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ORIGINAL RESEARCH

Q angle and subtalar pronation are not good predictors for pain and function in subjects with patellofemoral pain syndrome

Ângulo Q e pronação subtalar não são bons preditores de dor e função em indivíduos com síndrome da dor femoropatelar

No son buenos indicadores de dolor y de limitaciones funcionales el ángulo Q y la pronación subastragalina en los sujetos con síndrome de dolor patelofemoral

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ABSTRACT | The aim of this study was to evaluate the capability of Q angle and subtalar pronation clinical tests in predict pain and functional limitations reported by individuals with patellofemoral pain syndrome (PFPS). 31 individuals with PFPS were recruited for this study. The Anterior Knee Pain Scale questionnaire was applied to identify the functional limitations and the Visual Analogue Scale was used to identify the pain referred during the last month. Two clinical tests were performed in order to obtain the Q angle and subtalar pronation measurements. The values of the tests were entered in a multiple and linear regression models to obtain the R2 and the regression coefficients for non-continuous standardized measures, with a statistical significance set at α = 0.05. Both tests, when entered separately into the linear regression models achieved low values of pain and function prediction. On the other hand, when placed together in a multiple regression model, the tests explained 9% and 4% of the pain and functional limitations of the individuals with PFPS, respectively. Although there was an improvement in the pain and function limitation prediction when the tests were analyzed together, our findings showed that both measurement, Q angle and subtalar pronation, are not good predictors of pain and functional limitations of individuals with PFPS.

Keywords | Linear Models; Knee; Patella; Patellofemoral Pain Syndrome.

RESUMO | Este estudo teve como objetivo avaliar a capacidade dos testes clínicos de mensuração do ângulo Q e pronação subtalar em predizer a dor e as limitações funcionais referidas por indivíduos com Síndrome da Dor Femoropatelar (SDFP). 31 indivíduos com SDFP foram recrutados para este estudo. O questionário Anterior Knee Pain Scale foi utilizado para identificar as limitações funcionais, e a Escala Visual Analógica de dor foi utilizada para identificar a dor vivenciada por esses indivíduos referente ao último mês. Foram realizados dois testes clínicos estáticos, mensuração do ângulo Q e mensuração da postura da pronação subtalar. Os valores dos testes foram inseridos em modelos de regressão linear e múltipla para a obtenção do R2 e dos coeficientes de regressão para medidas não contínuas padronizadas com o nível de significância estabelecido em α=0,05. Ambos os testes quando inseridos isoladamente em modelos de regressão lineares obtiveram resultados

This study was conducted at Universidade Estadual do Oeste do Paraná, Physical Therapy Course, at the Human Movement Research Laboratory (Laboratório de Pesquisa do Movimento Humano – LAPEMH) and at Universidade Estadual Paulista "Júlio de Mesquita Filho" (FCT/UNESP), at the Biomechanics and Motor Control Laboratory.
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baixos de predição de dor e função. Por outro lado, quando inseridos conjuntamente em modelos de regressão múltipla, os testes explicaram 9% e 4% da dor e das limitações funcionais de indivíduos com SDFP, respectivamente. Embora houve melhora da predição da dor e limitação funcional quando os testes foram avaliados em conjunto, as descobertas deste estudo mostram que ambas as medidas, ângulo Q e pronação subtalar, não são bons preditores de dor e limitações funcionais de indivíduos com SDFP.
Descritores | Modelos Lineares; Joelho; Patela, Síndrome da Dor Patelofemoral.

RESUMEN | En este estudio se buscó evaluar la capacidad de las pruebas clínicas de mediciones del ángulo Q y de la pronación subastragalina como indicadores del dolor y de las limitaciones funcionales en los sujetos con Síndrome de Dolor Patelofemoral (SDFP). A los 31 participantes con SDFP del estudio se les aplicaron el cuestionario Anterior Knee Pain Scale para identificar las limitaciones funcionales y la Escala Visual Analógica para medir el dolor sentido por ellos en el último mes. Se realizó dos pruebas clínicas estáticas, la medición del ángulo Q y la de postura de pronación subastragalina. Los valores de las pruebas se insertaron en los modelos de regresión lineal y múltiple para la obtención del R2 y de los coeficientes de regresión de las medidas no constantes con el nivel estándar de significancia de un α=0,05. Ambas pruebas fueron insertadas separadamente en los modelos de regresión lineales y resultaron en índices bajos de dolor y función. En cambio, cuando insertadas juntas a los modelos de regresión múltiple, mostraron un 9% y un 4% de los dolores y de las limitaciones de los sujetos con SDFP, respectivamente. Aunque haya demostrado esta mejora, los resultados de este estudio llaman la atención para las dos medidas, la del ángulo Q y la de la pronación subastragalina, que no son buenos indicadores del dolor y de las limitaciones funcionales en los sujetos con SDFP.
Palabras clave | Modelos Lineales; Rodilla; Rótula; Síndrome de Dolor Patelofemoral.

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is characterized as a pain with an insidious onset in anterior, peri, or retropatellar regions. It is one of the main disorders which affect the knee, and it predominantly occurs in females, reaching approximately 13% of women of ages 18 to 35 years[1]. This painful condition is made worse by functional gestures such as going up or down stairs, squatting, and running, which limits those individuals' participation in sports and everyday activities (EDAs)[2].

Despite its high incidence, the set of procedures to diagnose that dysfunction has not yet been defined, the literature has not reached a consensus in regards to its etiological factors[3]. Due to that, investigations on biomechanic variables are often found, in order to identify specific musculoskeletal behaviors in individuals with PFPS, aiming to characterize that disorder[4-6]. A systematic review which investigated biomechanical factors that are associated with PFPS listed 47 studies with good quality methodologies which evaluated 523 different biomechanic parameters in total[6]. However, even with that arsenal of parameters investigating PFPS in a multifactorial fashion, there is much controversy on which parameters are found to be altered in individuals with PFPS[2,7].

In that context, a concern is observed in the field, to find static and/or dynamic kinesiological alterations which are related to or can explain pain and the functional limitations of individuals with PFPS[8–10]. For instance, Nakagawa et al. investigated, through a motion analysis system, to which extent three hip and knee kinematic variables could predicted the related pain an functional limitations in those subjects; they found a 63% prediction for pain variation and 44% for functional limitations[8]. However, the biomechanic tools that are used to verify those results are not common or usual instruments in the everyday clinical practice. 3D Motion analysis systems are very costly, and they require specialized workforce to be used; likewise, kinetic analysis systems such as force platforms and isokinetic dynamometers are common in scientific research, but they are rare in rehabilitation and diagnose clinics. Such fact reinforces the idea that clinical tests may be the most feasible option, and they must be further explored as they are easily applied and inexpensive. Due to the lack of a golden standard diagnostic tool, studies have been using sets of clinical tests to compose their inclusion criteria and to classify subjects as either PFPS-affected or not[11,3]. Clinical tests for static alterations such as Q angle and subtalar pronation posture measurements have been part of sets of tests which classify individuals as either suffering from PFPS or not[2,12]. However, there are gap

in the literature concerning how much those tests are capable of explaining pain and functional limitations that are found in those individuals. Although they are found to have good interrater reproducibility values[13-15], those clinical tests need to show their ability to predict pain and function in PFPS. That type of approach may be directly related and transported to clinical practice, as they have to be analyzed, as in this study, in order to know they can still be possibly used.

The aim of this study is to evaluate the ability from clinical tests to measure Q angle and subtalar pronation as predictors for pain and functional limitations that are reported by subjects with PFPS.

METHODOLOGY

Sample characterization

64 volunteeers with knee pain were selected to take part in the study; however, only 31 volunteers fit the inclusion criteria - all of them were identified with PFPS. In order to be included in the study, subjects were submitted to a screening process which is recommended by high-quality studies in PFPS area[7,16].

The inclusion criteria were: (1) anterior knee pain during at least two of the following activities: sitting for a prolonged time, during the squatting position or performing squats, kneeling, running, climbing up or down stairs; (2) patellar tenderness; (3) insidiously-onset symptoms for at least a month; (4) average pain level of at least three centimeters in visual analog scale (VAS), in which 0cm means no pain and 10cm, the maximum amount of pain the previous month[17]; and (5) 3 or more positive clinical signs in in the following exams: Clarke's sign, McConnell test, Nobel compression test, Waldron test, and patella in medial or lateral positions. Subjects had to necessarily fulfill all five requirements in order to be identified as having PFPS. As a non-inclusion criterion, any conditions other than PFPS were considered. They included the following: patellar subluxation or luxation events, inflammatory process in any of the lower limbs, osteoarthritis, damaged patellar tendon or meniscus, and neurological diseases. All subjects were evaluated according to the inclusion or non-inclusion criteria by two physical therapists, both with five-year experience in evaluating patients with PFPS. Subjects were only included in the study when both physical therapists agreed on the criteria. Subjects' anthropometric data are displayed in Table 1.

Table 1. Anthropometric data and characterization of subjects

Characteristics	Average	Standard deviation
Age (years)	21,90	3,67
Mass (Kg)	65,76	10,77
Height (m)	1,66	0,05
Pain*	5,32	1,37
AKPS (Final score)	72,64	9,22
Q angle clinical test (º)	22,61	2,23
Subtalar pronation clinical test (º)	8,42	2,24

* The data regarding pain were obtained through visual analog scales, which were applied at the time of the inclusion criteria. The pain the data refer to is the pain the subjects experienced over the month prior the collection of data

Experiment design and procedures

All participants were informed of procedures to be conducted, and they signed consent forms (*termo de consentimento livre e esclarecido*), according to the regulations from the Research Ethics Committee from Universidade Estadual do Oeste do Paraná, approved under official opinion no. 096/2013

An Anterior Knee Pain Scale questionnaire (AKPS) that had been validated for the Brazilian population[18] was used to evaluate the functional limitations from the subjects. AKPS is a questionnaire with 13 items, and it evaluates subjective symptoms and functional limitations that are associated with anterior knee pain. Subjects are scored in a scale from 0 to 100 points; the total maximum score of 100 indicates no functional limitation. When it is below 82, it indicates a tendency for patellofemoral disorders[19]. After answering the questionnaire, subjects were submitted to two clinical tests; Q angle and subtalar pronation measurements.

Q angle measurement was conducted in the following way: subjects lay on their backs on gurneys, with feet perpendicular to the floor. With a dermographic pencil, anatomic points were marked in the anterior superior iliac spine (ASIS), in the anterior tibial tuberosis (ATT), and also in the superior, inferior, lateral, and medial patellar edges, thus locating the patellar center. Based on those points, two lines were drawn, the first of which between ASIS and the center of the patella, and the second one between ATT and the patellar center. Following that, with the use of a universal goniometer (CARCI®), a rater marked the angle between those two lines[13]. A test is considered to be positive when Q angle value is over 20[13].

Subtalar pronation measurement (Figure 1), in turn, was performed on the following manner: with subtalar joints in neutral positions, subjects lay on their backs in gurneys, with their ankles and calcaneus bones parallel to the ground. The neutral position of the subtalar joint was determined through the palpation of the talus bone head in the medial and lateral edges of the talonavicular joint. When the talus bone could not be palpated or was felt to equally protrude to both sides, the neutral position was reconsidered. After that, leg bisection was determined through the palpation of medial and lateral leg regions, regardless of which direction the calcaneal tendon was turned to. The longitudinal calcaneal midline was also estimated through the palpation of medial and lateral calcaneal edges. Vertical lines were drawn with a ruler, in order to support the goniometer alignment. After that stage, subjects were instructed to stand on a bench; the angle between those two lines represented the subtalar joint angle[14]. Tests are considered to be positive when angles are equal to or above 8[20]. The analyzed limb for both tests was the one affected by PFPS. In case of bilateral pain, the most symptomatic one was analyzed.

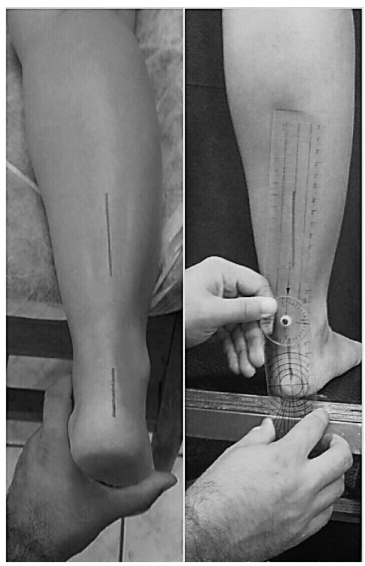

Figure 1. Static measurement clinical test of subtalar pronation posture

STATISTICAL ANALYSIS

Data were analyzed through *Statistical Package for the Social Sciences* (SPSS v. 18.0, Inc. Chicago, Illinois, USA). Descriptive statistics was used to characterize subjects, and Shapiro-Wilk confirmed data were normally distributed. Linear and forced-entry multiple regression models were executed in order to test to which extent clinical tests could predict the related pain and the functional limitations of subjects with PFPS. Associations within each multivariate model were considered to be significant when $p \leq 0.05$. The predictive power of clinical tests in each multivariate model was determined by the regression coefficients for non-continuous standardized measures (B) with confidence intervals being established at 95%. The general performance of final models was evaluated through the use of Nagelkerke's R^2, which estimates the variation of measures as explained by the model[21]. Besides that, in order to verify whether data were correctly adjusted to the model, regression analyses were conducted in order to check for the presence of outliers, colinearity, or residue. An α=0,05 significance level was considered for all analyses.

RESULTS

The average AKPS score and the average pain in subjects are reported in Table 1, with their respective standard deviations.

In regards to regression models, a linear regression was first executed for each clinical test, and then a multiple regression with both tests inserted, in order to identify the pain variation as accounted by the models. The best combination was obtained in the multiple regression model, which was capable of accounting for 9% of the pain that was reported by the subjects with PFPS. No B values were significant, and the confidence intervals - established at 95% - were long, ranging from negative to positive (Table 2).

Table 2. Linear and multiple regression models with the values that were found in subtalar pronation and Q angle clinical tests as predictor variables, and pain values as a dependent variable

Model	Variables	R2	F-ANOVA	B – (95% CI)	P-value (B)
1	Q angle	0.067	2.089	0.16 (-0.066; 0.38)	0.159
2	Subtalar pronation	0.01	0.027	0.01 (-0.21;0.25)	0.872
3	Q angle	0.09	1.406	0.20 (-0.47; 0.45)	0.678
	Subtalar pronation			0.10 (-0.14; 0.35)	0.396

Table 2. Model 1 and model 2 refer to linear regression, and model 3, to multiple regression. Three colinearity cases were identified in model 3, and subjects were discarded through the forced-entry multiple regression test. P values for the three models were p<0.05

The same regression analysis method was used to quantify to which extent clinical tests were capable of

accounting for functional limitations that were found through AKPS questionnaire. Similarly, the best prediction value was found in the multiple regression model, which was capable of accounting for 4% of functional limitations that were mentioned by subjects. As with pain, no B value was significant (Table 3).

Table 3. Linear and multiple regression models with the values that were found in subtalar pronation and Q angle clinical tests as predictor variables, and AKPS values as a dependent variable

Model	Variables	R2	F-ANOVA	B – (CI 95%)	P-value (B)
1	Q angle	0.006	0.178	-0.32 (-1.88; 1.24)	0.676
2	Subtalar pronation	0.001	0.007	0.06 (-1.49; 1.62)	0.934
3	Q angle	0.04	1.093	-0.36 (-2.12; 1.40)	0.678
	Subtalar pronation			-0.08 (-1.83; 1.66)	0.918

Table 3. Table 2. Model 1 and model 2 refer to linear regression, and model 3, to forced-entry multiple regression. P values for the three models were p<0.05

The F-ANOVA values, seen in tables 2 and 3, were lower than 1 when the tests were isolatedly inserted in the regression model, with the exception of Q angle as a pain predictor. In turn, F-ANOVA results in the multiple regression models were all above 1.

DISCUSSION

Clinical tests have been used in order to characterize individuals with PFPS; Nonetheless, no studies are found to report how much the results from those tests can account for the pain and functional limitations those individuals undergo. Subtalar joint hyperpronation and excessive Q angles are already well-established in the literature as being characteristic of PFPS[22,23]; due to that, this study investigated the ability from two clinical tests - Q angle and subtalar pronation posture measurements - to predict pain as reported through VAS and functional limitations through AKPS.

In regards to the regression models, the authors took measures to avoid type-II error, as each variable inserted in a model is suggested to be accompanied by a 15-subject sample size. As two predictor variables were used, the 31-subject sample was enough to avoid compromising the regression quality[24]. When tests with linear regressions were inserted in an isolated manner, they were shown to weak in accounting for the pain the subjects reported. For example, the subtalar pronation clinical test accounted for only 0.1% of the pain variation, which indicated that alteration may exist in PFPS, as reported by recent studies[2,25]; nevertheless it shows little relationship with those individuals' source of pain. As reported by Aliberti et al.[26], who used a photogrammetry system to identify the subtalar pronation and Q angle measures in subjects with PFPS, there is no significant association between those measures and the pain that is found in PFPS. However, results were improved when the multiple regression model was performed. Together, the tests accounted for 9% of the pain. Those results indicate that, concerning clinical tests, the association among tests can generate better results.

When the regression was performed based on functional limitations, the prediction power of tests was lower than the values obtained with pain. When isolated, the subtalar pronation test accounted for 0.1%, and the Q angle test, for 0.6% of functional limitations in those subjects, which shows that those measures, separately, are even weaker in regards to function. Multiple regression was then again capable of improving the predictive power; together, the variables accounted for 4% of functional limitations. Freedman and Sheehan[9] indicated that static measurement instruments cannot predict dynamic functions well, and as the questions in AKPS regard dynami conditions, our results corroborate the statement from that study.

As the PFPS-related literature has several clinical tests which are used as inclusion criteria, the results in this study suggest subtalar pronation and Q angle tests not be used, as they cannot predict pain and functional limitations in individuals with PFPS well.

The relationship between Q angle and PFPS is based on the theoretical model in which increased Q angles represent a source of excessive stress in the patellofemoral joint[27]. That fact causes pain, causing the PFPS symptoms[27]. Besides that, there is evidence that suggests that high Q angle values may lead to degenerated joint cartilage[28]. It must be stressed that assumption is based on the premise that Q angle represents the angle that arises from the quadriceps force vector and the direction the patellar tendon points towards[29] p<0.001. In order to test that concept, the findings from Freedman et al.[30] may back the findings in this study, as the authors compared three different ways to measure the Q angle during activities either with or without weight unloading, through magnetic resonance, with aims to determine whether the Q angle clinical test truly represents the quadriceps force application

line, and to analyze its relationship with patellofemoral kinetics. Corroborating those authors' hypothesis, the Q angle has not represented the quadriceps action line, and higher Q angle values have not been found to correlate with the lateral patellar course. Therefore, the authors suggested that static clinical Q angle measures are not related to PFPS.

Nonetheless, those results question the classic assumption that increased patellofemoral stress is a result from the patella moving towards the femoral condyle. Although it seem to be a reasonable explanation, during weight unloading activities, the contact between the patella and the femoral condyle may be a result from the excessive femoral rotation under the patella[31]. Thus, analyzing the Q angle in activities with no weight unloading (Q angle clinical test) may be a strong bias source, as the femur remains fixed throughout the measurement - as it is well established in the literature, femoral rotation may be an important factor in the event of abnormal Q angles[31].

In regards to the standing posture, a possible explanation for the findings in this study is that the theoretical model which supports the relationship between subtalar hyperpronation and individuals with PFPS[32] is based on a dynamic condition. The excessive range of subtalar pronation movement during the support phase of gait was proposed to result in excessive internal tibial rotation, which could delay or reduce the external tibial rotation range in relation to the femur. This movement is essential to allow for knee extent during the support phase; thus, as a compensatory mechanism, the femur allegedly performs excessive internal rotation, diminishing the contact area of the patellofemoral joint and consequently increasing lateral compression and joint stress, which could enable PFPS development[32]. Recently, in the study by De Oliveira Silva et al.[2], individuals with PFPS were evaluated in the dynamic and static conditions. They found that, in the dynamic condition, most subjects were found to have excessive subtalar pronation; nevertheless, the same subjects were not found to have altered clinical tests in the subtalar pronation posture.

Future studies on the use of dynamic and functional tests to characterize those individuals are necessary. Results from static tests have not been effective, unlike the ones found by biomechanical parameters in functional conditions. Another subject which must be taken into account is the popularization of biomechanical tools in the clinical context, as they have been found to yield better results. For example, a study on diagnostic accuracy was capable of diagnosing PFPS through electromyographic measurements[16]. The validation of low-cost electromyographic devices may be an excellent alternative, and it could also contribute to characterize PFPS in the clinical reality.

The lack of studies on prediction analyses for clinical tests in PFPS has limited the comparison of this study with the literature. Another limitation which can be pointed out was the non-inclusion of dynamic clinical tests in order to confirm the hypothesis that dynamic tests can better predict PFPS; however, the authors only opted for using the two classic tests which are often resorted to in the characterization of individuals with PFPS.

CONCLUSION

The results found show that clinical tests for Q angle and subtalar pronation posture measurement are not good predictors for pain and functional limitations which are reported by individuals with PFPS.

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