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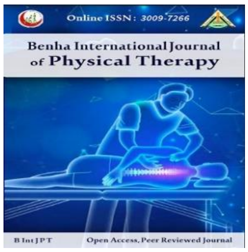

Original research

Relationship between sagittal spinopelvic parameters and Knee Joint Function, Position Sense, and Dynamic Balance in Chronic Patellofemoral Pain.

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Abstract:

Background: Patellofemoral pain (PFP) constitutes one of the most debilitating knee illnesses worldwide. The back and the lower extremities link closely; yet, however, no clarification was found to explain the fundamental and compensatory factors. **Purpose:** This study investigates the link between sagittal spinopelvic characteristics; (pelvic tilt (PT), lumbar lordosis (LL)) and knee joint function, position sense (JPS), and dynamic balance. **Methods:** Forty-two (36 females and 6 males) participants with chronic patellofemoral pain syndrome (>3 months). Their ages were (18 to 35 years old). Participants were examined for their degree of pelvic tilt, lumbar lordosis angle, knee joint function, knee joint position sense, and dynamic balance. **Results:** Pelvic tilt exhibited a moderate negative connection with JPE and a moderate positive relationship with the posterolateral direction of (Y) balance test. However, no significant link detected between pelvic tilt and AKPS, anterior, posteromedial, and composite Y-balance tests. Lumbar lordosis demonstrates a moderately negative significant association with AKPS but no with other measures. **Conclusion:** The spinopelvic parameters assessment should be considered and addressed in the assessment and management of participants with chronic PFPS for improved outcomes.

Keywords: Joint position sense, lumbar lordosis, Patellofemoral pain, pelvic tilt, spinopelvic parameters.

Introduction

Patellofemoral pain is among the most widespread disabling knee disorders worldwide that has a quite prevalent in general population with frequency reports of 22.7%, a higher prevalence in females than males by a ratio (4:1).[1] It is known for its poor long-term prognosis, which results in substantial disability levels.[2] It usually affects adolescents, active adults, athletes, and military recruits.[2] There is a high rate of recurrence (40%–56% of participants)[3] and reported ongoing symptoms by participants, who already received a rehabilitation program .[4]

The symptoms of PFP include retro-patellar aching, pain, and frequent crepitus during numerous activities such as running, squatting, and jumping, stairs ascending& descending, patellar pseudo-locking, snapping, knee stiffness, and periodical effusions.[5] Overuse, immobility,

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obesity, hereditary factors, trauma, mal-alignment of extensor mechanism of the knee, congenital incongruities of the patella, chronic synovitis, biomechanical and muscle strength deficits are only a few of numerous contributing factors for the development of PFPS [5, 6] In many cases, however, there are no clear and definite factors behind the PFP. [5]

The unique anatomical and mechanical structure of the patellofemoral joint (PFJ) exposes it to highly complex interaction between all forces that act on it .[7] It's considered a recipient of forces rather than a force production component, so it's more valuable to understand and investigate these forces rather than addressing the PFJ itself .[7] The final limb movement is produced by integrating various trajectories, velocities, and muscle activation patterns, it is essential to consider the assessment of such factors in the context of mechanical alignment, as pelvic, lower limb, and spinal postures are crucial for proper muscle action .[7]

When it comes to the connection and biomechanical interaction between the sagittal spinal parameter and the lower extremity, degenerative alterations in the knee were found to reduce its extension (and hence increase the knee flexion deformity) are counterbalanced in the spinal level as decreased lumbar lordosis.[8,9] In addition, poor dynamic balance and higher degrees of kinesiophobia were also addressed in participants with PFP.[10] Lower sagittal trunk excursion was found to be more in females with PFP during mini squats, 11 furthermore, a noteworthy correlation was found between lumbar lordosis angle and pain, and functional ability in women with PFP.[4]

Additionally, several studies advised that clinicians treating PFP participants must consider patient alignment during exercise as it affects muscle activation.[4,7] There is a certain interaction between the lower extremities and the spine; however, no explanation was found to identify which parameter precedes the other.[8, 9]

Few studies have addressed the PFP in the context of sagittal spinal alignment, hence; the current study intended to provide insight into the close association between the selected spinopelvic parameters and PFJ (the knee joint function, position sense, and dynamic balance).

Methods

Design and setting: a cross-sectional investigation was performed at the faculty of physical therapy, Cairo University, and Al_kasr Alainy Hospital from December 2023 to June 2024

Sample size calculation:

The sample size was calculated using G* power statistical (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany), based on the results of El Melhat et al., (2022). The study required a sample size of 40 participants. The calculation was performed with α=0.05, power=80%, and moderate effect size = 0.43.

Participants:

Fifty-five individuals were interviewed, 13 of them excluded (previous knee & ankle injuries (n=6), high BMI (n=4), and Knee surgery within the last 6 months (n=3)). Forty-two (36 females- 6 males) subjects were included in study diagnosed as chronic patellofemoral pain. The participants were enrolled in this study if they were eighteen to thirty-five years old with a BMI up to 30kg/m2,[12] and complained for more than 3 months of anterior or retropatellar knee pain with a minimum of two of the following activities: "Prolonged sitting, stair ascending, descending, running, hopping, squatting, kneeling /jumping, quadriceps isometric contraction, and tenderness over the medial and/or lateral facet of the patella" ***figure (1)***.[13] Participants were excluded if they had any inherited, traumatic, ligamentous, or meniscal injury or any intraarticular knee pathology, lumbar spine, hip, knee, or ankle surgery, ankle sprain, lumbar spine, hip pain within the last six months before participation, leg length discrepancy, flat or high arched feet, any neurological disorder, balance deficits due to inner ear infection or vestibular imbalance.[13]

Ethics approval and consent to participate:

The research's protocol received approval by the research ethical committee of the faculty of physical therapy, Cairo University (3/9/2023, P.T.REC/012/004778). Participants signed informed consent for their approval to participate

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in this study after a comprehensive illustration of the study's aim and procedures.

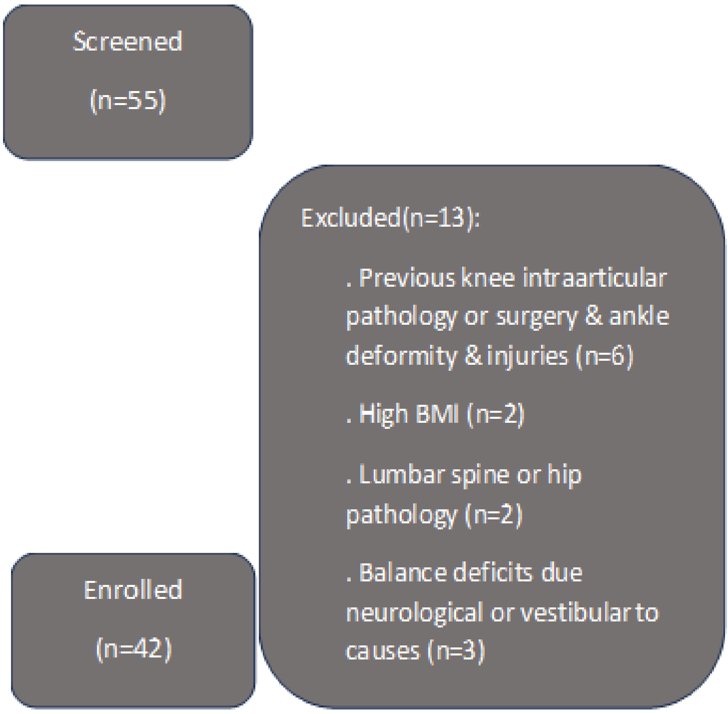

Figure (1): *Flow chart of the study procedure*

Procedures:

After enrolling the participants who met the inclusion criteria, all participants were informed of the study's aim and procedures and handed a signed informed consent for publication of their anonymous information and data. Participant characteristics, including name, age, gender, BMI, affected knee, and other investigated variables of assessment were collected in the datasheet

Caliper-based inclinometer (PALM) device (Performance Attainment Associates, St. Paul Minnesota, USA), It has an inclinometer and two caliper arms. The inclinometer is a circular in shape arc with one-degree gradations that run from 0° to 30° on either side of the midpoint.[14] It was utilized to measure the inclination of pelvic, which is the angle connecting ASIS and PSIS in relation to the horizontal line.[15] It is a proper, reliable, safe, inexpensive, and simply implemented method for measuring .[14]

Participants were asked to keep a standing position with the space between feet equal to the space between right and left acromion,[16] with equal load bearing on feet, arms crossed over the chest, and fixing their eye gaze on stationary point to limit any posture or trunk sway.[16,17]

The examiner palpated and pointed out the anterior and posterior superior iliac spines. The caliper tips of the PALM device were put and fixed against those marks and the angle of pelvic tilt was measured.[16, 17] Measurement was done in the affected lower limb. Positive degree values reflected anterior pelvic rotation (APR), whereas negative values reflected (PPR) **(Figure 2).** This process has been repeated three times and the average value was recorded in the sheet for further statistical analysis.[16,17]

Figure 2*: Measurement of pelvic tilt using a caliper-based inclinometer*

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Lumbar lordosis angle:

A bubble inclinometer (Baseline® Bubble Inclinometer, Fabrication Enterprises INC, White Plains, New York 10602, USA) was utilized to measure the lordosis angle. It's a valid and reliable tool for lumbar lordosis measurement, simple, fast economical, and radiation-free -compared to X-ray. [18]

Participants were then asked to stand in a relaxed position with their arms resting at their sides and take three deep breaths to relieve any muscular tension.[19] Bony landmarks were defined and marked with a dry-erase marker at the T12 and S1 spinous processes. The iliac crest has been used as a baseline reference for L4-L5. After locating L4-L5, the investigator continued to palpate downward to the S1 spinous process. For optimum identification of T12, the investigator located the 12th rib and followed it to the midline,[19] The inclinometer was placed according to these landmarks. To guarantee a precise zero starting point before assessing each participant, the device was calibrated using a flat surface of a wall.[19]

Each device was positioned on the landmark T12-L1 and S1-S2 and the angles were noted and summed up and the resultant was the angle of lumbar lordosis (**Figure 3**).[19] This procedure is then repeated 3 times, and the average value was recorded in the spreadsheet for further statistical analysis.

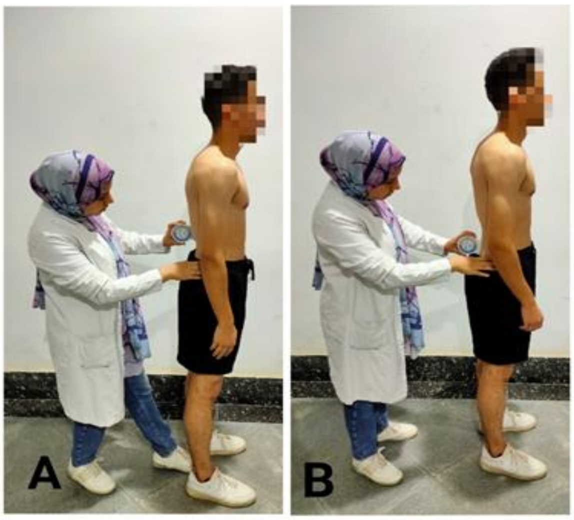

Figure 3: *measurement of lumbar lordosis (A) inclinometer on T12-L1 landmark, (B) inclinometer on S1-2 landmark*

Dynamic balance test:

The participants were then asked to stand on the central intersecting point of the 3 tape measurements adhered to the floor, with the bare foot of the affected side bearing the weight.[19, 20] Tape measurements were used to measure the affected leg length, foam brick for the application of the Y-balance test.[21]

The participant was instructed to push a rectangular foam brick as much as possible in three directions: (the anterior (ANT), posterolateral (PL), and posteromedial (PM) directions) **(Figure 4)**. Rehearsal of four trials before the actual test was done by each participant to become comfortable and familiar with test procedures and to minimize the learning effect,[10,20] during the actual test, they performed three successful repetitions in each direction in the following order (ANT, PL, and PM) with a 10-seconds rest following each trial. The three testing directions were randomized to control the order effect .[10, 20, 22]

The trial was considered invalid if the patient was unable to sustain the reaching foot contact with the reach indicator (foam brick) while in motion, the stance foot was lifted during reaching out, or lost their balance during reach out and return, kicked the reach indicator to reach further or heavily rested on the ground,[10,20] The limb length (from the anterior superior iliac spine to the medial malleolus) was used to normalize reach distance using tape measurement graded in cm ,[10,22,23] after asking the participants to do bridging exercises for 3 repetitions, for pelvic tilt adjustment.[10] YBT-LQ Score sheet was used for recording each patient's test results.[19,20]

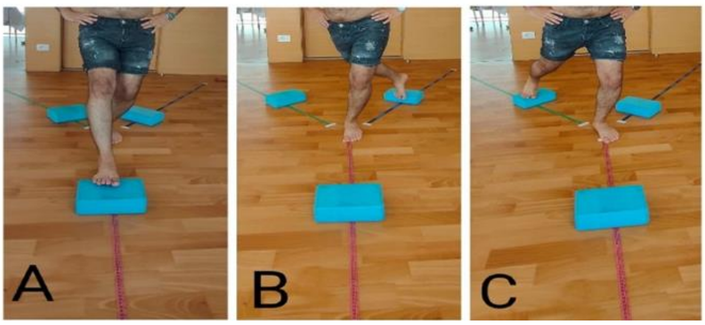

Figure 4: *Dynamic Y-balance test (A) Anterior direction, (B) Posterolateral direction, and (C) Posteromedial*

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Joint position sense of knee in closed kinetic chain:

The participants were instructed to stand with their affected limb bearing their weight; while supporting their hands on a chair for stability.[6] To help reduce passive tension in the triceps surae during the test, the heel was elevated with a 5 cm wedge, Additionally, a 20 cm height step was used to keep the untested lower limb relaxed in a mild degree of hip flexion.[6]

The bubble inclinometer was secured to the lateral aspect of the middle third of the participants' thighs using two Velcro straps to ensure its stability and good contact with the participant and was calibrated to zero using a flat surface before starting the test.[6]

In order to estimate the accurate target angle, the participants were instructed to close their eyes to block visual inputs and to actively squat until the tested knee reached the target joint angle, then to pause and hold this position for 5 seconds (**Figure 5**).[6]

A 30 degrees of knee flexion ROM in the affected knee was chosen to be the target angle, an angle with low compressive force at the PFJ**,** as the patella starts to contact with the femoral condyles at 20°**.**[24] They were instructed to return to the original position (full knee extension) after 5 seconds. Following a spoken "reposition" command, the participants were asked to accurately replicate the target joint angle and hold the position for 3 seconds until a "return" command was given. Three trials were done with 2 seconds rest between each trial**,** holding time was based on previous studies**.**[6, 25]

The angles shown on the bubble inclinometer were documented. The absolute angular error (AAE) is the most significant variable in determining JPS; AAE is the difference between the targeted and the criterion angle.[14] It obtained as follows, "AAE = [| (target position – trial 1) | + | (target position – trial 2) | + | (target position – trial 3) |]/3", the results were recorded for interpretations and statistical analysis.[6,25]

Figure 5: *Measurement of joint position sense in a closed kinetic chain*

Knee joint function through AKPS:

The Arabic version of the anterior knee pain scale (AKPS) also known as (the Kujala Scale), is sufficiently reliable, valid, and appropriate for knee function assessment**.**[26,27] There are thirteen knee-specific -self -reported items in the questionnaire. It records participants' responses regarding six activities such as prolonged sitting, squatting, walking, stairs climbing, running, and jumping.[16] Additionally, AKPS records symptoms such as limping, swelling, difficulty of weightbearing on the affected lower limb, diminished knee flexion ROM, abnormal patellar movement, muscle atrophy.[17, 27]

All participants were asked to fill their given questionnaire with their personal information and after reading each question, they were asked to circle the answer that resembles their symptoms. For bilateral symptoms, the most affected lower limb was assessed. The final score ranged between zero and 100, with the lowermost score indicated substantial disability, discomfort and pain**.**[1]

Data analysis

Descriptive statistics are being used to present the subject's demographic and collected data. The Shapiro-Wilk test was performed to examine the data is normally distributed or not. The Pearson Correlation Coefficient is being used to analyse the association between sagittal spinopelvic parameters and knee joint function, position sense, and dynamic balance. All statistical tests were deemed significant at $p < 0.05$. The

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Statistical Package for Social Sciences (SPSS) version 25 for Windows was utilized to conduct the analysis.

Results

Subject characteristics:

Forty-two participants with chronic patellofemoral pain were included. Their mean ± SD age, weight. height and BMI were 25.02 ± 3.15 years, 63.98 ± 11.73 kg, 163.79 ± 6.66 cm and 23.68 ± 2.86 kg/m² respectively. Participant characteristics are provided in table (1).

Table 1: Participant characteristics

	Mean ± SD	Maximum	Minimum
Age (years)	25.02 ± 3.15	35	19
Weight (kg)	63.98 ± 11.73	110	50
Height (cm)	163.79 ± 6.66	190	154
BMI (kg/m²)	23.68 ± 2.86	31.2	19.2
	N	%	
Sex			
Males	6	14	
Females	36	86	
Affected side			
Right	25	60	
Left	17	40	

Correlation between pelvic tilt, AKPS, JPE, and Y-balance test:

A moderately negative and significant correlation was noticed between pelvic tilt and JPE ($r = -0.372$, $p = 0.015$) and a moderate positive significant correlation with posterolateral Y balance test ($r = 0.317$, $p = 0.04$); while there was no statistically significant correlation between pelvic tilt with AKPS and anterior, posteromedial and composite Y-balance test ($p > 0.05$) **(Table 2).**

Correlation between lumbar lordosis, AKPS, JPE, and Y-balance test:

There was a moderate negative significant correlation between lumbar lordosis and AKPS ($r = -0.327$, $p = 0.034$); while no significant correlation noticed between lumbar lordosis with JPE and anterior, posterolateral, posteromedial, and composite Y-balance test ($p > 0.05$) **(Table 2).**

Table 2. Correlation between pelvic tilt lumbar lordosis and AKPS, JPE, and Y-balance test

	Pelvic tilt (degrees)		Lumbar lordosis (degrees)	
	r value	p-value	r value	p-value
AKPS	-0.090	0.569	-0.327	0.034*
JPE (degrees)	-0.372	0.015*	-0.262	0.094
Y-balance test				
Anterior	0.040	0.8	0.155	0.327
Posterolateral	0.317	0.041*	0.105	0.506

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Posteromedial	0.258	0.099	0.117	0.460
Composite score	0.238	0.130	0.155	0.327

r value: Pearson correlation coefficient; p value: Probability value, * significant at $p < 0.05$

Discussion

To our knowledge, few studies have considered the relationship between the spinopelvic parameters in the context of their effect on knee function, JPS, and dynamic balance. It would be of great value to give a clue about the effect of each variable on the lower extremity function and mechanical efficiency.[9]

Pelvic tilt and Lumbar lordosis with AKPS:

No correlation was identified between PT and AKPS, and a moderate negative correlation between lumbar lordosis and AKPS. Such finding can be explained as the greater lumbar lordosis angle is possibly leading to greater internal rotation ROM in hip joint, increasing knee valgus angle, and consequently adding more compression on the lateral articular surface of the PF joint resulting in increasing pain and thus compromising the patient's daily activities, given the fact that pain resembles a main section in the AKPS tested as a variable in our study. These findings come in agreement with the findings of other studies.[4,24] Femoral internal rotation has been reported as a deterioration factor in the affected side when compared with a symptomatic side of participants with PFP.[28]

Pelvic tilt and lumbar lordosis with knee JPS:

Regarding the knee JPS, A moderate negative significant correlation was noted between pelvic tilt and JPS and non-significant correlation between lumbar lordosis, this finding comes in accordance to a previous study,[29] which reported that quadriceps muscle strength is correlated to Knee JPS, a lower quadriceps strength in both types of muscle contraction(eccentric and concentric) in the involved lower limb, it is could be explained by the effect of the pelvic alignment of on the quadriceps muscle fibers length, and how it impacts the muscle efficiency and JPS.[29]

Our findings come from another study which reported that the JPS was markedly affected in participants with PFPS in wether in weight-bearing or non-weight-bearing positions when compared to the control group in terms of AAE,[30] however, no definite explanation was given regarding its connection with proximal pelvic alignment, nor determination of which abnormality of them (PFPS or JPS deficits) preceded at first, otherwise, different explanations were recognized as disturbances of the patellar tracking system, either due to central nervous system alterations following different afferent signals emitting from passive and active supporting structures or abnormal tissue stresses and muscle weakness .[30]

Another important explanation was recognized as the muscular proprioception deficit,[30] which comes in agreement with our study proposition that proximal pelvic alignment in the sagittal plane affects muscle activation pattern, consequently its proprioception function especially the quadriceps muscle regarding its anatomical attachment to the pelvic through the ilium and the femur. The larger degree of pelvic tilt was related to limited hip mobility,[7,31] which definitely will affect the muscle length of hip and knee joints, and consequently will alter the muscle tension - relationship and the final movement quality since there is a mechanical disturbance in the mechanoreceptors of the affected muscle, this will end up with resulting in JPS alteration.[28,31]

Pelvic tilt and lumbar lordosis with dynamic balance:

Despite of different mechanical misalignment of lumber and pelvis that accompanies PFFS, it didn't seem to have a significant impact on the dynamic balance when assessed using the Y- balance test. Despite of the moderate positive significant correlation that was found between PT and posterolateral Y-balance test, on the contrary, non-significant correlation was found with anterior, posteromedial & composite directions.

Regarding Lumbar lordosis, it also showed no correlation in all Y-balance test directions (anterior, posteromedial, posterolateral, and composite). Participants with PFPP were reported to have a greater degree of kinesiophobia that reflects the disturbance of their dynamic balance when compared to the healthy group ,[10] but this disturbance not correlated to lumber and pelvic alignment according to our findings.

On the contrary, the higher degree of knee valgus, accompanied by the increased PT and LL angles should result in more painful knees that were always reported to limit normal and efficient movement,[29] however, it can be explained as the increased knee valgus angle allowing the tested knee to have a more compensatory range of motion in the mini squat movement during the reaching trial. Giving the fact that the Y-balance test mainly evaluates the joint range of motion and neuromuscular control,[32] another explanation could be the compensations that take place on the reaching lower limb, including the excessive pelvis and trunk rotation, or the possible flexibility of the anterior thigh muscles (iliopsoas) of the reaching non-weight bearing limb.

Limitation

Limitations may affect the isolated sagittal plane parameters assessment, overlooking other factors due to body motion complexity.

Conclusion:

In light of the findings of this study, a moderate correlation was found between spinopelvic parameters and clinical outcomes of chronic PFPS, it could have a further long-term effect if not addressed and treated, especially if occurred with any other biomechanical or anatomical disturbance. The implementation of biomechanical principles must be applied through a comprehensive assessment of different spinal planes of movement.

DECLARATIONS

- **Consent to publish:** I certify that each author has given their consent to submit the work.
- **Competing interests:** None.
- **Funding:** No fund.

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