



## Influence of pronated foot on spinal curves and 'Q' angle among young adults- A cross sectional study

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### Abstract

**Background with Purpose:** The aim of the study undertaken was to assess the effect of pronated foot on Quadriceps angle, lumbar lordosis index and thoracic kyphosis index.

**Methodology:** The study was cross sectional study conducted after screening for inclusion and exclusion criteria on 58 subjects. The subjects were divided into 2 groups based on navicular drop value. Group A - Normal feet group (29), consisted of 5 males and 24 females with the mean age of  $22.03 \pm 2.784$  years. Group B - Pronated feet group (29), consisted of 6 males and 23 females with the mean age of  $21.75 \pm 2.016$  years. The participants in both the groups were assessed for navicular drop value using broady's navicular drop test. Outcome measures included was Q angle, lumbar lordosis index and thoracic kyphosis index which were measured in erect standing position.

**Results:** The results showed that there was significant difference observed in the Q angle (right and left side), lumbar lordosis index and thoracic kyphosis index between 2 groups (p value-  $<0.001$ ).

**Conclusion:** From the present study it can be concluded that pronated feet alter the lower extremity and spinal alignment. Therefore, considering the effect of distal segment alterations on proximal kinetic chain is essential for the precise assessment and treatment of musculoskeletal system.

**Keywords:** pronated feet, Q angle, lumbar lordosis, thoracic kyphosis

### Introduction

Foot is the most distal part of the lower extremity kinetic chain. It provides support to maintain the body's balance and has an important role in standing and walking. Pronation and supination are the important movements at the ankle complex. Pronation involves movements of abduction, dorsiflexion and eversion. Supination includes adduction, plantar flexion and inversion [1]. These motions occur at certain points in stance phase to assist the mobility, stability of joint and reduce forces within the foot and lower limb. Excessive motion or restricted motion in the foot reduces the ability of the foot to act as a shock absorber, torque convertor, mobile adaptor to the terrain, and a good rigid lever to push off. With the changes in the joint mobility, alteration in connective tissue and muscle function is seen [2].

The feet are vulnerable to structural deficits such as excessive pronation or supination as a result of abnormal forces applied to the medial longitudinal arch during daily activities. An increased amount of pronation due to ligament laxity and repetitive stresses may cause medial longitudinal arch to alter. Abnormally low medial longitudinal arch is known as flat foot or pes planus [3]. In excessively pronated subtalar joint, the plantar fascia may be overstretched leading to rarefoot valgus. Flat foot can lead to unequal weight bearing throughout the foot complex [4]. Abnormally low medial longitudinal arch may also alter the alignment of lower extremity.

The knee complex is the important joint of the kinetic chain. The quadriceps tendon is inserted over tuberosity of tibia via patellar tendon. The orientation of quadriceps muscle pull with respect to the pull of the patellar tendon provides information about net force of patella in frontal plane. This can be assessed clinically by the measurement of quadriceps angle (Q angle) [5]. It is defined as, the angle formed by the line from anterior superior iliac spine (ASIS) to the center of patella and a line from patella center to the tibial tuberosity. A Q angle of 10-15 degree considered as normal [5]. An excessive angulation may predispose individuals to injuries of knee joint. This is due to the abnormal quadriceps forces acting at the tibiofemoral and patellofemoral joints [6].

Pelvis is an important segment in postural alignment. It acts as an intermediate joint between lower extremities and spine. Spine is responsible for anatomic connection and transmission of forces between lower limbs and upper body [7]. Structural and functional performance of an individual depends on alignment of the lower extremity and spine. Pelvic alignment and spinal curvatures are interdependent. The lumbar lordosis is determined by shape of the lumbar spine and intervertebral discs. Each segment in the lumbar spine contributes to lordosis. The last segment contributes 40% whereas first segment only 5% to overall lordosis [8]. Lumbar lordosis is a key component in maintaining the sagittal balance. The abnormal lumbar curvature can lead to imbalance in the standing position. While increased lordosis may increase the risk of disk degeneration and injury to spinal ligaments [9].

The next segment in kinetic chain is thoracic spine. Thoracic kyphosis is defined as the outward thoracic sagittal plane curvature between the T1 and T12 vertebral bodies. The thoracic region subjected to more amounts of forces as greater amount of body weight needs to be supported by the kyphotic shape<sup>[5]</sup>. Increase in thoracic kyphosis and lumbar lordosis are the most common postural alterations. These postural alterations have an impact on muscle performance. These subjects are susceptible to musculoskeletal abnormalities and neural disorders.<sup>10</sup> Increase in the curvature of the thoracic spine causes the shortening of the thoracic muscles and weakness of the respiratory muscles. This affects the pulmonary system by decreasing the thoracic volume and lung volume<sup>[10]</sup>. Kyphosis is due to poor posture and weak postural muscles. Increase in the thoracic curve may lead to pain and dysfunction in shoulder and spine.

Many studies have described the relationship between components of lower extremity and spine. But very few have taken into account the effect of foot pronation on spine and lower extremity alignment in standing position. Hence the purpose of this study is to find out the effect of foot pronation on spinal curves and Q angle.

### **Aims and Objectives**

**Aim:** To study the effect of pronated foot on spinal curves and quadriceps angle in young adults.

### **Objectives**

1. To assess the spinal curves and Q angle in young adults with pronated foot.
2. To assess the spinal curves and Q angle in young adults with normal foot.
3. To compare the thoracic kyphosis, lumbar lordosis and Q angle in young adults with pronated foot and normal foot.

### **Hypothesis**

#### **Null Hypothesis**

There is no significant effect of pronated foot on spinal curves and quadriceps angle.

#### **Experimental Hypothesis**

There is significant effect of pronated foot on lumbar lordosis, thoracic kyphosis and quadriceps angle.

### **Methodology**

**Study Population:** 18 to 35 years healthy asymptomatic males and females.

**Study Design:** Cross-sectional analytical study

**Study Duration:** 6 months

**Sample Size:** 58 (29 in each group)

**Sampling Technique:** convenient sampling

### **Method of Selection of Study Subjects (Eligibility Criteria)**

#### **a. Inclusion criteria**

1. Healthy individuals both male and female between the age group of 18-35years.
2. Navicular drop distance between 2-6mm for normal feet and above 6mm for pronated feet.
3. Subjects willing to give written consent.

#### **b. Exclusion criteria**

1. Individuals with present or previous history of trauma, infection of the spine and lower limb.
2. Individuals with recent fractures of the lower limb within 1 year.
3. Individuals with recent surgeries of the lower limb within 1 year.
4. Individuals with congenital abnormalities.
5. Individuals with neurological impairments.
6. Individuals with recent musculoskeletal injuries within 1 year.

### **Selection of Control Group**

The subjects in the control group were healthy individuals having navicular drop distance between 2-6mm.

### **Procedure**

The study was explained to all participants and Informed consent taken from all subjects. The demographic data was collected as per the Case Record sheet. The participants were tested for navicular drop for both the feet and were divided into two groups based on the values of navicular drop i.e. if navicular drop was 2mm to 6mm then in Group A- the normal feet group and if the value is more than 6mm then in Group B - pronated feet group.

## Test Procedure

### a. Navicular Drop Measurement

Navicular drop measurement was performed using the brody method. Individual subject was in sitting position with their feet flat on a firm surface with hip and knees flexed at 90 degree and ankle joints in neutral position. Subtalar neutral position achieved when talar depression equal on medial and lateral side of the ankle. The examiner takes measurement by kneeling in front of the subject. While the subject in sitting position, a dot was marked on navicular tuberosity. An index card was placed and marked at the level of navicular tuberosity. Then the subject was ask to bear an equal weight on both the feet and asks to stand. The new position of navicular tuberosity was mark on index card. The difference between the marks in index card was measure in millimeter. Both right and left feet was assessed <sup>[3]</sup>.

### b. Q angle measurement

Q angle was measure in standing position. It is measured in standing so that normal weight bearing stresses were included. The angle was obtained by ensuring that the lower limbs are at a right angle to the line joining to the ASIS. The foot is placed in neutral position. The q angle has the ASIS, midpoint of patella and the tibial tubercle as standard anatomical landmarks. The anatomical landmarks was located through palpation and then marked by the marker. With the pivot of the goniometer place on the midpoint of patella, the stationary arm on the line joining the ASIS to the midpoint of patella, and movable arm is place over line joining tibial tubercle to the midpoint of patella. The angle thus form between two arms of goniometer was measured as the Q angle. Angle was measured in right and left feet. It was measured in degrees <sup>[11]</sup>.

### c. Assessment of lumbar lordosis index

The subject was in the relaxed standing position. First the anatomical bony landmarks were mark as C7, T12, L1, S1, and S2 by the examiner. A flexicurve of 60cm is used for the assessment of lumbar spine. This flexicurve was place on the dorsal aspect of the spine i.e. on the spinous process of lumbar spine and shape to fit the contours of these spinal curves. The instrument was carefully remove and trace onto a graph paper. A vertical line drawn to join the C7 and S1 landmarks. Calculation was perform for the lordosis index as lumbar width/ lumbar length\*100. A ruler with 1/10<sup>th</sup> cm markings was used to measure the length and width of each segment <sup>[12]</sup>.

### d. Assessment of thoracic kyphosis index

The subject was in the relaxed standing position using flexicurve method. The flexicurve was placed over the spinous process of thoracic and lumbar spine. The ends of the flexicurve were aligned according to the C7 and S2 spinous processes and the shape of the flexicurve was confirmed to the curvature of the spine. The flexicurve was carefully removed and place on graph paper and the curve will be trace onto the paper. A ruler with 1/10<sup>th</sup> cm markings was used to measure the length and width of each segment. Calculation is perform for the thoracic kyphosis index as thoracic width/ thoracic length\*100 <sup>[13]</sup>.

## Result and Analysis

### Data Analysis

The data was entered using Ms- Excel 2010 and analyzed using SPSS version 15 software. Descriptive analysis of numerical data was expressed in MEAN and SD for various parameters. Normality of data was assessed using Kolmogorov - Smirnov test. Non parametric test were used as the data did not pass the normality. For quantitative data, the means of the 2 groups were compared using Mann-Whitney test. P-Value less than 0.05 considered as statistically significant.

Group A consisted of 29 subjects. It included 5 males and 24 females with the mean age of  $22.03 \pm 2.784$  years. Group B consisted of 29 subjects. It included 6 males and 23 females with the mean age of  $21.75 \pm 2.016$  years. The quadriceps angle (on the right side and left side) was increased in the pronated feet group and the results were statistically significant. (Table No.1) The lumbar lordosis index and thoracic kyphosis index was increased in pronated feet group and the results were statistically significant. (Table No.1)

**Table 1:** Discriptive Statistics of Demographic Data and Outcome Measures

Variables	Group A	Group B	P-value
Age	$22.03 \pm 2.784$ (23)	$21.75 \pm 2.016$ (22)	0.2396
BMI	$23.42 \pm 4.27$ (22.7)	$23.72 \pm 3.36$ (23.4)	0.4367
Q Angle (Right Side)	$13.41 \pm 2.163$ (14)	$17.06 \pm 2.329$ (18)	<0.0001
Q Angle (Left Side)	$13.41 \pm 2.163$ (14)	$17.06 \pm 2.329$ (14)	<0.0001
Thoracic Kyphosis Index	$7.95 \pm 2.31$ (7.56)	$10.65 \pm 1.52$ (10.7)	<0.0001
Lumbar Lordosis Index	$22.2 \pm 5.269$ (21.4)	$28.9 \pm 5.688$ (28.8)	<0.0001

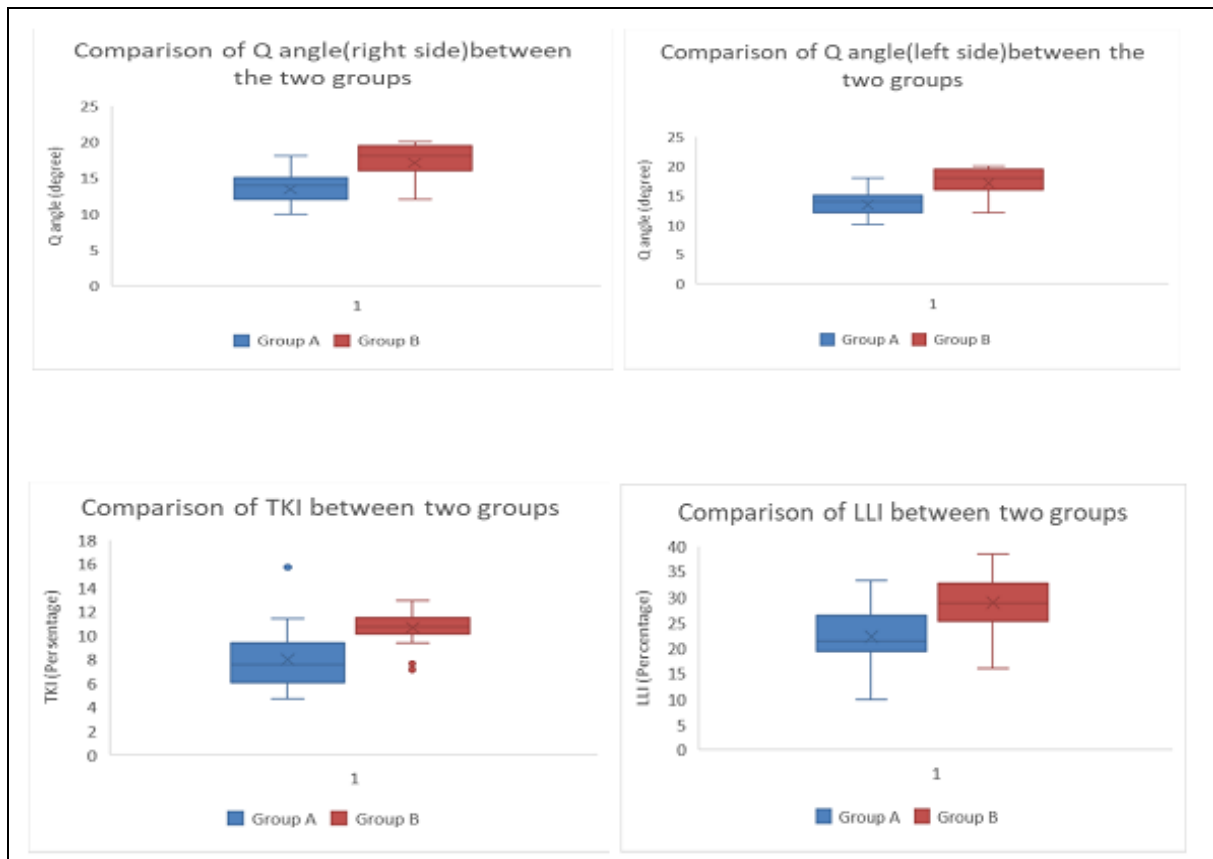


Fig 1

## Discussion

The present study was undertaken to assess the effect of pronated foot on the lower extremity and spinal alignment. Quadriceps angle, thoracic kyphosis index and lumbar lordosis index was assessed in healthy young adults. These findings are supported by the study carried out by Sam Khami, Gali Dar *et al*. They studied in standing induced foot pronation was coupled with internal rotation of the tibia, femur and anterior pelvic tilt. Foot hyperpronation initiates kinetic chain reaction and tibia and femur acts as a mediator producing anterior pelvic tilt while standing<sup>[14]</sup>. The change in the alignment of tibia and femur can lead to increase in Q angle. An increased Q angle represents a larger lateral vector of the lower extremity. This is caused by decreased knee abduction and decreased ground reaction forces. The lateral force may increase the compression of the lateral patellar facet against the lateral lip of the femoral sulcus. The presence of large lateral force may dislocate or subluxate the patella over the femoral sulcus when quadriceps muscle activated in knee extension.<sup>5</sup> Studies have shown that greater Q angle is a risk factor for various musculoskeletal conditions.

The alteration in the alignment of sagittal plane such as knee flexion posture or hyper extended posture is associated with change in the activity of the anterior and posterior muscles of the lower limb. The association between structural alignment and muscle activity is seen even in the frontal plane. From genu valgum (increased Q angle) to varum (decreased Q angle) would change the activity of the patello femoral muscles. This change influences the balance between medially and laterally directed force on the patella and may lead to altered patellofemoral kinetics<sup>[15]</sup>. Mohamed N. Al Khouli Anees S. Ghait Amr A. Abogazy determined the relationship between flatfoot and Q Angle in male secondary school students in standing position. Participants with flat foot showed significant increase in the Q angle than those with normal foot group. Excessive pronation of feet causes the internal rotation of the entire leg. This internal rotation causes the excessive stress on the patellar tendon and lateral patellar facet. They concluded that significant relationship is observed between Q angle and flat foot deformity<sup>[16]</sup>.

The alteration in Q angle leads to imbalance between vastus medialis and vastus lateralis causing various abnormalities. MOHSEN MAKHSOUS *et al* in their study on patello femoral pain syndrome (PFPS) reported that net force on the patella directed too laterally in PFPS patients causing patellar maltracking in the femoral groove. Imbalanced torque contribution from VMO, VML AND VL in PFPS is related to tightness of the lateral structures and changes in Q angle<sup>[2]</sup>. Study done by Ju-Eun LEE, Ga-Hyeon Park, noted that rare foot varus in the flat foot causes abnormal kinetic sequence between tibia and femur leading to increases the Q angle. Flat feet alter the tension in the muscles around foot and fascia and increase the internal rotation at hip joint and lumbar lordosis. EMG activity showed that flat feet had lower activation of VM, AH while higher activation of VL muscle suggesting increase lateral forces at the knee<sup>[17]</sup>.

Similar study was done by Nakyung Lee to examine effect of larger Q angle on muscle activation ratio for VM, VL and RF during various activities. They concluded that, as the quadriceps angle became larger, and the laterally directed force on the patella become greater. Lateral tracking of the patella occurred [15]. Defne KAYA, Mahmut Nedim DORAL studied the relationship between Q angle and lower extremity malalignment in women with unilateral PFPS. Results of the study showed that there is no relationship between Q angle and lower extremity malalignment. This was due to subjective nature of Q angle measurement technique [18]. Cebulski-Delebarre correlated the primary flat foot and lower extremity rotational misalignment in adults. The results of the study showed that no significant differences were found between patients and control subjects on the coronal and sagittal planes. Similarly, Between the 2 groups for rotation of the lower limbs (femoral torsion, tibial torsion, tibiofemoral rotation) no significant difference were observed. They found no rotational abnormalities of the lower extremities in adult patients with primary symptomatic flat foot [19]. Knee malalignment i.e. lower or higher Q angle has an effect on anatomical cross sectional area (CSA) of total quadriceps muscle and its individual components. Studies show that higher Q angle (>15) has low CSA of the entire quadriceps. (VM, VL and VI) [20]. As a consequence of these changes in the Q angle the femur rotates internally at the hip joint compressing posterior aspect of pelvis. In order to regain the postural balance the trunk moves anteriorly and shifts the center of mass anteriorly. This changes force the pelvis to tilt anteriorly in the sagittal plane [8].

The posture of the feet has an influence on spinal alignment i.e on lumbar lordosis and thoracic kyphosis. The result of the present study showed that subjects with pronated feet have statistically significant increase in lumbar lordosis index. The change in thoracic kyphosis index was less significant in pronated feet subjects. Greater mean difference was observed in lumbar lordosis index as compare to thoracic kyphosis index. A study done by Mohamed taher *et al.* reported that subjects with bilateral and unilateral flat foot had an influence on pelvic alignment. They found that subjects with bilateral or unilateral flat feet had pelvic anteversion in sagittal plane while unilateral flat feet had lateral pelvic tilt in the direction of affected feet in frontal plane. The anatomical relationship exists between pelvis and lumbar spine. Any change in the pelvic alignment has an effect on lumbar spine specially in standing position. Therefore ante version and lateral tilt of the pelvis may lead to increase in degree of lumbar lordosis and its index. These changes in the lumbar spine cause upper thoracic spine to compensate leading to an increase in postural stress [21].

Mohammad Sadeq Ghasemi *et al* reported that pronation of the subtalar joint causes medial downward movement of the talus and internal rotation of tibia affecting knee joint function. Internal rotation of hip joint lead to anterior pelvic tilt. As the pelvis is connected to the spine at sacroiliac joint, anterior tilt increases the lumbar lordosis. These changes shift line of gravity at a greater distance from optimal position. Extension movement in lumbar spine increases to maintain the lumbar lordotic curve. Further to maintain the head over sacrum the posterior convexity of thoracic curve increases and becomes kyphotic. Khamis and Yizhar reported that the pelvis being an important segment of the body, situated in the center of the body between upper body and lower limb, alteration in foot mechanics alter mechanics in the pelvis. These changes occur even when foot alteration is temporary. Thus hyperpronation can lead to change in the pelvis and lumbar position [23].

Studies have shown that lumbar hyperlordosis results in an increase load on different spinal structures. An Increase in lumbar lordosis increases the load on lumbar facet joints thereby producing mechanical stress. As a result of pelvic and spinal malalignment (anterior tilt and increase lumbar lordosis) abdominal muscles lengthen and the erector spinae, quadratus lumborum and iliopsoas become tight which lead to further increase in lumbar lordosis [24]. These postural changes in the spine place the musculoskeletal system at a great risk. One of the most common condition includes lower back pain. Duval *et al.* reported that foot pronation (artificially induced) did not have a relationship with pelvic tilt which is in disagreements with the results of current study due to methodological differences [25]. Colin B. O'Leary, Caroline R. Cahilla *et al.* reported that abnormal or excessive pronation causes either leg length discrepancies or pelvic tilts to maintain balance and an erect posture. This correction of the spine to maintain the center of gravity causes extra strain on muscles and ligaments in the back or sacroiliac joint [26].

Study done by Susan Dsouza, Dhanesh Kumar noted Static and dynamic functions of the foot and lower extremity. They found that changes in the feet can be responsible for causing postural imbalance. In pronated foot the transition movement from supination to pronation is absent and foot is in the unlocked position at the midtarsal joint. The force generated by pronated foot is not sufficient for completing push off during gait. This places greater demand to stabilize the foot and maintain upright stance on surrounding neuromuscular structures [28]. In previous research done by Dalia Shewitta *et.al* reported that alteration in the foot mechanics caused alteration of whole body mechanics including pelvis and spine. An increased lumbo-sacral angle was an important finding in patients with foot pronation [29]. The alterations in the spinal curvatures have effects on the trunk area either internally or externally. Mattox *et al* studied the Variations in spinal curvature which may alter these vector forces and possibly potentiate the development of pelvic organ prolapse. These observations underline the importance of taking into account the abnormal changes in spine curvature in subjects with pronated foot [30].

In the present study statistical significant difference was observed in all of the three outcome measures (Q angle, lumbar lordosis index and thoracic kyphosis index) which showed that pronated foot posture alter the kinetic chain. This may predispose the individuals to lower extremity injuries and spine injuries. Considering these findings of the study in subjects with pronated feet alignment of lower extremity and spine assessment is very crucial.

It is important to assess the biomechanical foot alterations in adults who may develop malalignment of lower extremity and spine. The alignment of the foot and ankle complex is essential to maintain optimal function of proximal and distal kinetic chain. The study was conducted in a limited geographical area. The study may be done in multiple centers at different geographical locations. Longitudinal study may be conducted on the same participants. Anthropometric comparisons may be considered.

### Conclusion

The present study concluded that, pronated feet affect lower extremity and spinal alignment. The quadriceps angle, lumbar lordosis index and thoracic kyphosis index was found to be increased in subjects with pronated foot.

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