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CORRELATION BETWEEN PRONATED FOOT AND PELVIC INCLINATION, FEMORAL ANTEVERSION, QUADRICEPS ANGLE AND TIBIAL TORSION

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ABSTRACT

Background: A pronated foot can produce changes in the lower limb kinetic chain. This can affect the gait and increase energy expenditure. However, the relationship between pronated foot and other static alignment factors remains poorly understood. Hence, the objective was to correlate pronated foot with pelvic inclination, femoral anteversion, Q-angle and tibial torsion.

Method: An observational study was performed on 60 subjects in the age group of 18-30 years with a BMI of not more than 30. Foot Posture Index was performed on the subjects, and people with a score of +6 or more were selected. Pelvic inclination, femoral anteversion, Q-angle and tibial torsion were measured. Correlation between the Foot Posture Index score and the above four static alignment factors was done using Graph Pad Prism 7 (Pearson's correlation coefficient and Spearman's correlation coefficient).

Results: There was no significant correlation between Pronated foot and Pelvic inclination (r-value = 0.03309, p-value = 0.8018), Pronated foot and Femoral anteversion (r-value = 0.2185, p-value = 0.0934) Pronated foot and Q-angle (r-value = 0.1801, p-value = 0.1685), Pronated foot and Tibial torsion (r-value = -0.1285, p-value = 0.3277).

Conclusion: There is no significant correlation between foot pronation and pelvic inclination, femoral anteversion, Q-angle and tibial torsion. However, the correlation between these factors cannot be completely ignored, and thus, further studies and literature are required to prove the same.

Keywords: FPI, pelvic inclination, femoral anteversion, tibial torsion, Q-angle.

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INTRODUCTION

Lower extremity alignment is a major influencing factor in the dynamic motions of the human body. Slight variations in the normal alignments may prove to be a propagating factor for injuries due to altered joint biomechanics, altered neuromuscular control and imbalance between ligamentous and muscle forces. Deviant alignment of the lower extremity can lead to unequal forces on the joints, mechanical insufficiency of the muscles, and altered proprioception and feedback from the hip, knee, and ankle. These changes may result in abnormal neuromuscular function and control of the lower extremities. This in turn, can increase compressive forces in particular areas of the joint surface and thus, subject the joint and cartilage to speedier wear and tear [1,2].

It has been seen that changes in the alignment of any one joint of the lower limb cause a change in the alignment of the proximal and distal joint thus linking all the joints as a chain – the kinetic chain. In 1995, Dr. Arthur Steindler proposed that the appendicular skeleton should be considered as “rigid, overlapping segments in series” and as defined by him, the kinetic chain is a “combination of several successively arranged joints constituting a complex motor unit”[3].

Abnormally low medial longitudinal arch is known as ‘Flatfoot’ or ‘Pes planus.’ In the excessively pronated subtalar joint, the plantar fascia may be overstretched leading to a rearfoot valgus posture.[4] Excessive flat-foot can lead to unequal load bearing throughout the foot complex [4]. An overpronated foot can produce increased excursions within the foot and tibia and can even lead to subluxations of the joints of the foot. It may also lead to consequences on all the other joints of the lower extremity while walking too which include valgus strain at the knee, internal rotation, flexion and adduction at the hip [4].

Lower extremity malalignment has been advocated as a risk factor for various acute and chronic lower extremity injuries. These conditions include patellofemoral syndrome, anterior cruciate ligament injuries, medial tibial stress syndrome, stress fractures, and plantar fasciitis. It has been propounded that biomechanical changes arising from deviant alignment can lead to neuromuscular dysfunction. However, there is a poor understanding of the relationship between anatomical alignment and injury risk. Existing research articles (Nguyen A-D, Boling MC, et al., 2009, Ivan Hvid and Lars Ib Andersen, 1982, Khamis S, Dar G, et al., 2015, Khamis S., Yizhar Z., 2007) have taken into consideration only one alignment factor or a small number of alignment factors [1,5,6,7]. Taking into account the probable interdependence of the diverse alignment faults along the lower body kinetic chain, examining only one or a limited number of alignment factors may not adeptly describe the static position of the lower extremity [2].

There aren't sufficient studies (Nguyen A-D, Shultz SJ, 2009) to determine the correlation between foot pronation and other static alignment factors of the lower limb [2].

Many studies by (Nguyen A-D, Boling MC, et al., 2009, Ivan Hvid and Lars Ib Andersen, 1982, Khamis S, Dar G, et al., 2015, Khamis S., Yizhar Z., 2007) have focused on correlating only one or two components of the alignment factors [1,5,6,7], but not many have taken into account the effects of foot pronation on the lower extremity kinetic chain. Hence, attributing to the paucity of literature, our study aims to find out if any correlation exists between foot pronation and static alignment factors such as pelvic inclination, femoral anteversion, Q-angle and tibial torsion.

METHODOLOGY

Approval for the study was taken from the Institutional Research Committee. An observational study was conducted among 60 students of K. J. Somaiya College of Physiotherapy, Mumbai, at the Physiotherapy Department, K. J. Somaiya Hospital and Research Centre in October-November 2016. The subjects were assessed for eligibility based on inclusion and exclusion criteria.

Normal, asymptomatic individuals (both male and female) aged 18-30 years, having no complaints of pain/stiffness at knee/ankle or any history of knee injury, or with a history of Grade 1 and/or 2 ankle sprain (not less than 3 months old), with a FPI score of not less than +6, and a BMI not more than 30 were included in the study.

Individuals with a history of any pathological condition at spine or any of the lower limb joints, or those with a history of any traumatic conditions at spine, hip or knee (including fractures, surgery and/or ligament injuries) and individuals with a history of Grade 3 ankle sprain or Grade 1/2 ankle sprain <3 months were not taken as a part of the study group.

Written consent was taken from those included in the study and assessment of the following outcome measures were done – Foot Posture Index, Pelvic inclination, femoral anteversion, Q-angle and tibial torsion using a 360° goniometer, handheld pelvic inclinometer, and a plinth.

The Foot Posture Index© (Anthony Redmond 1998) examines the multisegmental alignment of the foot in all three planes, in the weight bearing position. The Foot Posture Index© employs 6 clinical criteria for assessment of the foot [8]: Talar head palpation [8], Supra and Infra lateral malleolar curvatures [8], Calcaneal frontal plane position [8], Prominence in the region of the Talonavicular joint [8], Congruence of the medial longitudinal arch [8], Abduction/adduction of the forefoot on the rearfoot [8]. All observations were done with the client in a relaxed double limb support in a static stance position [8]. Each of the components was graded from -2 (clear signs of supination) to +2 (clear signs of pronation), with 0 being graded for a neutral foot. The final score was a whole number between -12 and +12 [8,9]. Clients who had a score of +6 or more on any one foot were selected for further evaluation.

“The angle of Pelvic inclination/pelvic tilt is defined as the angle between the horizontal plane and the midpoint of the posterior superior iliac spine (PSIS) and the midpoint of the anterior superior iliac spine (ASIS).” (Sanders G,

Stavrakas P, 1981) [10]. The angle of pelvic inclination was measured using a handheld pelvic inclinometer with the client in a relaxed, double limb support stance [10]. One tip of the caliper was applied to the PSIS, and the other tip was applied to the ASIS, and the closed ends of the caliper were brought to a position where the pendulum hung freely over the protractor. This position allowed the plane of the protractor to become perpendicular to the floor, thus enabling the therapist to measure the angle of tilt of that ilium from the protractor scale [10]. (Picture 1).

Picture 1: Measurement of pelvic inclination



“Femoral anteversion is the degree of forward projection of the femoral neck from the frontal plane of the shaft” (Magee, D. J., 2008) [11]. Anteversion of the hip is assessed by the angle formed by the femoral neck with the femoral condyles [11], which is also known as the CRAIG’S TEST. The client was made to lie in the prone position with the knees at the edge of the plinth in 90° flexion [11]. The examiner palpated the posterior aspect of the greater trochanter of the femur, and the hip was then passively rotated medially and laterally until the greater trochanter was parallel to the examining table or it reached its most lateral position [11]. The degree of anteversion was then measured with the help of a goniometer, between the vertical and a line passing through the shaft of the tibia which bisected the medial and lateral condyles [11]. (Picture 2)

Picture 2: Measurement of Femoral anteversion



“The quadriceps angle (Q-angle) is defined as the angle between the quadriceps muscles (primarily the rectus femoris) and the patellar tendon and represents the angle of quadriceps muscle force” (Magee, D. J., 2008) [11]. The client was in an eased, double limb support stance, with uniform weight bearing while keeping the quadriceps muscle relaxed. A line was drawn joining the ASIS and the midpoint of the patella and another joining the midpoint of the patella to the tibial tuberosity which was then extended above the knee. With the help of a goniometer, the angle formed between these two lines was measured [11]. (Picture 3).

Picture 3: Measurement of Quadriceps angle



Tibial torsion is defined as the rotation of tibia around its longitudinal axis, ensuing change in alignment of the movement planes of the proximal (knee) and distal (ankle) joints (Hutter & Scott, 1949). The patient lay supine. The femoral condyles of the client had to lay in the frontal plane. The apex of both malleoli was palpated with one hand, and a line was drawn on the heel representing a joining of the two apices. A second line was drawn on the heel parallel to the floor. The tibial torsion was calculated by the angle formed by the intersection of the two lines indicated [11]. (Picture 4).

Picture 4: Measurement of Tibial torsion



DATA ANALYSIS

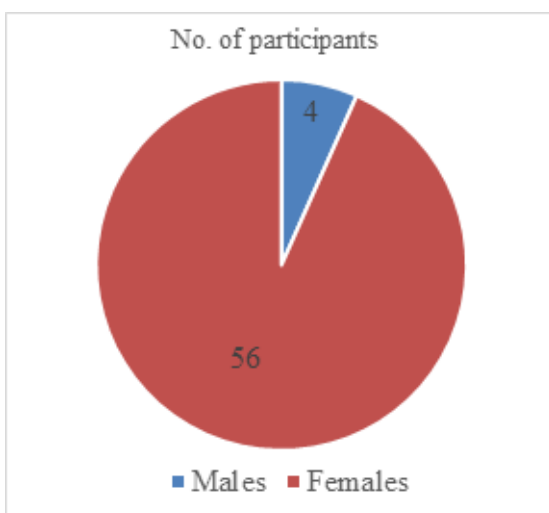
The statistical analysis of the collected data was done using Graph Pad Prism 7. Descriptive statistics for the age and BMI was calculated. FPI scores and values of pelvic inclination, femoral anteversion, Q-angle and tibial torsion were checked for normality using the D'Agostino and Pearson normality test. Pearson's Correlation Coefficient of Pelvic inclination and Femoral anteversion with foot pronation was calculated. Spearman's Correlation Coefficient of Q-angle and Tibial torsion with foot pronation was calculated.

RESULTS

The statistical analysis of the collected data was carried out for the total sample size (n=60) using Graph Pad Prism 7. 60 subjects, 56 females and four males were selected by simple random sampling, having any one foot pronated and a BMI <30. FPI scores and values of Pelvic inclination, Femoral anteversion, Q-angle and Tibial Torsion were checked for normality using the D'Agostino and Pearson normality test. Correlation between Foot pronation scores and Pelvic Inclination, Femoral anteversion, Q-angle and Tibial torsion was done using the parametric Pearson's correlation coefficient for the data that passed normality and using the non-parametric Spearman's correlation coefficient for data that did not pass normality. The level of significance of this study was set to 'p' value <0.05.

Table 1: Number of Participants

GENDER	FREQUENCY	PERCENTAGE
MALES	4	6.67
FEMALES	56	93.33
TOTAL	60	100

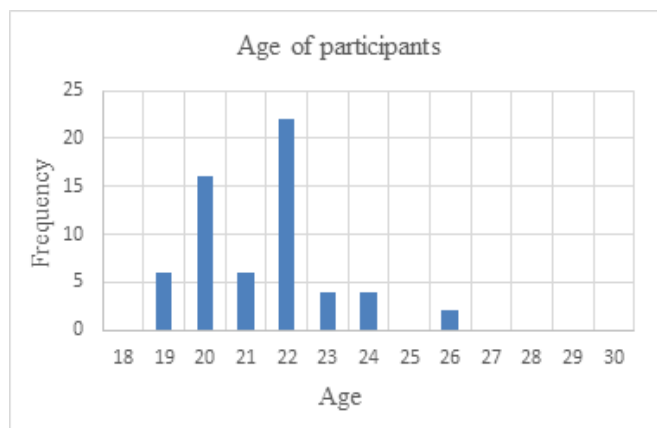


Graph 1: Number of Participants

The mean age of the subjects was 21.4 ± 1.618 years (Table 2, Graph 2), mean BMI of the participants was 23.192 ± 2.8986 (Table 3, Graph 3) and the mean foot pronation score of the subjects was 8.65 ± 1.665 . Foot pronation scores, Pelvic inclination, and femoral anteversion, passed normality whereas Q-angle and tibial torsion did not pass normality.

Table 2: Age of Participants

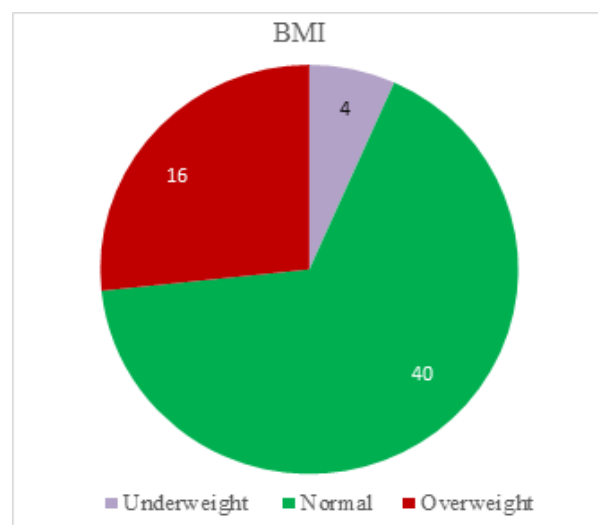
AGE	18	19	20	21	22	23	24	25	26	27	28	29	30
FREQUENCY	0	6	16	6	22	4	4	0	2	0	0	0	0



Graph 2: Age of Participants

Table 3: BMI of the Participants

BMI	FREQUENCY	PERCENTAGE
UNDERWEIGHT (<19)	4	6.67
NORMAL (19-24.9)	40	66.67
OVERWEIGHT (25-29.9)	16	26.67

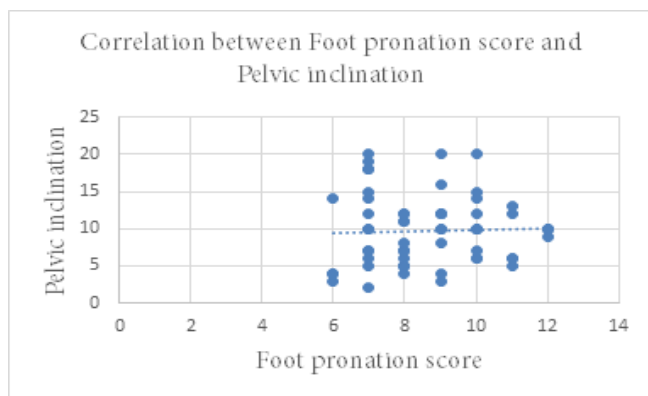


Graph 3: BMI of the Participants

On correlating foot pronation score with pelvic inclination using Pearson's Correlation coefficient, r value of 0.03309 was obtained, and the p-value was 0.8018, suggesting no significant correlation between the two. The mean pelvic inclination was 9.767 ± 4.645 (Table 4, Graph 4).

Table 4: Correlation between foot pronation and pelvic inclination

Foot Pronation		Pelvic Inclination		PEARSON'S CORRELATION COEFFICIENT (r value)	p-value	Significance
Mean	S.D.	Mean	S.D.			
8.65	1.665	9.767	4.645	0.03309	0.8018	Not significant

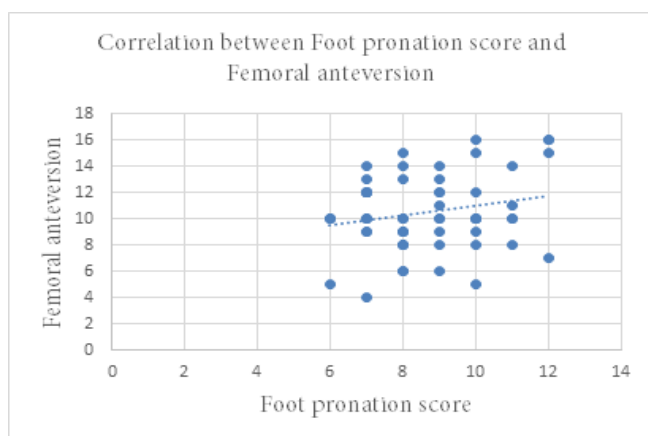


Graph 4: Correlation between foot pronation score and pelvic inclination

On using Pearson's correlation coefficient, no significant statistical correlation was found between foot pronation score and femoral anteversion (r-value = 0.2185, p-value = 0.0934) (Table 5, Graph 5). The mean femoral anteversion was 10.47 ± 2.831 . (Table 5, Graph 5)

Table 5: Correlation between foot pronation score and femoral anteversion

Foot Pronation		Femoral Anteversion		PEARSON'S CORRELATION COEFFICIENT (r value)	p-value	Significance
Mean	S.D.	Mean	S.D.			
8.65	1.665	10.47	2.831	0.2185	0.0934	Not significant

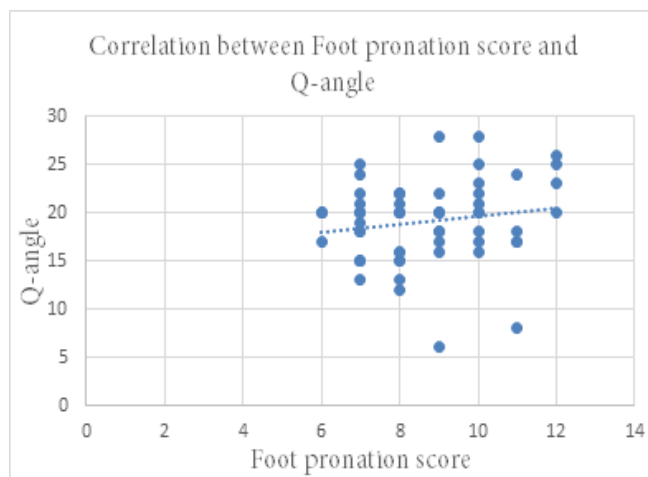


Graph 5: Correlation between foot pronation score and femoral anteversion

foot pronation score and Q-angle were correlated using the Spearman's correlation coefficient where an r value of 0.1801 and a p-value of 0.1685 was obtained, thus suggesting an insignificant correlation between FPI and Q-angle. The mean Q-angle was found to be 19.15 ± 4.186 . (Table 6, Graph 6).

Table 6: Correlation between foot pronation score and Q-angle

Foot Pronation		Q-Angle		SPEARMAN'S CORRELATION COEFFICIENT (r value)	p-value	Significance
Mean	S.D.	Mean	S.D.			
8.65	1.665	19.15	4.186	0.1801	0.1685	Not significant

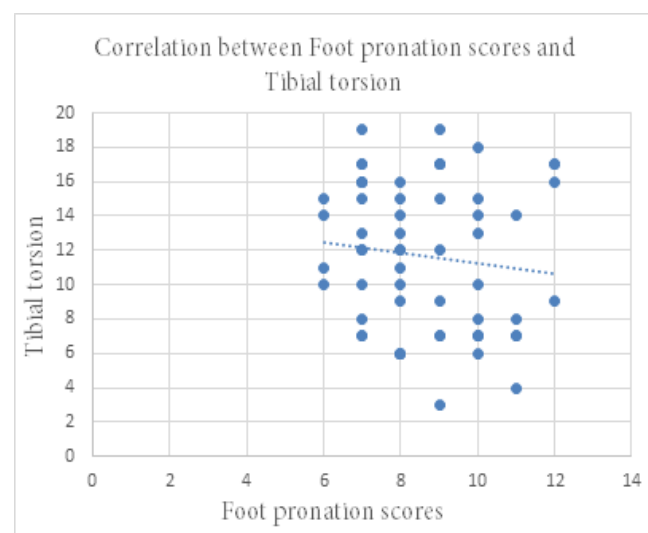


Graph 6: Correlation between foot pronation score and Q-angle

Similarly, foot pronation score and Tibial torsion did not show significant correlation. Spearman's correlation coefficient was used. (r value = -0.1285 and p-value = 0.3277). A mean tibial torsion of 11.63 ± 4.294 was found. (Table 7, Graph 7).

Table 7: Correlation of foot pronation score with tibial torsion

Foot Pronation		Tibial Torsion		SPEARMAN'S CORRELATION COEFFICIENT (r value)	p-value	Significance
Mean	S.D.	Mean	S.D.			
8.65	1.665	11.63	4.294	-0.1285	0.3277	Not significant



Graph 7: Correlation between foot pronation and tibial torsion

DISCUSSION

A study was conducted to correlate the pronation of foot with the pelvic inclination, femoral anteversion, Q-angle and tibial torsion in 60 normal, asymptomatic individuals having no complaints of pain/stiffness at knee/ankle or any history of knee injury. These included 56 females and four males, in the age group of 18-30 years, having a BMI of not more than 30 and a foot pronation score of not

less than 6 in at least one foot. The mean age of the subjects was 21.4 ± 1.618 . The mean BMI of the subjects was 23.192 ± 2.8986 .

The mean foot pronation score of the subjects was 8.65 ± 1.665 . The mean pelvic inclination was 9.767 ± 4.645 . The mean femoral anteversion was 10.47 ± 2.831 . The mean Q-angle was 19.15 ± 4.186 . The mean tibial torsion was 11.63 ± 4.294 . All the five outcome measures were tested for normality out of which, FPI, pelvic inclination and femoral anteversion passed normality. However, Q-angle and tibial torsion did not pass normality. The level of significance of this study was set to p-value < 0.05 .

According to the statistical analysis, no significant correlation was obtained between foot pronation and Pelvic inclination. (r value = 0.03309, p-value = 0.8018)

On using Pearson's correlation coefficient, foot pronation score and femoral anteversion did not show significant correlation (r value = 0.2185, p-value = 0.0934).

foot pronation score and Q-angle were correlated using the Spearman's correlation coefficient where an r-value of 0.1801 and a p-value of 0.1685 was obtained. This suggested that foot pronation and Q-angle did not show significant correlation.

Similarly, foot pronation and Tibial torsion did not show a significant correlation. Spearman's correlation coefficient was used. (r value = -0.1285 and p-value = 0.3277)

The outcome measures taken in this study are not the sole markers of lower limb static alignment. Lower limb alignment also depends on factors such as individual bony alignments, individual anatomic variations and soft tissue structure and integrity, the measurement of which was beyond the scope of this study. There are several interdependent factors such as genu recurvatum, patella position, and strength of core which also affect the factors of static alignment, that were not taken into consideration in this study. Also, Craig's test is not a very reliable method (interrater ICC = 0.85) of measuring the femoral anteversion [11] and also, it doesn't make use of the weight bearing position, thus not giving completely accurate results. Similarly, there is no valid test to measure tibial torsion in the weight bearing position [11] thereby making it a poor measure of the lower limb alignment in the functional weight bearing position. Also, as each varies based on their anatomic and physiologic variations, each person's body has a different mechanism of coping with the changes occurring at any one segment of the body [2]. Thus, as seen in this study, everyone with an increased foot pronation may not necessarily have a proportional increase in the other variables of leg alignment. The body may assume different compensatory strategies to deal with changes occurring at any one joint of the lower extremity.

In a study conducted by Nguyen A-D, Shultz SJ, 2009, no correlation was found between femoral anteversion and any other lower extremity alignment variable. According to their results, a significant relationship was also not found between femoral anteversion and quadriceps angle.

The reason provided by them for the same was poor measurement reliability leading to inconsistent measurements [2].

In a study conducted by Sam Khamis, Gali Dar, et al., 2015, it was found that on evaluating the cumulative effect of the segmental alignments, the calcaneal angle variation had no consistent significant effect on the shank, thigh and pelvic alignment. Furthermore, no significant effect of the calcaneal alignment on the shank was found while standing indicating a poor association between calcaneal eversion and internal tibial rotation. Their results indicated that calcaneal alignment had a weak effect on the thigh and pelvis alignment while standing. They have said that the discrepancy in the results as compared to other studies where higher correlation has been achieved might be due to the versatile maneuvering of the foot (KappelBargas et al., 1998) and the functional ability of the foot to compensate on different terrains [6].

However, this study also has its limitations. The Craig's test that was used to measure femoral anteversion in prone lying position has a low validity and reliability (interrater ICC = 0.85). The most reliable way to measure femoral anteversion is to calculate the degree of femoral anteversion from a CT scan [12], which was not a feasible option. Also, Craig's test and measurement of tibial torsion were carried out in the non-weight bearing positions, i.e. prone and supine respectively. A valid and reliable clinical method to measure tibial torsion in the weight bearing position is required. This may have led to us getting inaccurate results. Lastly, all factors which affect the static alignment of the lower limb joints in the weight bearing positions were not measured or taken into consideration in the study. This includes factors such as tibiofemoral angle, patellar position, ligamentous laxity, neck shaft angle of the femur which must be considered for a more detailed understanding of the functioning of the lower limb kinetic chain [13,14]. The study must also be repeated with a larger sample size to rule out any wide variations in the population.

Thus, according to our study, no significant correlation was obtained between foot pronation and pelvic inclination, femoral anteversion, Q-angle and tibial torsion. However, the correlation between these static alignment factors cannot be completely ruled out as the existence of a kinetic chain has already been proved in many research articles and studies [15,16,17,18]. Thus, all practicing clinicians should keep in mind that the position of any one joint in the kinetic chain can be affected by the alignment of the distal and proximal joints, and therefore, while evaluating the dysfunction of any one joint, evaluation of all joints of the kinetic chain must be done to rule out the presence of deviations in other joints. Also, this study did not take into account many other interdependent factors which affect the position of various joints in the kinetic chain. Thus, further detailed examination and assessment of the topic are required to establish the existence of a correlation.

CONCLUSION

In this study, we concluded that there was no significant correlation between the Pronated foot and Pelvic inclination, Femoral anteversion, Q-angle and Tibial torsion. However, it must be kept in mind that the position of one joint is affected by the position of the proximal and distal joints and thus, practicing therapists must not ignore the role of the foot while evaluating cases of the back, hip or knee.[18]

ABBREVIATIONS' LIST:

Q-angle – Quadriceps Angle

FPI – Foot Posture Index

BMI – Body Mass Index

ASIS – Anterior Superior Iliac Spine

PSIS – Posterior Superior Iliac Spine

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