild to Moderate Knee Osteoarthritis: A Cross-sectional Study

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**Abstract:**
**Objective:** This study examined KOA and non-KOA individuals to find out if there is an association between KOA and sagittal pelvic inclinations, frontal knee alignment, and foot posture.
**Methods**: Fifty-two subjects were allocated to two groups, group A (mild, moderate KOA) and group B (without KOA), based on the diagnostic criteria, both between 40-55 years with a BMI of 25–29.9 kg/m2. Knee pain and function were assessed by the WOMAC. The sagittal pelvic angle (PA), the femoro-tibial angle (FTA), and the rear foot angle (RFA) were measured by AutoCAD software, while the foot posture was assessed by the navicular drop (ND) test and the intrinsic foot muscle strength (IFMS) test.
**Results:** KOA was found to have a moderately significant negative correlation with all FTA ($r = -0.376$; $p = 0.006$), PA ($r = -0.376$; $p = 0.006$), and IFMS ($r = -0.317$; $p = 0.022$). Moreover, although not statistically significant, a weak positive correlation between KOA, RFA ($r = 0.235$; $p = 0.093$), and ND ($r = 0.081$; $p = 0.568$) was found. KOA and WOMAC had a strong positive and significant correlation ($r = 0.912$; $p = 0.001$).
**Conclusion:** In patients with mild to moderate KOA, knee varus alignment, posterior pelvic tilt, and pronated foot posture have all been reported.
**Key words:** Femoral –tibial angle; foot posture; knee osteoarthritis; rearfoot angle, and sagittal pelvic angle.

## 1. Introduction:

Knee osteoarthritis (KOA) is the most common progressive degenerative joint disease that can cause pain, dysfunction, and crepitus of the knee joint with weakness of its surrounding muscles, especially the quadriceps muscle (1). KOA's discomfort and limitations can make it difficult to carry out daily tasks and function well at work. Moreover, a patient's health-related quality of life is negatively impacted by frequent medical consultations, hospitalizations, and excessive treatment costs (HRQoL) (2).

Knee OA is a common musculoskeletal condition, with its prevalence rising with age. Approximately 37% of participants older than 60 years had radiographic KOA, with females being more affected than males (3).

According to research conducted in Egypt, the female-to-male ratio was 3:1 (4). The American College of Rheumatology (ACR) criteria for the diagnosis of KOA are established, including clinical and radiological

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data, and radiologic grades are developed and approved using the Kellgren-Lawrence grading scale (5).

A change in hip, knee, and ankle alignment will primarily alter how much load is distributed at the knee. The loading axis passes medially to the knee, generating a moment arm that increases force over the medial compartment, as genu varus is the most frequent frontal malalignment in knee OA (6).

Yasuda et al. (2020) (7) reported that severe KOA has poor lumbopelvic sagittal alignment and a strong link with pelvic retroversion as varus deformity in KOA rotates the hip externally and pelvic retroversion. Thus, kinematic chain reaction suggests that varus knee deformity and hip external rotation are related to pelvic retroversion while a person is standing.

As misalignment is the most significant risk factor for structural deterioration, weight-bearing joints like the hips and knees are often affected. About 53.57% of patients with KOA complained of higher values of the navicular drop test, which indicated foot pronation or flatfoot. As a result, a higher navicular drop is a potential risk factor for the progression of radiographic KOA grades (8).

The loss of the knee's natural valgus alignment was correlated with the pronated foot position. Loss of valgus alignment is a typical consequence of KOA. It increases knee adduction moment and contributes to faster loading of the medial tibiofemoral knee joint (9).

Although the foot is important for receiving and distributing forces during walking, foot mechanics may have a significant impact on lower limb musculoskeletal conditions. Yet less attention has been paid to studying changes in IFMS associated with KOA and comparing them to subjects without KOA.

A comprehensive understanding of the relationships between the degenerative processes and associated risk factors, such as body mechanics, is essential to developing appropriate preventive and therapeutic strategies for our assessment process. Therefore, the primary goals of this study were to determine whether there was a relationship between sagittal pelvic inclination, frontal knee alignment, and foot posture and KOA, as well as compare patients with and without KOA.

## 2 Materials and Methods:

### 2.1. Study Design and Participants

This was a cross-sectional study that was conducted in the orthopedic physical therapy clinics at Tahta General Hospital in Sohag, Egypt from July 2022 till February 2023 to investigate the association between sagittal pelvic tilt, frontal knee alignment, foot posture, and KOA.

The study was carried out in accordance with the 1964 Declaration of Helsinki's ethical criteria and was authorised by the Faculty of Physical Therapy, Cairo University, Egypt's ethical committee (No. P.T.REC/012/003946).

With the use of the statistical programme G*POWER, the sample size was determined (version 3.1.9.7; Franz Faul, Universitat Kiel, Germany) with 80% power (alpha = 0.05) and Cohen's d = 0.80, and 52 subjects were recommended. Subjects were allocated into 2 groups with an equal gender distribution (23 females and 29 males), ages 40 to 55, and BMIs of 25 to 29.9 kg/m2. Group (A): mild to moderate KOA subjects; and group (B): subjects without KOA. Both groups were recruited through direct referrals by orthopedists and screened once by clinical plus radiographic symptoms such as chronic knee pain for most of the previous month, crepitus with motion, and morning stiffness ≤ 30 minutes were included based on the American College of Rheumatology criteria (ACR) (10, 11).

Subjects were excluded if they had any of the following criteria: rheumatologic conditions such as rheumatoid arthritis; a history of OA in the hip or ankle; previous surgery in the lower limb alignment; previous hip or knee replacements; diabetes for more than ten years; neuropathy and sensory disorders; intraarticular corticosteroids injection within six months.

### 2.2. Procedures:

#### 2.2.1. Knee pain and function:

We evaluated the subject's pain, stiffness, and function using the Arabic version of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). It includes 24 questions (5 for pain, 2 for stiffness, and 17 for physical function). It is an ordinal scale from 0 to 4. The items from the three subscales are added to obtain the final WOMAC score (12).

#### 2.2.2. Lower limb (LL) alignment

The angles of LL alignment (FTA, RFA in the coronal plane, and PA in the sagittal plane) were measured by AutoCAD software. Photos were taken with a digital camera (Canon 8 M pixel, MV750i), 45 cm above the ground, and 90 cm away from the subjects, with the lens oriented at the center of the board and a view perpendicular to the plane of knee rotation. The camera was mounted on a tripod to prevent human mistakes. Reflective square markers were used as it was believed that they give more accurate data than circular markers (13, 14).

The sagittal pelvic angle is measured as the angle between the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) and a horizontal line in the sagittal plane from the standing position (**Figure 1. A),** normally from 7° to 15° (15). Femora-tibial angle is made by the midpoint connecting the ASIS and the center of the medial and lateral knee joint space and the midpoint connecting the medial and lateral malleolus (**Figure 1. B)** (16). It is a 180° to 185°normal medially valgus angle. Less than 180° means knee varus and more than 185° means knee valgus (17).

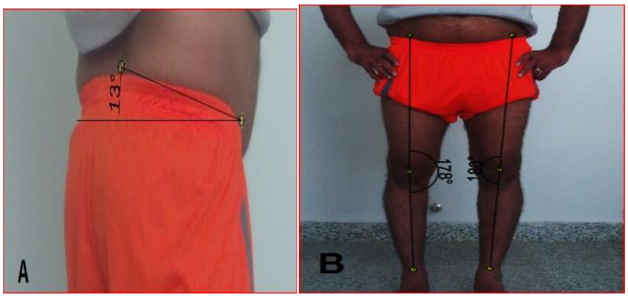


**Fig.1. (A) Pelvic angle& (B) Femora-tibial angle**

The Navicular Drop Test (NDT) was calculated by measuring the variation in patients' navicular tuberosities' height in the sagittal plane while seated with one foot on the ground and standing with the subtalar joint neutral. (**Figures 2. A, B)** (16). Over 10mm was considered abnormal, whereas 6 to 9mm was considered normal. The NDT has been proven to be reliable and valid**.** The rearfoot angle (RFA) was calculated between the calcaneus and lower third of the leg's bisections (**Figure 3. A)**. 4° valgus to 4° varus is a neutral foot (14).

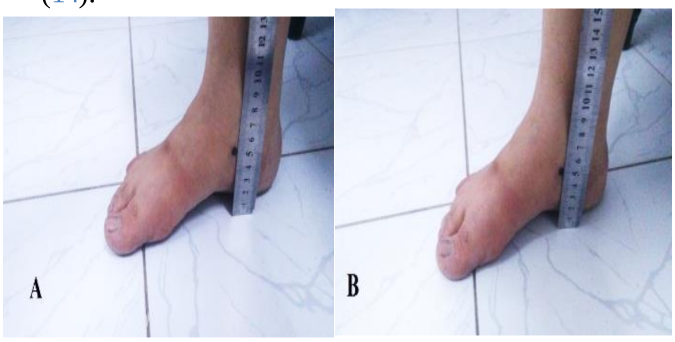


**Fig.2. Difference between Navicular drop (A-sitting & B-standing).**


**Fig.3. (A) Rear foot angle & (B) Intrinsic foot muscles strength**

The IFMS is considered "acceptable" if the neutral navicular height remains steady over the 30-second test without significant extrinsic foot muscle activity noted by the researcher's palpation. The IFMS is scored as "fair" if neutral navicular height is inconsistently unstable and/or excessive extrinsic foot muscular activity is noticed during the 30-second test. IFM is rated as "poor" if the patient is unable to maintain neutral navicular height at all or if significant extrinsic foot muscle activation is seen for the bulk of the 30-second test (18).

### 2.3. Statistical analysis:

The data were expressed as mean± SD. Independent t-tests for age, height, weight, and BMI were conducted. The Shapiro-Wilk and Kolmogorov-Smirnov tests were used for normality. Between group comparisons, MANOVA was used for alignment-related measurements and functional scale, while chi-square was used for IFMS. The alpha level was set at 0.05. The relationship between the KOA and the measured variables was evaluated using the Pearson correlation coefficient. Statistical analysis was calculated using version 20 for Windows from SPSS Inc., Chicago, Illinois, USA.

## 3. Results:

In **Table (I),** the demographic characteristics are shown. Age, weight, height, and BMI did not differ significantly between the two groups. Shapiro-Wilk and Kolmogrov-Smirnov tests for normality revealed that all measured variables were normally distributed except IFMT. Between group comparisons, MANOVA was used for parametric data and the Chi- Square test for non-parametric data.

**Table Ӏ: Demographic characteristics of the subjects**

| Measurd variable | Group A Mean±SD | Group B Mean±SD | t-value | p-value |
|---|---|---|---|---|
| **Age (years)** | 46.7±4.9 | 46.6±5.4 | 0.080 | 0.937 |
| **Weight (kg)** | 76.5±6.4 | 78.6±6.9 | -1.15 | 0.254 |
| **Height (cm)** | 166±7.6 | 167.2±5.5 | -0.646 | 0.521 |
| **BMI (kg/m$^2$)** | 27.7±1.4 | 28.1±1.8 | -0.778 | 0.440 |

### I- Knee Pain and function:

There was a strong, direct, and statistically significant correlation (r = 0.912; p =0.001) between KOA and WOMAC. The mean values of WOMAC

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increased in favor of group A (P=0.001) as shown in **Table II.**

**Table II: Comparison of WOMAC between groups.**

| Measured variables | Group A Mean ±SD | Group B Mean ±SD | Mean difference | P value |
|---|---|---|---|---|
| **WOMAC** | 40.6 ±10.9 | 4.6 ±4.2 | 36 | 0.001* |
| **Pain** | 8.7 ±3.2 | 1.4 ±1.2 | 7.3 | 0.001* |
| **Stiffness** | 3.9 ±1.8 | 0.23 ±0.5 | 3.7 | 0.001* |
| **Function** | 28 ±7.7 | 3±3 | 25 | 0.001* |

**WOMAC: The Western Ontario and McMaster Universities Osteoarthritis Index**
**SD: standard deviation**
**p-value: probability value *: significant**

## II -Pelvic/lower limb alignment:

KOA and FTA revealed a weakly significant negative correlation (r =-0.376; p=0.006), as with KOA and PA (r =-0.334; p=0.016). Moreover, the mean values of PA and FTA did not differ statistically significantly between groups as shown in **Table III.**

**Table III: Comparison of PA & FTA between groups.**

| Measured variables | Group A Mean ±SD | Group B Mean ±SD | Mean difference | P value |
|---|---|---|---|---|
| **PA (degree)** | 8±4 | 10.2±4.3 | -2.2 | 0.061 |
| **FTA (degree)** | 182.6±3.8 | 184.1±2.9 | -1.5 | 0.116 |

**SD: standard deviation p-value: probability value**
***: significant**
**PA: pelvic angle FTA: Femora-tibial angle**

As shown in **Table IV**, KOA and RFA showed a weak direct correlation (r = 0.235; p =0.093) as well as knee OA and ND (r = 0.081; p=0.568), although these correlations were not statistically significant. Besides that, there was no statistically significant difference between groups in the mean values of RFA and ND. The correlation between KOA and IFMS was negative but only marginally significant (r =-0.317; p =0.022). A statistically significant difference between the groups was also present (P =0.018) **Table V**.

**Table IV: Comparison of ND, RFA& IFMS between groups.**

| Measured variables | Group A Mean ±SD | Group B Mean ±SD | Mean difference | P value |
|---|---|---|---|---|
| **ND (mm)** | 7.8±2.5 | 7.5±1.7 | 0.3 | 0.568 |
| **RF (degree)** | 4.9 ±2 | 3.1±4 | 1.8 | 0.093 |
| **IFM** | | | | |
| **Poor** | 0 (0%) | 1 (4%) | | |
| **Fair** | 18 (69%) | 8 (31%) | $\chi^2$= 8.08 | 0.018 * |
| **Satisfactory** | 8 (31%) | 17 (65%) | | |

**SD: standard deviation p-value: probability value**
***: significant ND: Navicular Drop**
**IFMS: The intrinsic foot muscles RFA: Rear foot angle**

**Table V: Correlation between KOA and measured variables in group A.**

| Variables | Correlation coefficient | P-value |
|---|---|---|
| **WOMAC** | 0.912 | 0.001* |
| **FTA** | -0.376 | 0.006* |
| **PA** | -0.334 | 0.016* |
| **ND** | 0.081 | 0.568 |
| **IFM** | -0.317 | 0.022* |
| **RFA** | 0.235 | 0.093 |

**P value: Probability value *: Significant**
**PA: pelvic angle FTA: Femora-tibial angle**
**ND: Navicular Drop IFMS: The intrinsic foot muscle**
**RFA: Rear foot angle**
**WOMAC: The Western Ontario and McMaster Universities Osteoarthritis Index**

## 4. Discussion:

The main objectives of this study were to examine and evaluate the associations between sagittal pelvic tilt, frontal knee alignment, foot characteristics (ND, IFMS), and physical function in individuals with and without KOA. The findings revealed that KOA patients reported pain and restrictions during daily life activities and changes in LL alignment such as a posterior pelvic tilt, knee varus alignment, pronated foot posture, and IFMS abnormalities.

This study found a significant, direct, and strong correlation between KOA and WOMAC, with the KOA group's findings significantly worse than the non-KOA group's. These findings are consistent with previous studies that stated a strong direct relationship between patient ages, the severity of their knee OA, and their overall WOMAC score (19).

There was a statistically significant difference in the mean PA values between the two groups during the PA tests; however, an inverse weak relationship between KOA and PA was found as well. According to these findings, individuals with KOA had lower PA (pelvic retroversion) than those without OA, who had higher PA. These findings are consistent with a previous study that found pelvic retroversion in KOA patients and concluded that, biomechanically, the progression of KOA is associated with a knee varus deformity that externally rotates the hip and retroverts the pelvis (20). Thus, the sagittal alignment of the spine-pelvis-lower limb axis was correlated with the KOA.

This FTA investigation showed a strong inverse weak link between the KOA and the FTA. These findings support previous studies that revealed varus knee alignment as the most common frontal malalignment in KOA, which increases medial tibiofemoral stress (21). However, there were no statistically significant differences between the two groups in this study, which could be attributed to the fact that the patients enrolled had only mild to moderate KOA.

According to the current study's findings, patients with KOA are more likely to have pronated foot posture, as the ND was 7.8 ±2.5 mm in the KOA group and 7.5± 1.7 mm in the non-KOA group. This is similar to a previous study that discovered that subtalar pronation increased anterior pelvic tilt and internal rotation of tibia and femurs (22). Foot pronation, on the other hand, was more noticeable in KOA, and the pronation moment of the subtalar joint is increased in the knee varus while walking (6).

The current study's findings confirmed the hypothesis that people with KOA had a greater posterior pelvic tilt, varus, and pronated foot than people without OA. These findings are similar to previous research that found knee varus in addition to foot pronation in medial KOA (16).

Increased foot pronation may help the foot adapt to alleviate pressure on the medial compartment, which theoretically might reduce the adduction moment by lateralizing the pressure centre (6). However, the range of motion of the ankle, subtalar, and midtarsal joints determines the amount of genu varum that can be corrected by foot pronation. (6). As a result, future research should include the ROM (range of motion) of these joints and determine how it relates to foot posture

Supinated and pronated foot postures increased in patients with KOA. Consistent with these findings, people with KOA had abnormal foot posture as compared to healthy subjects. It may be difficult to differentiate between compensatory adjustments generated by KOA and changes in foot posture caused by KOA. However, severe KOA may cause foot posture changes as a compensatory response. KOA can occur as a result of poor foot posture (6, 23). As there was a non-significant weak direct association between knee OA and RFA in the current study, it is possible to predict RFA from the relationship between KOA and ND. Previous studies have shown that RFA pronation was altered in KOA patients as a compensation for varus alignment, allowing foot to be plantigrade (24).

The results of this investigation were supported by the fact that there was no statistically significant difference in the mean RFA and FTA values between the groups, which is consistent with previous investigation (25) that found the link between the mechanical axis and the rear foot valgus angle was greater in individuals with extreme varus alignments; however, it was less in those with milder varus alignment.

As a result of this study, IFMS was evaluated and demonstrated a difference between the KOA group and the non-KOA group that was statistically significant, as well as a statistically significant weak inverse correlation between KOA and IFMS. This weak relationship might be due to the selected patients' BMIs being less than 29.9 $kg/m^2$.

Previous research suggests that a compensating pronated foot posture may result from the lack of the physiological knee valgus to reduce the knee adduction moment arm. (8, 9). A flat foot sole is a primary contributor to KOA, and IFMS preserve the medial longitudinal arch as a result, which may limit their strength. KOA thus affects how the ankle and foot are positioned (8, 9).

## 5. Limitations:

This study has some limitations. Firstly, we need to focus on a larger sample size, as KOA is a common degenerative disease in Egypt. Secondly, the assessor and image readers were not blinded. Thirdly, these results cannot be generalized, as selected patients only had mild and moderate degrees of KOA. Finally, future research should employ various techniques to evaluate IFMS more precisely, such as a handheld dynamometer or electromyography analysis. Additionally, more research is needed to examine various levels of KOA separately and correlate them with LL alignment to determine if alignment impacts disease prognosis.

**6. Conclusion:**

In summary, this study supports the evidence that the pelvic inclination, frontal knee alignment, and foot characteristics (ND, IFMS) are alternated in subjects with mild and moderate KOA compared to non-KOA. Knee pain, stiffness, and physical function have a strong positive correlation and are more evident in the KOA group. KOA subjects had more pelvic retroversion than non-KOA subjects, which may have contributed to the medial FTA's decrease (knee varus deformity) in KOA subjects. Subjects with KOA tend to have pronated feet. With mild to moderate KOA severity, there is a weak relation in the IFM strength.

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**Data Availability**

Data are available under reasonable request to the corresponding author.

**Consent to participate and ethic approval:** All subjects were informed about all procedures and asked to sign a written informed consent form before being enrolled. The study was carried out in accordance with the 1964 Declaration of Helsinki's ethical criteria and was authorized by the Faculty of Physical Therapy, Cairo University, Egypt's ethical committee (No. P.T.REC/012/003946).

**Conflict of interest:** no conflict is stated by the authors.

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