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Correlation between frontal plane projection angle and pain, dynamic balance and function in patients with patellofemoral pain syndrome

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Abstract:

Purpose: The primary goal is to determine whether there is a correlation between knee frontal plane projection angle (FPPA) and dynamic balance, knee function, and pain in PFPS patients. A secondary purpose was to examine the differences in FPPA and dynamic balance between PFPS patients and healthy people.

Methods: 25 patients with unilateral PFPS and 25 Healthy volunteers from both genders were recruited. Assessment of FPPA using 2D video analysis system, and dynamic balance using star excursion test were carried out for participants in both groups for comparison. In addition, knee function by anterior knee pain scale and pain by visual analogue scale which were assessed in PFPS group only for correlation with FPPA.

Results: There was no significant correlation between FPPA during the single limb squat test and the dynamic balance, pain, and Knee function in PFPS patients. There was a significant difference in FPPA and dynamic balance between groups (p <.001*).

Conclusion: The current study strengthened the presence of significant differences between healthy subjects and patients with PFPS in all assessed outcomes. The PFPS patients displayed larger FPPA, lower star excursion balance test reach distances and anterior knee pain scale score and increased pain severity. However, no correlations were found between FPPA during the SLS test and the dynamic balance, pain and knee function in PFPS patients.

Key words: Patellofemoral pain; frontal plane projection angle; balance; function; pain.

1. Introduction:

One of the most prevalent musculoskeletal diseases, patellofemoral pain syndrome (PFPS), causes 20–40% of all knee complaints in adolescents and active young people (1). It is substantially more common in adult females especially between the ages of 18 and 35 (2).

PFPS is defined as aching pain in the anterior knee or retro patellar area with no other pathology. Crepitation in the patellofemoral joint occurs during and after weight-bearing activities such as squatting, going up or down stairs, and running.

Other symptoms of PFPS include pain when sitting with knee flexion, occasional weakness, and catching feelings (3).

During weight bearing activities, altered hip and knee transverse and frontal plane kinematics were

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commonly referred to as "apparent knee valgus," "dynamic valgus," or "dynamic malalignment" (4,5).

Poor lower extremity biomechanics and the development of greater knee valgus during limb loading were thought to contribute to the development of PFPS, despite the fact that the underlying mechanisms were still not fully understood (6).

In the literature, a variety of screening tests have been used to assess dynamic knee valgus Such as single limb squat (SLS) (7) and drop vertical jump (8).

The 3-dimensional (3D) motion analysis is considered as the gold standard for assessment of the lower limb biomechanics (9). However, it is a very expensive, sophisticated tool and not widely accessible for clinical settings. Therefore, the two-dimensional (2D) method of analysis, which is less expensive, easy-to-use, and portable may be more useful. A 2D analysis has already been used to measure the angle of the knee valgus in normal and injured athletic populations (10, 11).

According to Gwynne and Curran, individuals with PFPS displayed significantly larger 2D frontal plane projection angle (FPPA) compared to the healthy group during single-limb squat (12).

In their investigation of balance in PFPS patients, Citaker and his coworkers observed a statistically significant difference between the symptomatic and asymptomatic side (13).

Furthermore, Priore and his colleagues demonstrated that PFPS patients had a higher incidence of dynamic postural balance impairment (14). According to this theory, researchers found that during the star excursion balance test (SEBT), individuals with PFPS reduce the anterior reach distances and knee/hip flexion range of motion compared to healthy subjects (15, 16).

According to Long-Rossi and Salsich **(**17**),** pain limits function and lowers quality of life in PFPS patients. Previous studies have suggested that walking, climbing stairs, and up/down performances were reduced in PFPS. Retro patellar pain worsens during these physical activities that may increase the burden on patellofemoral joint **(**18, 19).

Valgus alignment of the knee joint may be greatly influenced by dynamic balance. Given that participants in these tests (SLS, single leg landing (SLL) and SEBT) are required to use a similar ability to maintain dynamic one-legged balance, it appears that there may be such a relationship between them.

There isn't enough information, though, to conclusively link dynamic balance, function, discomfort, and dynamic lower extremity alignment in PFPS patients. We hypothesized that lower extremity malalignment during dynamic functional tasks could have an impact on dynamic balance, physical function, and discomfort.

Therefore, the aim of this study is twofold, first to find the correlation between knee FPPA and dynamic balance, knee disability and pain in patients with PFPS. Second, to assess the difference between FPPA and dynamic balance in PFPS patients and normal subjects.

2. Materials and Methods:

Fifty participants from both genders, with age between 18-35 years were recruited to participate in this study. Subjects were assigned into 2 groups: control group A (n=25) including healthy volunteers and PFPS group B (n=25) including patients diagnosed with unilateral PFPS. Direct referrals were employed to find subjects who could participate in this study; as a result, the convenient sample was collected. The informed consent form was requested to be signed after demonstration of the study aim and procedures. The ethical committee approval no P.T.REC/012/004111

Subject was included if they have:

1. Unilateral anterior knee or retro-patellar pain with at least 2 of the following activities (21): prolonged sitting, climbing stairs, kneeling, running, squatting, hopping, and jumping.
2. Insidious appearance of symptoms not related to a traumatic incident at least two months or more.
3. Subjects should be between the ages of 18 and 35 in order to reduce the potential that arthritic changes may have complicated PFPS after age 35. Furthermore, to ensure that they also have closed epiphyseal growth plates (22, 23)
4. BMI 18.5-29 kg/m². We include this range of BMI to easily find our participants.
5. No history of lower limb injuries
6. Absence of knee pain when engaging in any of the activities previously mentioned served as the inclusion criterion for the control group.

Subjects were excluded if they have any of the following conditions:

1. History of cruciate or collateral ligament involvement, meniscal or other intra-articular pathologic disorders.
2. History of subluxation or traumatic dislocation of the patella.
3. Previous knee, ankle, and hip joint surgeries.
4. Osteoarthritis of the knee, ankle, and hip.
5. Any neurological disorders that affect balance and postural stability and subjects not able to balance in single limb standing.
6. Foot deformities

A) Frontal plane projection angle:

A 2D image analysis tool for measurement of FPPA was used by the aid of digital camera during SLS. Patients were asked to stand on the assessed limb, in front of a camera placed at the knee joint level, anterior to the landing target, and perpendicular to the frontal plane. Participants squat to a minimum knee flexion of 45° but no more than 60°. The FPPA was measured using Kinovia software through drawing two lines; the first between the markers at the anterior superior iliac spine and center of knee joint and the second line between the markers on the center of knee to the center of the ankle as shown in **Figure (1).** The angle value calculated using Kinovia and subtracted from 180º. Positive FPPA readings represent knee valgus, or it means knee moved towards the body's midline so that the knee marker was medial to the line connecting the ankle and thigh markers. Negative FPPA readings represent knee varus, or knee movement away from the midline of the body (24).

B) The Star Excursion Balance Test (SEBT):

Four lines, two of which create vertical and horizontal lines, two of which are perpendicular to one another and 45 degrees from the vertical and horizontal lines, make up the star excursion test arrangement. These lines were placed on the floor with adhesive tape. The patient must balance on one lower limb while extending the contralateral limb as far as he can in each of the eight directions. The assessor had marked the far distance reached in each direction and used the tape to measure the distance from the grid's center to the point of greatest distance by the reach leg (15) **Figure (2).**

C) Anterior knee pain scale (AKPS):

A total of 13 clinical situations were evaluated by the anterior knee pain scale (AKPS), including limping during gait, carrying weight, walking, running, squatting, jumping, prolonged sitting with knee flexion, pain, swelling, unusually painful patellar movements, flexion deficiency, and atrophy of the thigh (25).

It is used to assess the extent of affection of knee functional impairment secondary to patellofemoral pain. Its maximum score is 100 points. higher scores indicating good function and lower levels of pain. The Arabic version of the scale is a reliable and valid tool for knee functional disability (26**).**

Figure (1): FPPA during SLS

D) Visual analogue scale:

A typically 100-millimeter-long horizontal line makes up the VAS, a self-reported scale (100 mm) used for assessment of pain intensity, where 0 represented no discomfort and 10 represented the worst intolerable pain. We asked the patient asked to put a mark on the line that best describe his/her pain level. It has been validated and examined for reliability for the assessment of knee pain **(**25**).**

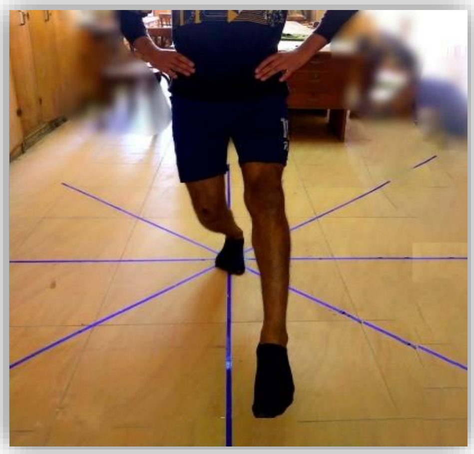

Figure (2) SEBT anterior direction

Statistical analysis:

All data were analyzed by IBM SPSS Statistics 28 (IBM Corp, USA) program. The descriptive statistics were expressed in mean, and standard deviation for quantitative variables and absolute frequencies and percentage for the qualitative variables. The Shapiro-Wilk test was used to assess the distribution of outcomes whether normal or not.

MANOVA of all dependent variables of all subjects in the two groups were used to find the significant difference between FPPA, dynamic balance, and knee function between PFPS patients and healthy subjects. A correlation analysis was performed between FPPA and knee pain and function of the affected limb at group B (PFPS). The Pearson correlation (rho) was used to test whether the correlation was present and its degree and classified as 0.1, 0.3, 0.5, 0.7, and 0.9 as small, moderate, strong, very large and extremely large, respectively. The statistical significance was set at $p < 0.05$. If the correlation test was significant, the coefficient of determination was calculated.

Results:

Fifty participants with 25 healthy subjects in group A (control) and 25 patients with patellofemoral pain syndrome in group B (PFPS). The gender distribution of the group A revealed that there were 13 females with reported percentage of 52% while the number of males was 12 with reported percentage of 48%. The gender distribution of the group B revealed that there were 19 females with reported percentage of 76% while the number of males was 6 with reported percentage of 24%. There was no significant difference between groups in sex distribution ($p = 0.077$). Furthermore, there was no significant difference in age ($p = 0.322$), weight ($p = 0.737$), Height ($p = 0.107$), and BMI ($p = 0.201$) between groups (**table 1**).

All dependent variables including FPPA, dynamic balance, pain, and knee function were normally distributed, therefore, MANOVA and Pearson correlation were used to assess the significant differences and the correlation between groups respectively.

Table (1): Descriptive statistics for demographic variables

	Group A (Control) N = 25 x̄ ± SD	Group B (PFPS) N = 25 x̄ ± SD	MD	t-value	p-value	Sig
Age (years)	22.04 ± 2.87	22.92 ± 3.34	-0.88	-1	0.32	**NS**
Weight (Kg)	64.24 ± 8.42	63.46 ± 7.9	0.78	0.39	0.74	**NS**
Height (CM)	170.16 ± 8.45	166.72 ± 6.18	3.44	1.64	0.11	**NS**
BMI (kg/m²)	22.046 ± 2	22.772 ± 1. 96	-0.73	-1.30	0.20	**NS**

x̄: Mean SD: Standard deviation MD: Mean difference
t value: Unpaired t value p value: Probability value
NS: Non-significant

MANOVA:

Multivariate analysis of variance (MANOVA) was conducted to investigate the difference between all dependent variables (FPPA and dynamic balance) in both groups; Group A (Control) and Group B (PFPS). The test revealed a significant difference between groups in FPPA and dynamic balance measured by star excursion test in eight directions (anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral, anterolateral) as shown in **table 2.**

Correlation: Pearson correlation coefficient was used to determine the strength and direction of the linear relationship between FPPA and dynamic balance (assessed by star excursion test), function and pain in Group B (PFPS). The results revealed no significant correlation between FPPA and star excursion test in all directions (anterior, anteromedial, medial, posteromedial, posterior, posterolateral, lateral, anterolateral) in Group B (PFPS), as shown in table 3. Furthermore, there was no significant correlation between the FPPA and knee pain, function and onset of symptoms in Group B (PFPS), as shown in **table 3**.

Discussion:

Results of our study revealed insignificant weak inverse relation between FPPA and balance, function, and pain. This non-significant result could be justified due to the possibility of low sample size. If we had a larger sample size, our results might have reached the level of significance. This is the first study to investigate that correlation. There is no relevant study previously assessed it to compare with the current study's results. Results of a recent study were consistent with the current findings in which they reported no significant correlations between FPPA and numerical pain rating scale (NPRS), AKPS during the lateral step down (27).

In agreement with our hypothesis**,** past results had been found no correlation between static lower limb alignment (tibial torsion, pelvic angle, femoral neck anteversion, quadriceps angle, tibiofemoral angle, navicular drop) and retropatellar pain in patients with PFPS. Static lower limb alignment was found not correlated to functional ability in patients with PFPS (28).

In addition, previous researchers examined the correlation between static lower limb alignment (Lateral distal femoral angle, medial proximal tibial angle) and the dynamic balance and functional disability (assessed by the 30-second chair stand test) in patients with PFPS. Based on this study, the dynamic postural balance didn't differ in either the affected or nonaffected sides. Valgus deformation was identified as a deterioration in the alignment of the lower extremities in the painful knees in patients with PFPS. On the other hand, their findings demonstrated that in PFPS patients, the degree of discomfort merely had an impact on posterolateral balance. In addition, no correlation was documented between the alignment of the lower extremity and dynamic postural balance on the painful side (29).

Contrary to our hypothesis, we found no significant correlation between FPPA and SEBT, VAS and AKPS. Almeida et al., (30) partially disagreed with our results and suggested that the FPPA was positively correlated with the severity of pain in females with PFPS. On the contrary, there was no correlation with functional disability which is consistent with our finding. Contradiction between us may be due to difference in sampling as they recruited females only. Whereas our sample recruited PFPS patients from both genders.

In another investigation, during the step-down task, there were strong correlations between 3D joint kinematics at the knee (peak abduction) and hip (peak adduction and internal rotation). In both males and females with patellofemoral pain, greater hip adduction, hip internal rotation, and knee abduction were linked to higher degrees of discomfort and decreased function (19).

Table 2. Mean values of all dependent variables and MANOVA testing between group A (Control) and B (PFPS).

Variable	Group A (Control) N = 25	Group B (PFPS) N = 25	MD	Univariate test		Multiple pairwise comparison test		Sig
	x̄ ± SD	x̄ ± SD		F-value	p-value	η2	p-value	
FPPA (degrees)	-.15±7.4	10. 8±10.2	-10.96*	18.8	<.001*	0.28	<.001*	S
SEBT (%) anterior	91.6 ±7.8	83.± 7.7	8.10*	13.6	<.001*	0.22	<.001*	S
SEBT (%) anteromedial	93 ± 7.9	85.± 8.1	7.84*	12.1	<.001*	0.20	<.001*	S
SEBT (%) medial	88.72 ±7.9	78.2± 7.8	10.54*	22.57	<.001*	0.32	<.001*	S
SEBT (%) posteromedial	91.6 ± 8.2	81.3± 10.2	10.34*	17.2	<.001*	0.26	<.001*	S
SEBT (%) posterior	90.5 ±7.5	80.±9.04	10.30*	19.1	<.001*	0.29	<.001*	S
SEBT (%) posterolateral	83.4 ± 6.8	73.8±10.5	9.55*	14.6	<.001*	0.23	<.001*	S
SEBT (%) lateral	73.5 ± 7.8	62.± 11.1	10.8*	16	<.001*	0.25	<.001*	S
SEBT (%) anterolateral	82.1 ± 7	74.7± 9.2	7.4*	10.2	<.001*	0.17	<.001*	S

x̄: Mean - SD: Standard deviation - MD: Mean difference
t value: Unpaired t value - p value: Probability value - S: Significant

The differences among results may be attributed to variabilities in assessment tools for lower limb kinematics, in which they used 3D motion analysis while the current study used 2D image analysis. Additionally, they used different tasks during the assessment as step down task (19) while the current study used SLS tasks.

Table 3: Correlation between frontal plane projection angle and dynamic balance in Group B (PFPS)

	Variable	r-value	p-value	Sig
FPPA	SEBT anterior (%)	- 0.116	0.582	NS
	SEBT anteromedial (%)	- 0.008	0.968	NS
	SEBT medial (%)	0.105	0.618	NS
	SEBT posteromedial (%)	0.190	0.363	NS
	SEBT posterior (%)	0.091	0.667	NS
	SEBT posterolateral (%)	0.164	0.434	NS
	SEBT lateral (%)	0.007	0.972	NS
	SEBT anterolateral (%)	-0.060	0.778	NS
	AKPS	-0.211	0.311	NS
	VAS	0.254	0.220	NS
	VAS mini squat	0.269	0.194	NS
	Onset of symptoms	-0.205	0.325	NS

Despite there being no correlation between variables in the PFPS group, the results of this study showed that there was a significant difference in FPPA and dynamic balance between groups subsequently we strengthened the results of previous research. The patellofemoral group has larger dynamic valgus angles and poorer lower limb kinematics compared to healthy participants. PFPS patients have greater hip adduction and internal rotation which may cause abnormal tracking of the patella within the femoral trochlea and aggregating the anterior knee pain.

Single limb squat FPPA was significantly larger for the painful leg (10.3°) compared to the symptomatic leg (7,12,31). Recent large prospective cohorts (32,33) identified risk factors for PFPS during different tasks. They reported that participants who experienced PFPS had several physical characteristics that significantly different from those of the non-injured group. The most predictive measure was a larger FPPA during Single limb landing, with angles larger than 5.2° associated with a 2.2x greater risk.

Our study proved that PFPS patients have dynamic balance deficits and decreased reach distances. These patients exhibit the lowest SEBT score in the lateral direction, in which participants must reach behind the stance leg to complete the task. We justify the lower reach distance of SEBT laterally as this task requires higher lower limb and pelvis control and put more challenges on the abductors and external rotators of the painful side. In addition, patients had excessive femoral adduction and internal rotation that increases the dynamic valgus angle and induces higher lateral patellar contact pressure which increases pain.

Results of our study were consistent with previous study **(**34**)** in spite it had smaller sample size, they found that PFPS subjects have shown considerable affection in the dynamic postural control in all directions as the current study showed when compared with normal counterparts. Similarly, other studies (15,16,35) showed that participants with PFPS had shorter distance during anterior reach of the SEBT.

There were several studies that supported our finding, while using the force platform; (13,36,37) they suggested that the static single limb standing balance performance in the PFPS group was significantly worse. The PFPS patients had higher oscillation velocity during single limb standing compared to healthy subjects.

On the other hand, there is a study that found no significant difference between the PFPS group and the control group regarding the balance (37).

Contradiction between us may be due to differences in sampling and the balance assessment tool as they conducted their study on females only, while recruited small number of participants with only 10 patients in PFPS group and 10 participants in the control group and used modified SEBT. The current study had males and females in both groups and had about double the number of sample size, in addition to dynamic balance was assess by the original SEBT in eight directions.

The current study has several limitations that should be considered in future studies. First, it was not possible to capture the rotational movements in the transverse plane (hip and tibial rotation) that occur concurrently with frontal plane motions when the knee joint's kinematics were assessed using a 2D analysis of FPPA. Hip internal rotation is an important element of the dynamic valgus. Additionally, image capturing and the angle measurement by the application is operator dependent. Finally, the study was unable to address the distal part of dynamic valgus components which is foot eversion.

It is recommended to use 3D motion analysis for kinematics assessment, especially lower quadrant (pelvis, hip, knee and ankle) kinematics and to include larger sample size of both men and women.

Conclusion:

The current study strengthened the presence of significant differences between healthy subjects and patients with PFPS in all assessed outcomes. The PFPS patients displayed larger FPPA, lower SEBT reach distances, AKPS score and increased pain severity. However, no correlations had been found between FPPA during the SLS test and the SEBT, VAS, and AKPS in PFPS patients.

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