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Muscle strength analysis of hip and knee stabilizers in individuals with Patellofemoral Pain Syndrome

Análise da força muscular dos estabilizadores do quadril e joelho em indivíduos com Síndrome da Dor Femoropatelar

Análisis de la fuerza muscular de los estabilizadores del cuadril y de la rodilla en sujetos con Síndrome de Dolor Patelofemoral

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ORIGINAL RESEARCH

ABSTRACT | The Patellofemoral Pain Syndrome is one of the most common disorders of the knee, characterized by pain in the frontal part of the knee, which is worsened by activities that increase compressive forces on the joint. Alterations in the muscle strength of the quadriceps and hip stabilizer muscles can change patellar biomechanics, increasing joint stress and exacerbating pain symptoms. The aim of the study was to compare the strength of the hip and knee stabilizing muscles of women without and with Patellofemoral Pain Syndrome. The study included 45 women, 20 volunteers without the syndrome and 25 with Patellofemoral Pain Syndrome. Using an isometric dynamometer, the strength of the knee flexors and extensors, hip abductors and adductors, hip external rotators, medial rotators, hip flexors and hip extensors was evaluated. Women with Patellofemoral Pain Syndrome had 22% less strength of the internal rotators and 23% less strength of the knee extensors compared to healthy ones. As for the other muscle groups assessed, no differences were found. Therefore, the present study emphasizes that the quadriceps muscles are still the most affected muscle in individuals with the Patellofemoral Pain Syndrome.

Keywords | Patellofemoral Pain Syndrome; Knee Joint; Muscle Strength.

RESUMO | A Síndrome da Dor Femoropatelar é uma das desordens mais frequentes do joelho, caracterizada por dor anterior no joelho, que se agrava com atividades que aumentam as forças compressivas na articulação. Alterações no padrão de força muscular do quadríceps ou da musculatura estabilizadora do quadril poderiam alterar a biomecânica da articulação femoropatelar e, assim, aumentar o estresse articular e exacerbar sintomas de dor. O objetivo deste estudo foi comparar a força da musculatura de quadril e joelho em mulheres com e sem tal síndrome. Participaram deste estudo 45 voluntárias, sendo 20 sem e 25 com a Síndrome da Dor Femoropatelar. A força isométrica dos músculos flexores e extensores de joelho, abdutores, adutores, flexores, extensores, rotadores laterais e mediais do quadril foi avaliada por uma célula de carga adaptada. Mulheres com Síndrome da Dor Femoropatelar apresentaram redução de 22% da força dos rotadores mediais de quadril e 23% dos extensores de joelho, em comparação àquelas sem a Síndrome da Dor Femoropatelar. Não foram observadas diferenças na força isométrica entre os outros grupos musculares. Portanto, os dados deste trabalho reforçam que a musculatura quadricipital e os rotadores mediais do quadril são os mais comprometidos em indivíduos com Síndrome da Dor Femoropatelar.

Descritores | Síndrome da Dor Patelofemoral; Articulação do Joelho; Força Muscular.

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RESUMEN | El Síndrome de Dolor Patelofemoral es uno de los trastornos más frecuentes de la rodilla, caracterizado por dolor anterior en la rodilla, que se agrava con actividades que aumentan las fuerzas compresivas en la articulación. Alteraciones en el estándar de fuerza muscular del cuádriceps o de la musculatura estabilizadora del cuadril podrían cambiar la biomecánica de la articulación patelofemoral y así aumentar el estrés articular y exacerbar los síntomas de dolor. El objetivo de ese estudio fue relacionar la fuerza de la musculatura del cuadril y de la rodilla en mujeres con y sin el síndrome. Ese estudio incluyó 45 voluntarias, 20 sin y 25 con el Síndrome de Dolor Patelofemoral. La fuerza isométrica de los músculos flexores y extensores de la rodilla, abductores,

aductores, flexores, extensores, rotadores laterales y mediales del cuadril fue evaluada por una célula de carga ajustada. Mujeres con el Síndrome de Dolor Patelofemoral presentaron reducción del 22% de la fuerza de los rotadores mediales de cuadril y un 23% de los extensores de la rodilla, cuando comparadas con las sin el Síndrome de Dolor Patelofemoral. No fueron observadas diferencias en la fuerza isométrica entre los otros grupos musculares. Por lo tanto, los datos de ese trabajo resaltan que la musculatura quadricipital y los rotadores mediales del cuadril son los más comprometidos en sujetos con el Síndrome de Dolor Patelofemoral.

Palabras clave | Síndrome de Dolor Patelofemoral; Articulación de la Rodilla; Fuerza Muscular.

INTRODUCTION

The Patellofemoral Pain Syndrome (PFPS) is characterized by a pain in the frontal part of the knee, which is worsened by activities that increase the compressive strength of the patellofemoral joint (PFJ)^{1,2}, such as walking, running, jumping, squatting, going up and down stairs and long periods in sitting position³. The etiology of PFPS is considered as being multifactorial and is still not clearly defined, however, some authors relate its origins to biomechanic and structural changes of the lower limbs, such as the anteversion of the femoral neck, the increase of adduction and medial rotation of the hip and muscle imbalances of the hip and knee. It is one of the most common injuries by overuse of the lower limbs, and therefore prevalently present in physically active individuals, although also affecting sedentary ones³⁻⁵.

The quadriceps and pelvic girdle muscles play an important role in stabilizing the PFJ^{6,7}. Variations of the quadriceps muscle strength may affect the contact and the stress of the joint's cartilage, interfering with the pain pattern^{3,8}. The same way, a deficit of strength of the stabilizing muscles of the pelvis, such as the abductors and the lateral rotators of the hip, may lead to adduction and excessive medial rotation of the hip in closed kinetic chain, which may be changed by the patellar biomechanics, increasing the contact between the lateral femoral condyle and the lateral facet of the patella, triggering and exacerbating painful conditions^{6,9,10}. Some authors showed that the weakness of hip muscles is a common characteristic among women with PFPS^{11,12}. However, Piva et al.¹³ found no such differences among women with PFPS.

Thus, the objective of this study was to assess the strength of the abductors, adductors muscles, external rotators, medial

rotators, hip flexors and extensors and knee extensors among women with and without PFPS. This study was developed on the hypothesis that individuals affected by PFPS present deficit of strength of all hip and knee stabilizing muscles.

METHODOLOGY

This cross sectional study was developed in the *campus* of the Universidade de São Paulo (USP), in Ribeirão Preto, São Paulo. We selected and assessed 45 sedentary female individuals who met the inclusion criteria for the PFPS group, which were: feeling pain of at least 3 cm in the Visual Analog Scale for Pain; having at least three clinical signs indicating PFPS (among excessive subtalar pronation, patellar mobility alterations, pain during palpation of the patellar edges and pain during range of movement of the knee) and reporting pain in at least two functional activities^{9,14}. The exclusion criteria were: previous PFPS treatment and history of osteoarticular injuries in lower limbs (n=25). The Control Group consisted of healthy individuals without history of knee pain and of osteoarticular injury in lower limbs (n=20). All participants were informed about the procedures performed during the research and signed an Informed Consent Form.

All volunteers in PFPS group had unilateral pain, considering the comparison was made by using the symptomatic lower limb for the PFPS group and the dominant leg for the Control Group (Table 1).

Muscle strength measurement

The strength (kilograms *versus* force – kgf) of the abductor and adductor muscles, the external rotators, medial

rotators, hip and knee flexors and extensors was measured isometrically (Figure 1), with the use of an adapted load cell (KRATOS®).

Tem patients were selected for the analysis of the test-retest reliability of the muscle strength. Patients were positioned¹⁵ and three repetitions were performed in order to assess the strength of each tested muscle group. This same procedure was performed within intervals of three to seven days for the analysis of the test-retest reliability.

During data collection, the participants was oriented to perform the maximum voluntary contraction of the tested muscles in its greatest mechanical advantage position, with its proper segment stability¹⁵. There were performed three attempts of five seconds of contraction each for each muscle group, and a 30-second rest between them. Only the peak of force was considered for each group. The strength values were normalized by the mass of each individual.

Processing and statistical analysis of the data

Initially, an exploratory analysis of the data through measures of the central and dispersion positions (mean,

Table 1. Anthropometric data of the volunteers in the group with and without Patellofemoral Pain Syndrome

Group	Age (years) Mean±SD	Height (cm) Mean±SD	Mean±SD
With PFPS (n=20)	22.2±2.19	159.62±3.4	55.34±1.9
Without PFPS (n=25)	23.36±4.13	154.62±2.8	57.36±2.1

PFPS: Patellofemoral Pain Syndrome; SD: standard deviation

standard deviation, median, minimum and maximum value) was performed.

The comparisons were made by orthogonal contrasts, using the linear model of mixed effects (random and fixed ones), which is applies in the analysis of the data in which the answers of an individual are grouped and the assumption of independence between the observations in a same group is inadequate¹⁶. For the use of this model, it is necessary that its residues have normal distribution with zero mean and Constant variance. The adjust of the model was made by using the PROC MIXED procedure of the SAS® software, version 9.1¹⁷.

For the reliability analysis, the intraclass correlation coefficient (ICC) was used, whose values were interpreted as poorly reliable when lower than 0.40; good, between 0.40 and 0.75 and excellent when higher than 0.75¹⁸.

RESULTS

The test-retest reliability was excellent for the abductors, adductors and hip flexors and knee flexors and extensors (0.80), except for the hip medial rotators (0.36) which was poor, and good for the hip extensors and external rotators (0.48 and 0.55 respectively), as seen in Table 2.

The knee extension and hip medial rotator muscles of women with PFPS presented a significant deficit of strength when compared to those without PFPS (Table 3). No significant differences were observed for the assessed

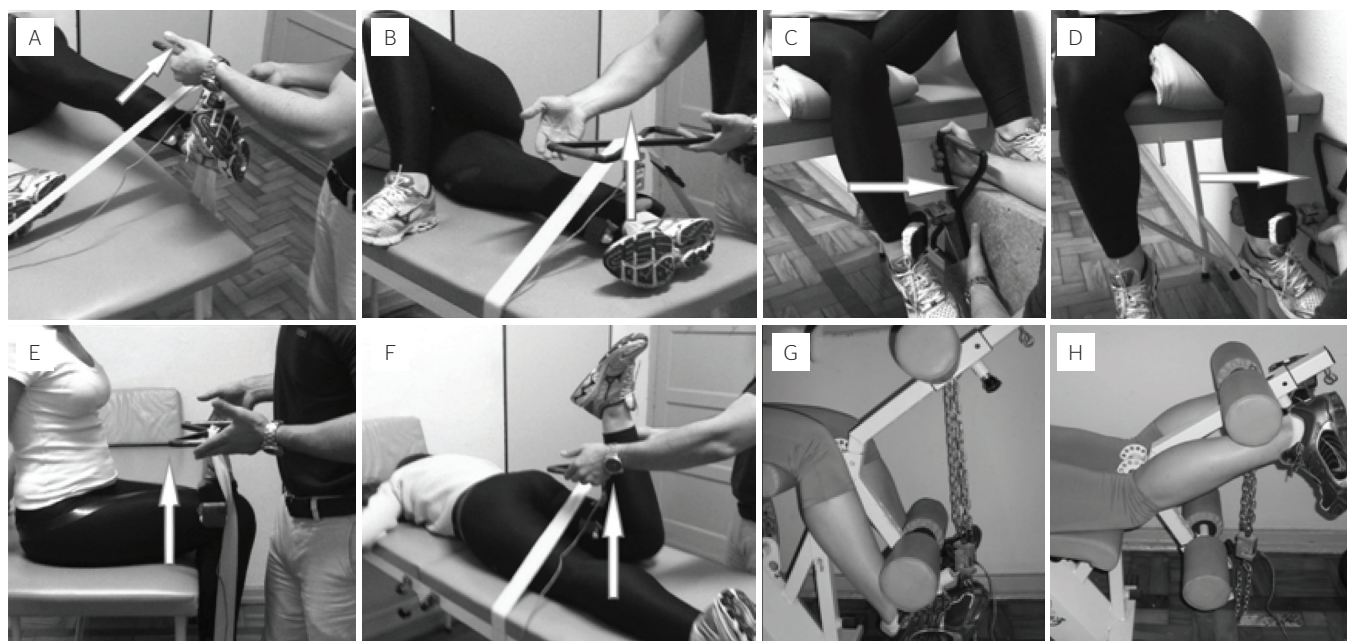


Figure 1. Position for the measurement of isometric muscle strength by the load cell of the abductor (A), adductor muscles (B), hip external rotators (C), medial rotators (D), hip flexors (E), hip extensors (F), knee extensors (G) and knee flexors (H)

muscle groups (knee flexors, abductors, adductors, external rotators, hip flexors and extensors).

DISCUSSION

Our results showed that the knee muscle extension muscles is yet the most affected one in individuals with PFPS when compared to asymptomatic ones. Despite the current tendency of focusing on hip muscles during rehabilitation^{1,11}, our data reinforce that the specific work for the quadriceps muscle must be performed since its weakness represents a risk factor in the development of PFPS⁵. These findings may positively influence rehabilitation, so that previously proposed programs are resumed¹⁹⁻²³.

Witvrouw et al.²⁴ stated that the decrease in the quadriceps strength, the main dynamic patella stabilizer in the femoral trochlea, is directly related to the incidence of femoropatellar pain and plays an important role in the beginning of PFPS. Therefore, it is indicated as a risk factor, which was also concluded in a recent systematic review⁵.

Few studies compared the quadriceps strength among women, with and without PFPS. Bolgla et al.²⁵ related the strength of the quadriceps muscle among women with PFPS and control individuals and, despite finding difference of 13% between such groups, it was not significant.

However, it was observed a relevant decrease of 22% in the strength of abductors and 21% in hip external rotators of women with PFPS. The present results reveal a significant deficit of 23% of the quadriceps strength of women with PFPS, though the hip external rotators do not present the same. The weakness of the quadriceps, already documented^{19,22,23,26}, evidences fundamental importance on the pain referred to by the patient with PFPS, once it is considered responsible for the poor patellar stabilization.

The medial rotators are also weaker, despite the poor reliability, probably due to the positioning and the difficulty of stabilization of the segment during the performance of the test (Figure 1D), which would facilitate compensation through the use of other muscle groups, such as knee extensors and evertors.

The other assessed groups did not show significant differences, with 3% for the abductors and 6% for external rotators, considerably lower values in comparison to those mentioned by Nakagawa et al.⁷, who found 18% for the abductors and 17% for the external rotators, a difference which may be justified by the fact that this study assessed not only women but also men with PFPS.

There are evidences that women with PFPS have deficit of strength of the abductor muscle, ranging from 12 to 17%, medial rotator from 5 to 36% and hip extensor from 16 to 52%, and no evidence for the deficit of hip adductors²⁷, which is not consistent with our results, since we did not find evidence that hip abductors and external rotators are weaker among women with PFPS.

Despite a deficit in the strength of the abductor and external rotator muscles among PFPS patients being expected, the present results corroborate with the ones of Piva et al.¹³, who also did not find this difference. Perhaps this could be explained by the fact that the position of test used in our study, muscles such as the gluteus maximus and the gluteus medius which are external rotators in standing position, became medial rotators in sitting position, precisely where such differences were found.

Table 2. Coefficient values of the intraclass correlation, confidence interval and measure standard deviation of the muscle strength data in test and retest

Muscle group	Test retest	95%CI	SD	MSD
Hip abductors	0.81	0.42-0.95	0.05	0.04
Hip adductors	0.82	0.31-0.95	0.03	0.02
Hip flexors	0.79	0.33-0.94	0.05	0.04
Hip extensors	0.48	-0.13-0.85	0.08	0.09
Hip internal rotators	0.36	-0.22-0.78	0.04	0.05
Hip external rotators	0.55	-0.1-0.86	0.02	0.02
Knee flexors	0.87	0.55-0.96	0.04	0.03
Knee extensors	0.78	0.35-0.95	0.14	0.11

SD: standard deviation; MSD: measure standard deviation; CI: confidence interval

Table 3. Comparison of strength deficits between muscle groups in control groups and groups with Patellofemoral Pain Syndrome (n=45; kgf)

Muscle group	PFPS Mean±SD	Control Mean±SD	Estimative of difference between means	p-value	95%CI		Deficit (%)
					LI	LS	
Hip abductors	0.20±0.06	0.21±0.05	0.001	0.982	-0,031	0,032	3
Hip adductors	0.16±0.04	0.16±0.03	0.007	0.546	-0,015	0,029	-4
Hip flexors	0.25±0.06	0.24±0.05	0.007	0.684	-0,027	0,041	-4
Hip extensors	0.33±0.09	0.39±0.10	-0.053	0.058	-0,108	0,002	16
Hip medial rotator	0.15±0.05	0.19±0.04	-0.028*	0.03	-0,054	-0,003	22
Hip external rotator	0.13±0.04	0.13±0.03	-0.012	0.229	-0,031	0,008	6
Knee flexor	0.20±0.04	0.22±0.06	-0.011	0.561	-0,05	0,028	9
Knee extensor	0.50±0.19	0.66±0.20	-0.165*	0.003	-0,271	-0,059	23

*p<0.05; PFPS: Patellofemoral Pain Syndrome; SD: standard deviation; CI: confidence interval

Despite the low and not significant deficit found, 6% for external rotators and 3% for abductors, these muscles should also be paid attention to, since other studies^{11,28} observed significant deficits which could lead to altered biomechanic patterns and, consequently, to an exacerbation of the painful condition.

Studies which assessed hip strength^{11,29} observed important deficits, around 12 and 36% of the hip muscles among individuals with bilateral PFOS and approximately 15 to 20% among individuals with unilateral pain¹¹, however when the leg in pain was compared to the healthy one, only hip abductors were observed weaker, in accordance with other studies^{12,13,30}. In the present study, non-significant deficits ranging from 3 to 16% were found for the hip muscles, except medial rotators, which had a significant 22%.

Recently, researches have been emphasizing the strengthening of the hip in the treatment of women with PFPS^{1,30}, however, our results suggest that rehabilitation programs cannot fail to include strengthening of knee extensors, considering that it is still the muscle with greater deficits of strength and represents a risk factor for PFPS⁵.

Currently, several studies have emphasized the strength pattern of hip muscles^{11-13,30-33}. Kodali et al.⁴ and Nakagawa et al.³³ emphasize that the strengthening of hip stabilizers alone would not be as effective as its association with the strengthening of knee extensors.

Magalhães et al.¹⁵ assessed the agonist-antagonist relation of the hip muscles and observed that individuals with PFPS have higher strength in the anteromedial muscle complex (adductors/ medial rotators / hip flexors), when compared to the posterolateral one (abductors/external rotators/hip extensors), which emphasizes the need for strengthening all these muscles groups.

CONCLUSION

This way, despite no all muscle groups having significant strength deficits among women with PFPS and our initial hypothesis not being confirmed, our data reinforces the need of strengthening the quadriceps muscle, which is the main muscle group stabilizer of the patella.

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