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Lower Limb Biomechanical Variables Are Indicators of the Pattern of Presentation of Patella Tendinopathy in Elite African Basketball and Volleyball Players*

Variáveis biomecânicas dos membros inferiores são indicadores do padrão de apresentação da tendinopatia patelar em atletas de elite africanos de basquetebol e voleibol

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Abstract

Objective The present study determined the pattern of presentation and severity of patellar tendinopathy (PT) and its relationship with selected biomechanical variables in elite athletes.

Methods The study involved 98 elite Nigerian basketball and volleyball players aged between 18 and 35 years. Clinical tests and ultrasound imaging were used to divide the participants into symptomatic and asymptomatic groups. Standard procedures were used to assess the quadriceps angle (Q-angle), tibial torsion, ankle dorsiflexion, hamstring flexibility, and foot posture. The Victorian Institute of Sport Assessment Questionnaire, Patellar Tendon (VISA-P) was used to assess the severity of the symptoms. The statistical analysis was performed using analysis of variance (ANOVA), and a post hoc analysis and Pearson correlation with significance level set at $p < 0.05$ were also performed.

Results Significantly lower sit-and-reach scores ($p = 0.01$), increased foot posture index score ($p = 0.01$) and reduced ankle dorsiflexion range ($p = 0.03$) were found in participants of both sexes with symptomatic PT. Higher Q-angles ($p = 0.02$) in males and tibial torsion angles ($p = 0.001$) in females were also found in the symptomatic PT groups. Symptom severity was significantly higher in the group with clinical symptoms only ($p = 0.042$), and it was significantly correlated with hamstring flexibility in both males (r = -0.618) and females (r = -0.664).

Conclusion Reduced hamstring flexibility, increased foot pronation and reduced ankle dorsiflexion range were significant in participants with symptomatic PT.

Keywords
- tendinopathy
- patella
- athletic injuries
- biomechanical phenomena
- volleyball
- basketball

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Resumo

Objetivo Este estudo determinou o padrão de apresentação e gravidade da tendinopatia patelar (TP) e sua relação com variáveis biomecânicas selecionadas em atletas de elite.

Métodos O estudo envolveu 98 jogadores de elite nigerianos de basquetebol e voleibol com idades entre 18 e 35 anos. Testes clínicos e ultrassonografia foram usados para separar os participantes em grupos sintomáticos e assintomáticos. Procedimentos padrão foram utilizados para avaliar o ângulo do quadríceps (ângulo Q), a torção da tíbia, a dorsiflexão do tornozelo, a flexibilidade dos isquiotibiais, e a postura do pé. Usou-se o questionário Victorian Institute of Sport Assessment Questionnaire, Patellar Tendon (VISA-P) para avaliar a gravidade dos sintomas nos grupos sintomáticos. A análise estatística foi realizada por meio de análise de variância (ANOVA), análise post hoc, e correlação de Pearson, com nível de significância estabelecido em $p < 0{,}05$.

Resultados Pontuações significativamente menores de sentar e alcançar ($p = 0{,}01$), aumento da pontuação do índice de postura do pé ($p = 0{,}01$), e redução da amplitude de dorsiflexão do tornozelo ($p = 0{,}03$) foram encontrados em participantes de ambos os sexos com TP sintomática. Ângulos Q ($p = 0{,}02$) maiores nos homens e ângulos de torção tibial maiores ($p = 0{,}001$) nas mulheres também foram encontrados nos grupos de TP sintomática. A gravidade dos sintomas foi significativamente maior no grupo que tinha apenas sintomas clínicos ($p = 0{,}042$), e estava significativamente correlacionada com a flexibilidade dos isquiotibiais tanto nos homens (r = -0,618) quanto nas mulheres (r = -0,664).

Conclusão A redução da flexibilidade dos isquiotibiais, o aumento da pronação do pé, e a redução da amplitude de dorsiflexão do tornozelo foram significativos em participantes com TP sintomática.

Palavras-Chave
- tendinopatia
- patela
- traumatismos em atletas
- fenômenos biomecânicos
- voleibol
- basquetebol

Introduction

Patellar tendinopathy (PT) is one of the common overuse disorders occurring especially in elite athletes who participate in sports that involve jumping, such as volleyball and basketball, hence the label "jumper's knee".[1,2] It is a major reason for interrupted training and/or competition, and may result in untimely retirement from competitive sports.[3,4] Patellar tendinopathy is a common chronic pathology of the knee, with a clinical diagnosis of pain and dysfunction in the patellar tendon.[3] It presents clinically as localized pain at the proximal attachment of the tendon to the inferior pole of the patella with a high-level load on the tendon, such as when jumping and changing direction.[3] The diagnosis is based both on clinical tests and ultrasonographic findings, with the clinical tests showing load-related pain localized to the patellar tendon, while the imaging findings (ultrasound or magnetic resonance) reveal focal thickening and hypoechoic regions in the patellar tendon.[3]

A variation in diagnostic presentations among individuals with PT has led to the documentation of different patterns of occurrence of PT.[3,5] These patterns as found in the literature include individuals that only present ultrasonographic abnormalities of tendinopathy; individuals with only clinical symptoms of tendinopathy; and individuals with both ultrasonographic abnormalities and clinical symptoms of tendinopathy.[3,5,6] Very few studies have considered every possible pattern of occurrence of PT in athletes.

It is still not understood why similar levels of tendon strain result in tendinopathy in some individuals but not in others.[7] Recent studies have attempted to identify specific lower limb biomechanical variables, such as decreased hamstring and quadriceps flexibility, excessive tibial torsion, increased quadriceps angle (Q-angle), and reduced ankle dorsiflexion range of motion, which may increase the risk of PT, and how their measured values vary in athletes who play sports that involve jumping.[1,8,9] A better understanding of the intrinsic biomechanical disposition of an individual to PT will facilitate the identification of modifiable risk factors and make a valuable contribution to the planning of preventative measures and interventions.[10] Addressing these intrinsic factors is also considered an important step in the successful rehabilitation of PT.[11]

However, there still remains a dearth of information on the relationship between these intrinsic lower limb biomechanical variables and the presentation and severity of PT in athletes, particularly among black Africans, in order to account for racial variations.[9] A concern from a global perspective is that most population-based sports injury prevalence rates are based on data reported in developed countries, while there is often paucity of data on sports injuries in other parts of the world.[12] This study was therefore designed to determine the pattern of presentation and severity of PT and its relationship with selected lower limb biomechanical variables in elite basketball and volleyball players in Lagos, Nigeria.

Materials and Methods

Participant Selection

The present study was a cross-sectional analytical survey delimited to 98 elite basketball and volleyball players between the ages of 18 and 35 years, who were recruited from the National Stadium, Teslim Balogun Stadium, and Rowe Park, in Lagos, Nigeria. The athletes in the sample were engaged in full training and had match responsibilities for at least a year before recruitment for the present study. Athletes who had had prior knee surgery and had a history of injury to the knee in the 6 months preceding the beginning of the study were excluded. The participants who had used analgesics within 3 to 6 hours prior to the assessment were also excluded.

Ethical Consideration

Ethical approval was sought and obtained from the institutional Health Research and Ethics Committee. Informed written consent was also sought and obtained from every participant prior to the commencement of the study.

Determination of Sample Size

Sample size was determined using the protocol developed by Pourhoseingholi et al (2013),[13] which yielded a sample size of 98.

Diagnosis and Grouping of Participants

A purposive sampling technique was used to recruit the sample, with each participant screened according to the inclusion criteria. The diagnosis was based on both clinical tests and ultrasonographic findings. Two clinical tests were used: the Royal London test[14] and the single-leg decline squat,[15] which were carried out by one of the researchers who was blinded to the athletes' biomechanical variable measurements and ultrasound imaging results.

Ultrasonography

A musculoskeletal ultrasound machine (Siemens Acuson, P500; Siemens Medical Solutions Inc, Malvern, Pennysylvania, USA) was used to determine the participants with focal morphological abnormalities at the patellar tendon. Patellar tendons were imaged in gray scale with an ultrasound machine equipped with a 10-15 MHz Siemens Acuson linear transducer (Siemens Medical Solutions, Inc., Malvern, PA, US). A single musculoskeletal ultrasonographer, who was blind to the athletes' clinical history, performed all imaging in the transverse and longitudinal planes. The results were categorized as normal or abnormal/tendinopathic with hypoechoic regions in both transverse and longitudinal planes).[15]

The participants were then separated into four groups according to the pattern of presentation of the patellar tendinopathy:

Group A: Participants with ultrasonographic features of tendinopathy but negative or asymptomatic in the clinical tests.

Group B (control): Participants without ultrasonographic features of tendinopathy and also negative in the clinical tests.

Group C: Participants with ultrasonographic features of tendinopathy and positive or symptomatic in the clinical tests.

Group D: Participants positive or symptomatic in the clinical tests but with no ultrasonographic features of tendinopathy.

Groups C and D were the symptomatic PT groups.

Research Protocol and Procedure for Data Collection

Permission was sought from the management of the clubs, and the aims and objectives of the study were carefully explained to both the management and the athletes, including details of the research procedure. The following biomechanical variables were measured by two of the investigators, who were blinded to the participants' clinical status and ultrasound imaging result.

***Foot posture index*:** The foot posture index (FPI) is a diagnostic clinical tool to quantify the degree to which a foot can be considered to be in a pronated, supinated or neutral position, and gives an indication of the overall posture of the foot.[16] It rates weight-bearing posture according to a series of six predefined criteria, and a combination of these scores gives an aggregate value used in estimating the overall foot posture. The participants stood in their relaxed stance position with double limb support, and were instructed to stand still with their arms by their sides and looking straight ahead. Then, they were told to take some steps and march on the spot prior to settling into a comfortable stance position. Each measurement lasted about two minutes, during which the examiner moved the subject around, making observations. If an observation could not be made (because of soft tissue swelling, for example), the examiner indicated on the datasheet that the item was not scored.[16] High positive aggregate values indicate a pronated posture; high negative aggregate values indicate a supinated overall foot posture; for a neutral foot, the final aggregate score should lie somewhere around zero.[16,17] This tool has also been investigated and deemed a reliable and valid clinical measurement tool.[16,17]

Quadriceps angle: the Q-angle was measured using a long-arm goniometer (Victory Model: V-T052, Zhenjian, China Mainland).[18] To do so, both the midpoint of the patella and the tibial tubercle were located and marked using a marker pen. A line was drawn connecting the anterosuperior iliac spine (ASIS) and the midpoint of the patella, and another line was drawn from the tibial tubercle to the midpoint of the patella. Finally, the Q-angle was measured as the value between the intersected lines using a long-arm goniometer.[18] The Q-angle measurement has been validated as a reliable and important indicator of biomechanical function in the lower extremity, and it describes the lateral force applied to the patellofemoral joint by the contraction of the quadriceps muscle.[19]

Sit-and-reach test: The V sit-and-reach test, which has been established as valid and reliable, was used to assess the flexibility of the hamstrings.[20,21] The participants sat on a mat, with legs fully stretched, a measuring line between their legs, and with the soles of their feet placed immediately behind the baseline, with the heels 8 to 12 inches apart.[20] The participants reached slowly forward as far as possible with one hand on top of the other and palms facing down.[20,21] The examiner measured the point where the tips of the middle fingers extended with a long ruler or measuring tape.[20]

Ankle active range of motion: it was assessed by goniometry, following the protocol developed by of Schulze et al.[22]

Tibial torsion angle**:** to measure the internal or external tibia torsion, the participants were placed in prone position, lying with knees flexed in a 90-degree angle. A line was drawn to bisect the posterior thigh (representing the transcondylar axis), and another line was drawn to bisect the foot (representing the transmalleolar axis).[23] A long-arm goniometer was used to measure the angle formed by these two lines. The axis of the goniometer was positioned at the midpoint of the heel. The static arm was positioned to align with the line bisecting the posterior thigh, while the movable arm was positioned in alignment with the line bisecting the foot.[23] The angle is normally between 0 to 15 degrees. A torsion angle higher than 15 degrees indicates excessive external tibial torsion, and angles lower than 0 imply excessive internal tibial torsion.[23]

Victorian Institute of Sports Assessment Questionnaire, Patellar Tendon (VISA-P): the VISA-P score, which has been found to be reliable and valid tool, was used to measure the severity of the PT.[3,20] The maximum score for an asymptomatic athlete is 100 points, the lowest theoretical score is 0, and scores lower than 80 points correspond to dysfunction.[3,24]

Data Analysis

The Statistical Package for the Social Sciences (SPSS, IBM Corp., Armonk, NY, US) software, version 22.0, was used to perform the data analysis. Analysis of variance (ANOVA) and post hoc analysis using the least significant difference (LSD) were used to determine significant differences in the measured values of the selected lower limb biomechanical variables across the different groups of PT included in the sample. Inferential statistics of the Pearson correlation coefficient was used to determine the relationship between the selected biomechanical variables and the severity of the PT. Demographic and quantitative data were expressed in terms of frequency, percentages, mean and standard deviation. Every statistical test was performed with a level of significance of 0.05 ($p < 0.05$).

Results

A total of 98 participants (63 males and 35 females) were included in the study, and 53 of them were basketball players, while the remaining 45 were volleyball players. There were no significant differences in the descriptive characteristics of the participants across the four groups. The pattern of occurrence of PT in relation with the type of sport and gender is seen in ►**Table 1**. ►**Table 2** shows the results of the ANOVA regarding the differences in the measured values of the selected lower limb biomechanical variables in male participants, which were significant ($p < 0.05$) across the groups, except for the tibial torsion angle. The post hoc analysis using LSD was performed to determine the location of the significant differences across the groups (►**Table 3**). The ANOVA was also used to test for differences in the biomechanical variables of the female participants, and the results showed that the Quadriceps angle had no significant difference across the groups ($f = 2.274$; $p = 0.10$), while the other variables were significantly ($p < 0.05$) different (►**Table 4**). ►**Table 5** shows the results of the post hoc analysis. On ►**Table 6**, a comparison of the severity of the pain symptoms in the patellar tendon between symptomatic groups C and D showed that symptom severity in group D was significantly higher than in group C ($t = 2.07$; $p = 0.042$). However, the analysis according to gender showed no significant difference in symptom severity between groups C and D. The result of the analysis using the Pearson correlation coefficient showed no significant correlation between the severity of symptoms and the selected biomechanical variables, except for hamstring flexibility, which showed a significantly strong negative correlation in both males ($r = -0.618$; $p = 0.02$) and females ($r = -0.664$; $p = 0.042$) (►**Table 7**).

Discussion

The variations in the pattern of presentation of PT observed in the present study are in line with reports by several authors that, although the clinical diagnosis is often confirmed by morphological abnormalities on the ultrasound/magnetic resonance imaging (MRI), there are still individuals with clinical symptoms who have apparently healthy/normal ultrasound imaging findings.[4,5] This has led to conflicts as to how to determine patients with PT, as some authors have actually opined that sonographic findings in PT are not always associated with pain or result in pain over time; this is an indication that imaging findings dos not always correlate with the presence of histopathological findings.[5,6,25,26] Our results showed that most of the participants were asymptomatic, especially those that had neither clinical symptoms nor ultrasonography positive results. However, the tendency for these participants to develop PT subsequently cannot be ruled out, as observed by Fredberg et al[27] that ultrasound abnormalities in asymptomatic PT could resolve, remain unchanged or expand, hence the importance of this study in identifying biomechanical variables that could indicate a predisposition to the condition.

Relationship between PT Presentation and Biomechanical Variables

Stephen et al[28] had previously reported that a high Q-angle was a significant predictor of PT, and this may explain why our results showed that the Q-angle was significantly higher in the participants with both clinical symptoms and ultrasonographic features of PT. An abnormally high Q-angle increases the lateral pull of the quadriceps muscle on the patella, causing a misalignment of the extensor mechanism, which could result in PT.[19,29] Some studies, on the other hand, found no differences in the Q-angle between controls and subjects with PT, as seen with results from our female participants, who showed no significant differences in Q-angle across the different

Table 1 Pattern of presentation of patellar tendinopathy in relation with type of sport and gender

Variables		Group A	Group B	Group C	Group D	Total
General occurrence						
	Frequency/number	16	54	13.0	15.0	98
	Percentage	16.3	55.1	13.3	15.3	100
Occurrence per gender						
Male	Frequency/number	12	31	10	10	63
	Percentage	19	49.2	15.9	15.9	100
Female	Frequency/number	4	23	3	5	35
	Percentage	11.4	65.7	8.6	14.3	100
Occurrence per type of sport						
Basketball	Frequency/number	8	27	5	13	53
	Percentage	15.1	50.9	9.4	24.5	100
Volleyball	Frequency/number	8	27	8	2	45
	Percentage	17.8	60.0	17.8	4.4	100

Notes: Group A = ultrasonographic features of tendinopathy without clinical symptoms.
Group B = no ultrasonographic features or clinical symptoms of tendinopathy.
Group C = ultrasonographic features and clinical symptoms of tendinopathy.
Group D = clinical symptoms of tendinopathy only.

Table 2 Analysis of selected lower limb biomechanical variables across the different groups of patellar tendinopathy in male participants using analysis of variance

Variables	Group A	Group B	Group C	Group D	f-value	p-value
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**		
Q-angle	12.30 ± 2.35	11.27 ± 1.60	15.20 ± 1.75	14.40 ± 2.22	14.633	0.020*
Hamstring flexibility	18.83 ± 0.94	19.65 ± 1.50	17.40 ± 0.84	18.10 ± 1.60	8.559	0.010*
Foot posture	3.88 ± 2.03	3.29 ± 2.45	8.10 ± 2.85	7.10 ± 2.88	9.418	0.010*
Ankle dorsiflexion	18.08 ± 2.02	18.45 ± 1.23	13.50 ± 1.08	14.30 ± 1.89	6.539	0.000*
Tibial torsion	20.25 ± 5.74	17.18 ± 2.90	26.70 ± 3.97	27.60 ± 3.65	1.356	0.383

Abbreviation: SD, standard deviation.
Notes: *significant at *p* 0.05; f-value should be close to 1.0 if the null hypothesis is true. A large f-value shows the Null hypothesis is false.
Group A = ultrasonographic features of tendinopathy without clinical symptoms.
Group B = no ultrasonographic features or clinical symptoms of tendinopathy.
Group C = ultrasonographic features and clinical symptoms of tendinopathy.
Group D = clinical symptoms of tendinopathy only.

groups of PT.[2,30] This could be due to the fact that women normally have higher Q-angles than men, which might have resulted in biomechanical compensatory mechanisms that have mitigated the impact of the Q-angle on the development of PT. This is corroborated by recent studies, in which the Q-angle did not present any relationship with pain intensity and functional capacity in women with patellofemoral pain syndrome (PFPS), neither was it a predictor of PT.[31,32]

Hamstring flexibility was found to be a significant factor across the different presentations of PT in the present study. Our results also showed a strong relationship between decreased hamstring flexibility and symptom severity in both male and female participants. The participants without PT had significantly higher flexibility than those with symptomatic PT, which is in line with the study by Cook and Purdam,[33] who found differences in flexibility between subjects with PT and controls. Muscular tightness predisposes to the development of lower limb overuse injuries, including PT, as decreased flexibility alters the knee-joint mechanics, thus increasing tendon strain during joint movements, resulting in tendon overload.[34] Hamstring flexibility has recently been shown also to affect the angle–torque relationship for the knee flexors, resulting in an increase in knee flexion during stance, which is a predictive variable of PT.[35] These findings suggest that interventions aimed at improving the flexibility of the thigh muscles, particularly the hamstrings, may facilitate reductions in PT symptoms and be an important component of PT preventative and

Table 3 Post hoc analysis of significant differences in biomechanical variables in male participants using the least significant difference

	Q-angle	Hamstring flexibility	Foot posture	Ankle dorsiflexion
Groups	Mean difference (*p*-value)	Mean difference (*p*-value)	Mean difference (*p*- value)	Mean difference (*p*-value)
B-C	−3.93 (0.000)*	−4.81 (0.00)*	4.95 (0.000)*	2.245 (0.000)*
B-D	−3.13 (0.000)*	1.545 (0.002)*	−3.81 (0.001)*	4.15 (0.000)*
A-C	−2.91 (0.011)*	1.433 (0.015)*	−4.23 (0.001)*	4.58 (0.000)*
A-D	−2.11 (0.011)*	0.733 (0.206)	−3.23 (0.013)*	3.78 (0.000)*
A-B	1.0175 (0.117)	0.812 (0.08)	0.59 (0.560)	0.87 (0.474)
C-D	0.80 (0.346)	−0.700(0.248)	−1.00 (0.449)	0.80 (0.239)

Notes: *significant at p 0.05.
Group A = ultrasonographic features of tendinopathy without clinical symptoms.
Group B = no ultrasonographic features or clinical symptoms of tendinopathy.
Group C = ultrasonographic features and clinical symptoms of tendinopathy.
Group D = clinical symptoms of tendinopathy only.

Table 4 Differences in the measured values of selected lower limb biomechanical variables across the different groups of patellar tendinopathy in female participants using analysis of variance

Variables	Group A	Group B	Group C	Group D	f-value	p-value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD		
Q-angle (degrees)	15.25 ± 3.60	14.48 ± 3.08	18.00 ± 2.00	17.76 ± 2.97	2.274	0.100
Hamstring flexibility	20.5 ± 0.58	21.22 ± 1.51	19.67 ± 2.52	18.60 ± 1.52	4.457	0.010*
Foot posture	4.50 ± 1.52	3.33 ± 1.77	9.00 ± 1.00	7.40 ± 1.88	11.296	0.010*
Ankle dorsiflexion	18.00 ± 1.00	18.41 ± 1.32	15.33 ± 0.58	13.20 ± 1.64	6.147	0.030*
Tibial torsion	17.75 ± 2.35	16.78 ± 3.32	26.33 ± 2.77	24.40 ± 3.07	7.753	0.001*

Abbreviation: SD, standard deviation.
Notes: *significant at p 0.05.
Group A = ultrasonographic features of tendinopathy without clinical symptoms.
Group B = no ultrasonographic features or clinical symptoms of tendinopathy.
Group C = ultrasonographic features and clinical symptoms of tendinopathy.
Group D = clinical symptoms of tendinopathy only.

Table 5 Post hoc analysis using the least significant difference to determine significant differences in biomechanical variables in the female participants

	Hamstring flexibility	Foot posture	Ankle dorsiflexion	Tibial torsion
Groups	Mean difference (*p*-value)	Mean difference (*p*-value)	Mean difference (*p*-value)	Mean difference (*p*-value)
B-C	1.55 (0.109)	3.08 (0.000)*	−5.67 (0.000)*	−9.56 (0.001)*
B-D	2.62 (0.002)*	−4.07 (0.000)*	5.21 (0.000)*	−7.62 (0.001)*
A-C	0.83 (0.482)	−4.50 (0.04)*	2.67 (0.01)*	−8.58 (0.013)*
A-D	1.90 (0.074)*	−2.90 (0.038)*	4.80 (0.000)*	−6.65 (0.027)*
A-B	0.72 (0.394)	1.1739 (0.285)	−0.41 (0.552)	0.97 (0.679)
C-D	1.067 (0.348)	1.60 (0.280)	−2.13 (0.028)*	1.93 (0.540)

Notes: *significant at p 0.05.
Group A = ultrasonographic features of tendinopathy without clinical symptoms.
Group B = no ultrasonographic features or clinical symptoms of tendinopathy.
Group C = ultrasonographic features and clinical symptoms of tendinopathy.
Group D = Clinical symptoms of tendinopathy only.

Table 6 Comparison of severity of symptoms between the two symptomatic groups (groups C and D) using the independent *t*-test

Variables	Group C	Group D	*t*-value	*p*- value
	Mean ± SD	Mean ± SD		
Male	72 ± 0.14	79 ± 2.96	1.876	0.077
Female	78 ± 1.05	80 ± 1.55	0.527	0.617
Both	73 ± 1.60	79 ± 2.35	2.07	0.04*

Abbreviation: SD, standard deviation.
Notes: *significant at *p* 0.05.
Group C = ultrasonographic features and clinical symptoms of tendinopathy.
Group D = clinical symptoms of tendinopathy only.

rehabilitation strategies.[34] Our findings also showed that there were no significant differences in hamstring flexibility between the asymptomatic groups and the group with both ultrasonographic findings and clinical symptoms of PT, especially among the females. This suggests that the reduced hamstring flexibility seen in the asymptomatic groups could predispose to tendinopathy, and, as such, preventative hamstring flexibility exercise protocols are necessary even in athletes who do not show ultrasonographic or clinical symptoms of PT.[36]

Results from previous studies have shown a reduced range of ankle dorsiflexion in individuals with PT, as seen in the results of the present study for both the male and female participants.[4,8] Coupling between ankle dorsiflexion and eccentric contraction of the calf muscles is important in absorbing lower limb forces when landing from a jump; hence, reduced ankle dorsiflexion may increase the risk of PT by impairing the athlete's ability to dissipate forces to the lower extremity, thereby causing the patellar tendon to experience greater loads.[4,10,37] Hence, one of the goals in the management of PT is to address the kinetic chain to help modify the tendon load to diminish the symptoms.[4,36] There are some indications that large external tibial torsion moments combined with deep knee flexion angles during jump and landing increase the risk of PT because excessive external tibial torsion has a dramatic effect on the kinematics of the knee.[23,38] The findings from the present study support this claim, as the female participants with PT had significantly larger external tibial torsion angles. Several compensatory options that are biomechanically inefficient choices, such as internal rotation of the hip, adduction of the foot and slight knee flexion, are adopted by these individuals, thus resulting in an increased load bearing on the part of the patellar tendon.[23,38] Neal et al[39] reported that a pronated foot is considered a potential risk factor for several lower limb overuse injuries because it may alter the load-absorbing potential of the foot and influence the onset of PT. Findings from the present study showed a relatively more pronated feet in participants with symptomatic PT compared with their counterparts in the other groups. However, in a contrary finding, de Groot et al.[15] reported that a pronated foot posture was not associated with pain or imaging abnormalities.

Symptom Severity across the Different Groups

Symptom severity was significantly higher in the group with only clinical symptoms compared with the group that had both clinical symptoms and ultrasonographic abnormalities. This supports earlier reports by some authors that ultrasonographic features of PT dos not necessarily indicate a higher risk or severity of symptoms.[4,5] This may be explained by the fact that ultrasonographic abnormalities are characteristic features of end-stage PT, which in the continuum model are less associated with pain symptoms.[40] Additionally, within each of the symptomatic groups, the results showed a tendency towards higher severity scores in females, which could be attributed to the better coping mechanisms that have been reported in male athletes.[41]

Furthermore, though not significant, the findings from the present study showed a trend towards decreased symptom severity correlating with a greater ankle dorsiflexion range and a more pronated foot, especially in women, as these findings had a moderate correlation, though not significant ($r = -0.525$; $p = 0.181$). This is in line with the works by Backman and Danielson[37] and de Groot et al.[15] who opined that a mildly pronated foot and greater ankle flexibility might better attenuate mechanical loads to the patella tendon.

Limitations of the Study

The present study did not investigate the possibility of asymptomatic individuals with histopathological features

Table 7 Relationship between severity of symptoms and the selected lower limb biomechanical variables using the Pearson correlation coefficient

Variables		Q-angle	Hamstrings flexibility	Foot posture	Ankle dorsiflexion	Tibial torsion
Symptom severity						
Male	r	0.03	−0.618	−0.130	−0.003	0.018
	p	0.899	0.021*	0.585	0.991	0.939
Female	*r*	0.159	−0.664	−0.525	−0.425	−0.120
	p	0.706	0.042*	0.181	0.294	0.778

*significant at $p < 0.05$

of PT, or the genetic basis for the pattern of presentation of PT. Future cohort studies, with larger sample sizes and recreational athletes, and investigating the genetic basis for the different presentations of PT, are recommended.

Conclusion

Our findings suggest that reduced hamstring flexibility, increased foot pronation and reduced ankle dorsiflexion range were significant in participants with symptomatic PT, but only an increase in hamstring flexibility was strongly related to a reduction in pain symptoms in both male and female participants. Hence, attempts to modify these biomechanical factors through preventative and rehabilitative protocols could help reduce the incidence of PT and its impact on athletes who play sports that involve jumping.

Conflicts of Interest
The authors have none to disclose.

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