

Determining the knee joint laxity between the pronated foot and normal arched foot in adult participants

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Abstract. *Background and aim:* Foot pronation is often associated with increased internal rotation of the lower limb, predisposing the knee joint to greater stress. However, the impact of the pronated foot on knee joint laxity has not been well understood. The study aims to find out the effect of the pronated foot on knee joint laxity. *Methods:* Forty adult participants were recruited for the study: 20 with asymptomatic pronated foot and 20 control subjects with the normal arched foot. Foot assessments were performed by navicular drop test and rearfoot angle measurements. Knee joint laxity was measured by a KT 1000 arthrometer of the dominant leg. An independent t-test was performed to detect the differences between both groups. *Results:* Both groups were similar in age, BMI and physical activity level. The findings showed no significant differences between the pronated foot and control group in the knee joint laxity ($P = 0.645$). *Conclusions:* There were no significant differences in anterior knee displacement between the pronated foot and normal arch foot. The study showed that pronated foot might not be responsible for ACL injuries during the age of twenties and confounding factors. Further research is needed to investigate older subjects with the pronated foot. (www.actabiomedica.it)

Key words: pronated foot, flat foot, laxity, ACL, knee joint

Introduction

The foot posture index is a reliable instrument for determining whether a person's foot is supinated or pronated. The concept of supination and pronation are rotation of forefoot on the rearfoot. In the pronated foot medial longitudinal arch (MLA) is absent and rearfoot eversion is increased (1). Foot pronation is associated with internal rotation of the lower limb because of talus adduction (2). The structure and dynamics of the foot arches are important for foot activities such as pressure relief, body weight distribution, and acting as a lever to move the body forward during locomotion (3). The prevalence of pronated foot is 17.2% in 6-12 years of age, 16.4% in 13-17 years, and 17.1% in 18-24 years of age (4,5). The prevalence of

supinated foot is 0.94% in males and 0.34% in females, whereas pronated foot prevalence is 16.23% in males and 11.31% in females in the Israel defense force (3). MLA collapses in various degrees during weight bearing activities while during raising up leg from the floor normal foot arch form again. Foot position and weight bearing status affects the knee joint alignment (6). Weight-bearing activities are designed to improve joint stability and reduce ligament strain by applying compressive force to the knee joint (7). The knee joint demonstrates wide range of laxity, from fundamentally stable joint on one end to severely lax joint on the other. Knee joint laxity is of special concern because of the high rate of injuries, pain, and degeneration, all of which contribute to significant morbidity, functional loss, and health-care costs (8).

Knee joint laxity is caused by a misalignment of the knee joint, particularly the tibia's anterior displacement relative to the femur bone, which produces articular dislocations, subluxations, and arthralgia. Increased anterior knee laxity has been associated to risk of anterior cruciate ligament (ACL) injuries and can impact the biomechanics of other joints during weight-bearing activities (9). It has been reported that pronated foot or subtalar joint pronation leads to increased tibial internal rotation during weight bearing activities, leading to greater stress at the knee joint and the ligaments (10). Pronated foot is one of the causing factors to developed anterior knee pain. The aetiology of this state might be tendency for medial shift in weight bearing (11). Anterior knee pain prevalence among male participants is 16.23% and in females 11.31% with pronated foot (12). A study has shown that lower limb malalignment was significantly associated with increased knee joint laxity. They found that genu varum and low arched foot demonstrated the biggest effects on the knee joint anterior laxity in both women and men (13). Despite these reports, other researchers have rejected they claimed that there is no relationship between foot posture and lower limb injuries. For example, Lizis et al. stated that pronated foot should be considered within the normal range of a strong and stable foot and rarely cause disability (14). In addition, it has been reported that pronated foot is not responsible for altering the lower limb function or increase the risk of injuries and there is cofounding factors (15). Also, Lees et al. claimed that foot arch height, even though it's widely used to describe the foot posture, was not valuable to determine the foot function capacity (16).

It is believed that foot mechanics contribute to lower extremity malalignment and joint interaction with tibial internal rotation, and they may have potential lower extremity injury risk. Research has revealed that rearfoot motion is closely related to tibial motion and is potentially linked to femur transverse rotation. Based on this model of lower extremity joint coupling, there has long been a conceptual relationship between foot pronation and knee joint laxity. Therefore, the current study determining the knee joint laxity

between the pronated foot and normal arched foot in adult participants.

Methods

Study design and Setting

A cross-sectional study design was selected to conduct this study. The study took place at the biomechanics laboratory of the College of Applied Medical Sciences, Imam Abdulrahman Bin Faisal University, Dammam - Saudi Arabia.

Participants

Forty adult males voluntarily participate in the study. Twenty with asymptomatic flexible pronated feet and 20 with normal arched feet as the control group were matched for age, body mass index (BMI), and physical activity level. Both groups were recruited from Imam Abdulrahman Bin Faisal University by advertisement. Participants were initially screened for meeting the inclusion and exclusion criteria. These criteria were selected as they may alter movement patterns of the lower limbs.

Inclusion and exclusion criteria

Subjects included in the study if the foot arch height >10 mm by navicular drop test (ND). And rear-foot angle >5 degrees. Subjects were excluded if they had: Excessive foot deformity, systemic or neurological diseases, and foot or ankle surgeries or recent fractures. The control group was selected if they had normal foot arch with arch height <10 mm: no lower limb disorders or fractures.

Sample size calculation

The sample size was calculated by power analysis based on a study conducted by Tateuchi et al. using the hip internal/external rotation values of subjects with pronated feet (17). Means of the normal arched foot hip rotation (μ_0 value): 2.15 degrees, means of

the experimental group hip rotation (μ 1 value):9.52 degrees standard deviation (σ):7.8. Based on a two-sided test, an alpha level of .05 and power values of 0.80. A sample of 20 participants for both groups. The sample size analysis was conducted using the department of statistic at the University of British Columbia web page: <https://www.stat.ubc.ca/~rollin/stats/ssize/n1a.html>

Ethical considerations

The study was approved by the Institutional Review Board (IRB) of Imam Abdulrahman Bin Faisal University (IRB—PGS-2017-03-176), Dammam, Saudi Arabia. Participants who agreed to participate voluntarily were given a detailed written and verbal explanation of the study's procedures and methods and then asked to sign a consent form. All collected data were dealt with confidentiality and stored electronically in the researcher's laptop with a password.

Outcome measures

Knee anterior laxity: the amount of anterior displacement in millimetres. Knee anterior laxity measured by KT1000 arthrometer.

Procedures

The potential participant underwent an assessment to determine his eligibility for the study. Foot flatness was assessed by arch height using navicular drop test, while rearfoot angel assessment was used to determine the degree of foot pronation. Those who met the study eligibility criteria were asked to sign a consent form if they agreed to participate. Upon the participant arriving at the lab, the researcher measured his body weight, height. They were then asked to fill out the IPAQ questionnaire. The dominant leg was recorded for each participant by asking him which leg they would kick a ball stronger.

International Physical Activity Questionnaire

The International Physical Activity Questionnaire (IPAQ) was developed to determine the

individual's physical activities level in a normal week. The short version of IPAQ consists of 7 main questions to assess physical activities. The reliability of the Arabic version of the IPAQ has been investigated by several studies among the Saudi Arabian adult population and showed to be valid and reliable (18,19).

Navicular drop (ND) test

ND was measured to assess the MLA arch height by measuring the differences of the ND in the open kinetic chain (non-weight bearing) and closed kinetic chain (with weight-bearing). ND has been proven to be valid and reliable (20). The subject in the sitting position placed the foot on a firm surface with the knee flexed 90 degrees and the ankle joint in the neutral position. Navigational tubercle marked with a pen, an index card placed on the inner side of the hindfoot in a vertical position from the ground passing the navicular bone, the tubercle of the foot marked on the card. Then the subject stood without changing the position of the feet and distributed the weight evenly on both feet, and then they could measure again. Finally, the difference between the navicular bone in sitting and standing was measured by a ruler, the amount of ND in millimetres (mm). ND under 10 mm is considered normal and over 10 mm as flat arch (20).

Rear-foot angel

Rear-foot angel is a clinical method accepted in many studies (21,22)—measured to assess the calcaneal eversion or heel valgus and determine the amount of foot pronation. Kanatli et al. stated that the rear foot angle and the foot arch height MLA must be considered separately in flat foot assessment. A rear-foot angle was measured with the subject lying in the prone position, and the examined foot and ankle extended 10 cm out of bed. A longitudinal line was drawn with a pen along the posterior aspect of the lower third of the leg, and then the subject stood in both feet. A goniometer was used to measure the rear foot angle between the calcaneus and the lower third of the leg (23).

Knee anterior laxity

Knee testing device KT 1000 arthrometer (MED metric Corp. San Diego, USA) provides an objective assessment of laxity of the knee joint and the degree of anterior displacement of the knee. KT1000 helps to undertake a more objective evaluation of an individual's potential instability, and it has been studied and showed to be valid and reliable (24). The participant was in a supine position with the knee in 30° of flexion. The heels were in a symmetrical position. Participant's thighs were kept in a relaxed position during the testing. KT1000 has two sensing paddles: one on the tibia tubercle, the other one on the patella. The arthrometer device was secured with straps to the lower leg. Zero-point was determined as it was the same zero point for each participant. Then anterior force was applied through the handle, and the degree of displacement was recorded. Then the test was repeated three times of the dominant leg. The average degree of displacement was recorded for each participant.

Statistical Analysis

All statistical analyses were performed using IBM SPSS software (version; 20) with a significant level of $P < 0.05$. independent t -test was used to ascertain that both groups were similar in age, height, body mass index (BMI), and physical activity level. Furthermore, it was performed to detect the difference in the arch height and rearfoot angle. Independent t -tests were performed to compare and analyze the differences

between both groups regarding knee laxity by comparing anterior knee displacement.

Result

Participant characteristics

Forty adult males participated and, in the study, 20 with asymptomatic flexible pronated feet and 20 with normal arched feet. Table. 1 illustrate the participant's characteristics. There were no significant differences between the groups in age ($P = 0.674$), height ($P = 0.130$), body weight ($P = 0.278$) BMI ($P = 0.459$) or physical activity level ($P = 0.767$). However, there was a significant difference in the arch height ($P = 0.001$) and the rear-foot angle ($P = 0.001$).

The table 2 showed that normal arched foot participants have more knee laxity values than participants with pronated foot.

Our findings showed no significant differences in anterior knee displacement of the dominant leg between the pronated foot and normal arch foot ($P = 0.645$) (Table 3).

Discussion

The purpose of the study was to determine the comparison for knee joint laxity between the pronated foot and normal arched foot in adult participants. Our findings showed no significant differences between

Table 1. Participant's characteristics.

Characteristics	Pronated Foot (n=20) Means±(SD)	Normal Arched Foot (n=20) Means±(SD)	Sig.
Age, (years)	21.45±(4.1)	21 ± (2.5)	0.674
Height, (cm)	173.35± (5)	169.7 ± (6)	0.130
Weight, (Kg)	73± (12)	68 ± (16)	0.278
BMI, (kg/m ²)	24.6 ± (4)	23.5 ± (4.7)	0.459
Physical activity level (MET)	1600 ± (1173)	1726 ± (1484)	0.767
Arch height ND, (mm.)	13.5 ± (1.92)	7.4 ± (1)	0.001
Rear-foot angel. (degree)	8.2 ± (1.9)	3.52 ± (0.7)	0.001

BMI: body mass index, ±: Standard deviations SD, MET: metabolic equivalent, Sig.: significant level of $P < 0.05$

Table 2. Differences of the dominant leg's knee laxity between the pronated foot and normal arched foot

ID	Pronated Foot	Normal Arched Foot	Differences
1.	6.00	8.50	-2.50
2.	6.50	4.33	2.17
3.	6.00	5.50	1.50
4.	9.66	5.50	4.16
5.	7.83	7.33	0.30
6.	7.33	6.50	0.83
7.	11.33	4.00	7.33
8.	5.50	7.83	2.33
9.	8.33	6.66	1.67
10.	5.66	4.50	1.16
11.	5.50	9.16	-3.66
12.	5.00	3.83	1.17
13.	5.83	9.00	-3.17
14.	8.66	8.33	0.33
15.	5.66	10.33	-4.67
16.	9.66	10.00	-0.44
17.	6.33	9.00	-2.67
18.	7.30	11.33	-4.03
19.	6.66	7.50	-0.84
20.	8.16	9.66	-1.5
Mean	7.2	7.4	-0.2
SD	1.71	2.3	-0.59

both groups after measuring the knee joint laxity of the dominant leg. These results contradict our hypothesis, which means that the pronated foot will increase the knee laxity. We established our hypotheses on the literature that mentioned that pronated foot increases the tibia medial rotation, consequently increasing the stress on the knee ligaments (10). The loss of arch height impacts the weight bearing of the foot, resulting in pain, inflammation, or discomfort in the foot due to the synchronization in their biomechanics. Therefore, unexpected, or continuous foot stress can impair the biomechanics and functioning of proximal joints, resulting in pain in the knee, hip, pelvic, and lower back (25).

In comparison the results with literature, there is a disagreement with Shultz et al., who found that lower limb malalignment was significantly associated

with increased knee joint laxity (13). They concluded that genu varum and low arched foot demonstrated the biggest effects on the knee joint anterior laxity in both women and men. Nevertheless, their study includes hip and knee malalignment, which directly influence the knee joint. In addition, the study neglects the participants' physical activity level, which was considered an important factor that could influence the knee joint muscles and affect the joint's stability (26). Another limitation of the previous study was the techniques they used for classifying and assessment of foot posture. Gross et al. revealed that foot differences are associated with the knee joint laxity as morphology of pronated foot is the outcome of tibial internal rotation with the femur bone. This is due, if increased femoral internal rotation occurs, the lateral trochlea femoris may collide with the lateral patella. There is also a propensity for higher contact between the articulating surfaces of the lateral patellofemoral joint when pronated foot morphology is followed by a more proximal bone malalignment, which results in excessive joint stress and cartilage injury (27). Park et al. stated that individual with pronated foot have significantly greater laxity than individual without pronated foot, probably because of the femoral and tibial medial condyles defects (28). Pronated foot disorder had been found to be associated with medial tibiofemoral cartilage damage that causes forcing the tibia to rotate internally responsible for knee joint laxity (29). This might be interpreted as follows- the fact that a disruption in foot biomechanics can lead to excessive loads at the knee, causing discomfort and the development of deformities like genu valgus (30).

Our result showed no differences between both groups, and the possible explanation is the pronated foot type was investigated. Those who have asymptomatic flexible pronated feet have learned to adapt to the structural abnormality. pronated-footed individuals were found to have greater and varied muscle activations, which might be part of a compensatory mechanism to overcome the deformity (31). Similarly, there are no differences in the alignment of the lower extremities between the pronated foot and normal arched foot (32). In addition, even though it's widely used to describe the foot posture, Foot arch height did not show to be valuable to determine the foot function

Table 3. Comparison of the dominant leg's knee laxity between the pronated foot and normal arched foot

	Pronated foot (n=20) Means and (SD)	Control (n=20) Means and (SD)	Sig.
Knee Anterior Displacement, (degrees)	7.2 ± (1.71)	7.4 ± (2.3)	0.645

±: Standard deviations SD. Sig.: significant level of $P < 0.05$.

capacity (16). Moreover, de César et al. found that Individuals with ACL rupture showed higher foot arch than the control group, suggesting a relationship between a high MLA arch and ACL injuries (33). The literature showed that pronated foot rarely causes disability (15, 16). In 900 runners, cohort research investigated the relationship between injuries and foot posture. They discovered that having a pronated foot is not linked to an increased risk of injury, and that there is no difference between having a pronated foot and having a normal foot when it comes to lower limb injuries. They came to the conclusion that the popular idea that a pronated foot increases the risk of lower limb injuries is incorrect (15). It might point out that a pronated foot is not a major risk factor for other musculoskeletal lower limb injuries. Likely other confounding factors are affecting the joints. The fact that severe and moderate pronated feet had a higher incidence of anterior knee laxity which suggests that the degree of longitudinal arch flattening is more important than the stiffness of the pronated foot. The impact of the pronated foot severity on the rotating mechanical axis in the weightbearing areas might be the source of this association (34).

This study also has some limitations as all the participants were males, making it difficult to generalize the findings into all community populations. All the participants were similar characteristics regarding age, BMI, and physical activity level. The research focused on one issue to clarify it with no complications. The research focused on the Feet characteristics to ensure the pronated foot type is the same for all participants.

Conclusion

The present study's findings can provide important information for the clinical assessment of

individuals with pronated feet. The flexible pronated foot is not a major risk factor for other ACL and knee injuries, and likely other confounding factors are affecting the joints. The impact of pronated feet on knee joint laxity showed no significant differences between both groups. It indicated that pronated foot might be not responsible for the ACL injuries and there is confounding factors.

Conflict of Interest: There is no conflict of interest among authors.

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