ASSESSMENT OF KNEE KINEMATICS IN SUBJECTS WITH BILATERAL FLIXIBLE FLAT FEET (CROSS SECTIONAL STUDY)

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ABSTRACT

Background: Flatfoot is a common deformity in which there is a lowered medial longitudinal arch. It takes the calcaneus in the valgus position and the talus in plantar flexion with adduction making the excessive pronation of the foot when bearing full weigh. Objectives: The aim of the study was to investigate the effect of bilateral flexible flat foot on knee joint kinematics during squatting. METHODS: Eighty eight participants (44 bilateral Flexible flatfeet and 44 healthy subjects without flatfoot) had participated in this study, their age ranged from eighteen to thirty five years. Each participant undergone measurement for FPPA and hip adduction angle by Kinovea software for motion analysis. Results: The results showed that there was no association between navicular height and changes in knee joint kinematics. Conclusion: This study indicated that the height of medial longitudinal arch has no impact on changes in knee joint kinematics.

Key words: Flat foot, Flexible flat feet, Knee kinematics, FPPA, HADD.

I. BACKGROUND:

The prevalence of flatfeet in the general population is reported to be 26.62% (1). Flexible flat foot starts in childhood and may continue to adulthood (2). Childhood flatfoot can be associated with coalition, laxity syndromes, neuromuscular disease, and numerous other causes (3). Acquired flatfoot may be asymptomatic or may lead to profound symptoms and dysfunction that are disabling enough to incapacitate patients.

There are many causes for flexible flat foot as tibialis posterior dysfunction, ligament loosening, achilles tendon shortening, foot muscle weakness and foot bone malformation. These conditions lead to excessive pronation of the foot during weight-bearing (4).

Many individuals with flexible flatfeet walk with certain alterations in the lower extremity kinematics. The most common alteration is excessive pronation of the subtalar joint during stance phase (5). Arch height may affect the distribution of injury in the lower extremity through its influence on the mechanical coupling between the subtalar joint and the knee. Abduction and adduction at the subtalar joint translates to external and internal rotation, respectively, of the tibia. A low arch with a relatively low angle of inclination at the subtalar joint is thought to result in a higher component of eversion at the subtalar joint and a lower component of tibial internal rotation (6).

In normal gait, the subtalar joint starts to pronate after initial contact until the metatarsal head contacts the ground, where upon the subtalar joint starts to supinate and converts the foot into a rigid structure for propulsion in the late stance phase. In people with flexible flatfeet, the foot stays in a pronated position without turning to supination during the late stance phase, which is not efficient for completing the push-off during gait. Considering the coupling movement between rear foot inversion/eversion and tibial rotation, an excessive or prolonged pronation of the foot is often linked to excessive or prolonged tibial rotation and larger valgus at the knee (7).
Many previous researches on flat foot deformity have suggested that there was a relation between this deformity and knee related injuries (8-10). The purpose of this study is to investigate the effect of bilateral flexible flat foot on knee joint kinematics during squatting.

II. METHODS:

Design of the study:
This is a cross sectional study. The measurements of this study conducted at the department of Physical Therapy at Birmibal Alqadima family medicine center in Dakahlia, Egypt. The study extended from October 2020 to Mars 2021. This study is approved by ethical committee of faculty of physical therapy, Cairo University P.T. REC /012/002873

Subjects:
The current study was conducted on 88 participants aged from 18-35 years (11). They were assigned into two studies groups. Flatfoot group (group A) consisted of 44 subjects with mean age, body mass, height and BMI values of 24.79±5.83 years, 73.27±15.97 kg, 165.48±8.38 cm and 26.68±4.88 kg/m2 respectively. Control group (group B) consisted of 44 healthy subjects without flatfeet with mean age, body mass, height and BMI values of 23.68±5.66 years, 69.43±15.59 kg, 167.55±9.64 cm and 24.55±6.8 kg/m2 respectively.

The subjects were included if they had bilateral flexible flat foot (positive Jack’s Test) (12), Navicular drop is more than 10 mm (13, 14). Subjects were excluded if they had a history of foot and ankle surgery, trauma, fracture or dislocation (15), systemic or neurologic diseases that could affect lower extremity biomechanics (15) or congenital deformities in the ankle and foot (12). Each participant had a detailed explanation about the procedures and the purpose of conducting this research with insurance of full privacy and they signed an informed consent form before their participation.

Assessment Procedures:
Participants were instructed to wear tight shorts and to take off their shoes and socks. Then, the navicular drop test (NDT) was used for measuring navicular height by measuring the height difference between the navicular tuberosity and the floor when the subject stands from sitting. Normal measurement of navicular drop is 0.9-1cm, while more than 10 mm difference is considered excessive foot pronation (14).

Single leg squat (SLS):
Participants were asked to stand on the test limb, facing the video camera, facing the smart phone video recording camera. This phone was placed on a tripod at 2m from the participants and at the height of the knee joint in single-leg stance. They were asked to squat down to reach 45° knee flexion, over a period of 5 s. Knee-flexion angle was checked during practice trials using a standard goniometer, and observed by the same examiner throughout the trials. There was also a counter for each participant over this 5-s period, in which the first count meant to initiate the movement, the third was at the lowest point of the squat and the fifth indicates the end. This standardized test reduced the effect of velocity on knee angles. Trials were only accepted if the participant squatted to 45° knee flexion and maintained balance throughout the movement (16).

Two dimensions (2D) video assessment using Kinovea Computer Program (KCP):
Markers were placed on the lower extremity of each participant at the midpoint of the femoral condyles to approximate the center of the knee joint, midpoint of the ankle malleoli for the center of the ankle joint, and on the proximal thigh along a line from the anterior superior iliac spine to the knee marker, and also placed on the anterior superior iliac spines (17, 18). The midpoints were determined using a standard tape measure, and all markers were placed by the same examiner (16). Participants were instructed to raise their shirts so all markers were visible.

Outcome measures from 2D video assessment:
The knee Frontal plane projection angle (FPPA) and the hip adduction angle (HADD) were collected from the videos of all participants. FPPA was measured as the angle subtended between the line from the markers on the proximal thigh to the center of the knee joint and the line from the center of the knee to the center of the ankle at the frame that corresponded with the point of maximum knee flexion. Positive values of FPPA reflected knee
Valgus and negative values reflected knee varus. HADD was measured as an angle subtended between the line from the markers on the proximal thigh and the line between the two anterior superior iliac spines (16).

III. RESULTS:

Statistical analysis was conducted using SPSS for windows, version 23 (SPSS, Inc., Chicago, IL). The current study was conducted on 88 participants. They were assigned equally into two study groups (44 bilateral FFF and 44 healthy subjects without flat feet) as shown in (Table 1).

<table>
<thead>
<tr>
<th>Items</th>
<th>Group A</th>
<th>Group B</th>
<th>t-value</th>
<th>P-value</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>24.79±5.83</td>
<td>23.68±5.66</td>
<td>0.908</td>
<td>0.366</td>
<td>NS</td>
</tr>
<tr>
<td>Body mass (Kg)</td>
<td>73.27±15.97</td>
<td>69.43±15.59</td>
<td>1.143</td>
<td>0.256</td>
<td>NS</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.48±8.38</td>
<td>167.55±9.64</td>
<td>-1.074</td>
<td>0.286</td>
<td>NS</td>
</tr>
<tr>
<td>BMI (Kg/m²)</td>
<td>26.68±4.88</td>
<td>24.55±6.8</td>
<td>1.683</td>
<td>0.096</td>
<td>NS</td>
</tr>
</tbody>
</table>

Sex distribution N (%)

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
<th>χ²</th>
<th>P-value</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>16 (36.4%)</td>
<td>24 (54.5%)</td>
<td>2.933</td>
<td>0.134</td>
<td>NS</td>
</tr>
<tr>
<td>Females</td>
<td>28 (63.6%)</td>
<td>20 (45.5%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*SD: standard deviation, P: probability, S: significance, NS: non-significant

As indicated by the independent t test, there were no significant differences (p>0.05) in the mean values of age, body mass, height and BMI between both tested groups (Table 1).

Chi square revealed there was no significant differences between both groups in sex distribution (p>0.05).

The results indicated that there was no correlation between mean values of navicular drop test with mean value of FPPA at left leg in both groups (Table 2).

<table>
<thead>
<tr>
<th>Variables</th>
<th>FPPA at left leg (FFF group)</th>
<th>navicular drop test at left leg (FFF group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean±SD</td>
<td>193.11±9.07</td>
<td>13.68±2.62</td>
</tr>
<tr>
<td>ρ</td>
<td>0.09</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.562</td>
<td></td>
</tr>
</tbody>
</table>

FPPA at left leg (control group) | navicular drop test at left leg (control group)

| Mean±SD                    | 193.06±10.25                 | 7.56±1.74                                  |
| ρ                          | 0.191                        |                                            |
| p-value                    | 0.215                        |                                            |

ρ: Spearman's rank correlation, *Significant: p-value >0.05.( Table 2)

The results indicated that there was no correlation between mean values of navicular drop test with mean value of hip adduction angle at both groups (Table 3).

<table>
<thead>
<tr>
<th>Variables</th>
<th>hip adduction angle at left leg (FFF group)</th>
<th>navicular drop test at left leg (FFF group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean±SD</td>
<td>70.22±10.40</td>
<td>13.68±2.62</td>
</tr>
</tbody>
</table>
The results indicated that there was no correlation between mean values of navicular drop test with mean value of FPPA at right leg in both groups (Table 4).

The results indicated that there was no correlation between mean value of navicular drop test with mean value of hip adduction angle at right leg in both groups (Table 5).

The results showed that there is no association between navicular height and changes in knee joint kinematics represented by knee frontal plane projection angle and hip adduction angle.

IV. DISCUSSION:

This study was conducted aiming to investigate the effect of flexible flat foot on knee Frontal plane projection angle (FPPA) and Hip adduction angle (HADD) in bilateral flexible flat feet.

Frontal plane projection angle FPPA: 

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This is the first study that assessed the FPPA in subjects with bilateral flexible flatfeet. The results of this study clarified that there is no association between navicular height and changes in knee frontal plane projection angle.

The results of this study regarding FPPA may be attributed to individual differences in knee joint anatomy and laxity, which are known to lag behind dynamic valgus levels (19). Also may be attributed to the good strength of hip abductors of the participants as it is believed that strength of the hip abductors would affect the alignment of the pelvis during single-limb activities and, in turn, affect the frontal plane movement of the knee (20).

The findings of present study regarding the difference in FPPA between normal subjects and subjects with bilateral FFF came in agreement with a previous study (21) that has clarified that the arch height index was found to have no effect on the knee adduction angle during running in normal subjects. Our findings also agree with other previous study (22) that found no association between frontal plane hip and knee kinematics in single-leg squats or vertical drop jumps with overhead target and ACL injury risk in elite female handball and football athletes.

The findings of present study regarding FPPA disagree with previous studies (18, 23, 24). One study (18) found that female subjects with PFPS demonstrate more negative FPPA during single-leg squats than a healthy female control group. Other study (23) investigated the frontal plane projection angle (FPPA) during single leg squatting (SLS) and hop landing (SLL) tasks and noted that female patients with PFP have a greater degree of knee valgus on unilateral limb loading task than either their contralateral asymptomatic limb or an asymptomatic control group. Another study (24) concluded that increased valgus motion and valgus moments at the knee joint during the impact phase of jump-landing tasks are key predictors of an increased potential for ACL injury in females. The difference between the results of our study and these studies may be due to the homogeneity in their sample that was restricted only to female Subjects. Also the participants of our study may have greater hip muscles strength.

**Hip adduction angle (HADD):**

The results of this study clarified that there is no association between navicular height and changes in hip adduction angle.

This is the first study that measured hip adduction angle (HADD) in adult subjects with flatfoot conditions. One previous study (7) described and compared the lower extremity kinematics in primary school children with and without flexible flatfoot and clarified that children with flexible flatfeet have a tendency towards greater hip flexion, adduction and less hip internal rotation during the stance phase of gait. These inconsistent findings may be a result of subject variations, such as different age groups and severity of flatfoot in addition to the difference in the applied activity as the authors of this study have assessed from walking while we assessed from SLS.

The results of this study regarding hip adduction angle match with the results of a previous study (25) that compared hip strength and hip and knee kinematics in subjects with no discernable cause of PFPS, except for overuse, to matched controls and found that Subjects with PFPS demonstrated hip external rotator and hip abductor weakness; however, no differences were found with respect to hip internal rotation and hip adduction angles during stair descent. The results match also with a study (26) that studied the differences in hip kinematics, muscle strength, and muscle activation between subjects with and without patellofemoral pain and did not find group differences in peak hip adduction. Although the average amount of peak hip adduction was greater in females with PFP (11.0°) compared to that of the control group (9.6°), this difference did not reach statistical significance.

The findings of this study disagree with some previous studies (27, 18) which indicated that hip adduction is greater in PFPS during gait and activities such as run, jump and squat. This may be because the participants of these studies were only females. A study (27) compared the influence of proximal and distal factors on lower extremity running mechanics between runners with PFPS and uninjured runners and concluded that runners with PFPS displayed weaker hip abductor muscles when compared to uninjured runners, while hip external rotator strength was similar between the 2 groups. Another study (28) compared lower-extremity kinematics during a 45° and 90° cutting maneuver and examined the relationships between lower-extremity rotations during these maneuvers and found that knee abduction is a common mechanism of ACL injury and is related to increased risk of ACL injury in athletic women as when the hip adducted, knee abduction increased during both 45° and 90° unanticipated cuts. These result differences between these previous studies (27, 28) and our results regarding hip
adduction angle may be because of strength difference between the participants of these studies. Participants of our study may have greater hip abductor muscles strength.

V. CONCLUSION:

This study indicated that the height of medial longitudinal arch has no impact on changes in knee joint kinematics.

Limitations:

This study is limited to 2D motion analysis.

Recommendations:

Further studies are needed to be done on older subjects to identify whether the current findings will change with longer time. Future similar studies are also needed to use different assessment tools like 3D motion analysis rather than 2D analysis for measurement of knee kinematics and to use different tasks rather than single leg squat for measuring knee kinematics.

Declarations: Not applicable.

Competing interests: The authors declare that they have no competing interests.

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REFERENCES:


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