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Hip Abductors Strength and Endurance in Individuals with Recent and Long-Standing Patellofemoral Pain.

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Context : Numerous studies report deficits in hip muscle performance in individuals with patellofemoral pain (PFP). However, the exact stage at which these deficits emerge and the impact of symptom duration remain unclear.

Objective: To compare hip abductor strength and endurance based on the presence or absence of PFP and its duration.

Design : Cross-sectional study

Patients or Other Participants : 68 with PFP and 29 pain-free controls

Main Outcome Measure(s): We evaluated isometric maximal strength, isometric endurance, and dynamic endurance of hip abductors. Comparisons were made between participants with PFP and pain-free controls and among different PFP duration subgroups ($<$ 12 months, $\geq$ 12 months, $\leq$ 6 months, $>$ 24 months) and pain-free controls.

Results: Hip abductor isometric strength (% body mass [BM]) was significantly lower in the PFP group (203.8 $\pm$ 46.8) and all PFP subgroups ($<$ 12 months: 203.9 $\pm$ 57.0; $>$ 12 months: 203.7 $\pm$ 42.2) ($\leq$ 6 months: 205.1 $\pm$ 59.6; $>$ 24 months: 207.7 $\pm$ 41.9), compared to pain-free controls (254.6 $\pm$ 60.3). However, no significant differences were found between PFP subgroups. There were also no significant differences in hip abductor isometric or dynamic endurance between PFP group and pain-free controls, or between PFP subgroups and pain-free controls.

Conclusion: Hip abductors strength deficits emerge early in the course of PFP. However, further studies are needed to understand the observed lack of difference in endurance.

Introduction

Patellofemoral pain (PFP) is one of the most common knee conditions, with a prevalence of 22.7% in the general population and up to 28.9% in active adolescents and young adults (1). PFP is characterized by anterior, retro or peripatellar pain during loaded activities, such as squatting, kneeling, sitting, climbing or descending stairs, running and jumping (2,3). Individuals with PFP report significant limitations in their daily activities, during physical activities, and at work (4). PFP is 2.2 times more likely to occur in women than in men (5).

Numerous cross-sectional studies report hip muscle strength and endurance deficits in individuals with PFP compared to their unaffected side or pain-free controls. These deficits specifically concern the hip abductors, extensors, and external rotators (6–9). Prospective studies suggested that hip muscle deficits should be considered as consequences of PFP rather than risk factors (9,10). However, the relationship between hip muscle deficits and PFP symptoms is still poorly understood. Recently, Van Cant et al. (11) highlighted that hip abductor strength and endurance deficits are more pronounced in individuals with more severe and frequent symptoms of PFP. Although symptom severity appears to impact hip muscle function, the exact stage at which these deficits emerge remains unknown. Furthermore, no studies have investigated the effect of the duration of PFP symptoms on hip muscles impairments.

Previous studies have suggested that individuals with longstanding PFP tend to reduce their level of physical activity (12), which can impact muscle properties and sensory inputs (13). It could therefore be hypothesized that the decreased isometric hip muscle strength and endurance observed in individuals with PFP might stem from longstanding symptoms. This study aimed to investigate whether such changes in hip muscle function are already evident in individuals experiencing PFP for a relatively short duration or if they become more pronounced over time with persistent symptoms. Our primary objective was to assess whether hip abductor function (isometric strength and isometric and dynamic endurance) differs between individuals with recent and longstanding PFP. Additionally, we sought to compare both subgroups with pain-free controls to determine if hip abductor deficits reported in the literature are specific to longstanding PFP rather than recent PFP. Hip abductors were chosen because significant deficits have been reported in individuals with PFP (6,7,9,14). These muscles play a crucial role in controlling frontal plane motion and stabilizing the pelvis during weight-bearing activities, such as walking, running, and stair climbing, which are often associated with PFP (7). Focusing on this muscle group allows for a targeted investigation of potential impairments that may contribute to functional limitations in individuals with PFP. Our hypothesis was that individuals with recent PFP would have stronger and more enduring hip abductors in comparison to those with longstanding PFP. Furthermore, we anticipated that, in comparison to pain-free controls, these muscular deficits would be evident in individuals with longstanding PFP but not in those with recent PFP.

Methods

Study Design

This cross-sectional study investigated the impact of symptom duration on hip abductor function (strength, isometric endurance, and dynamic endurance) in individuals with PFP. Participants were divided into two groups: individuals with PFP and pain-free controls. Within the PFP group, participants were further classified twice based on symptom duration. The first classification divided participants into < 12 months and ≥ 12 months, while the second classification divided them into ≤ 6 months and > 24 months. This approach allowed the analysis of four distinct symptom periods while maintaining sufficient sample sizes in each subgroup. Each participant in the PFP group was classified into two subgroups across the two classification schemes, providing complementary insights into the relationship between symptom duration and hip abductor function. The independent variables were group (PFP vs. pain-free controls) and symptom duration (< 12 months and ≥ 12 months; ≤ 6 months and > 24 months). Dependent variables included hip abductor strength, isometric endurance, and dynamic endurance.

Participants

Participants were recruited on a voluntary basis through advertisements posted at the University, local hospital, sports halls, fitness rooms, local physiotherapy clinics, physicians' offices and the institutional mailing list of *XXX*. For the PFP group, inclusion criteria were age 18-45 years, insidious onset of symptoms for at least 4 weeks, and anterior, retro or peripatellar pain in at least two of the following activities: climbing or descending stairs, running, kneeling, maintaining a prolonged sitting position, skipping, or isometric contraction of the quadriceps. Finally, participants had to have pain on palpation of the medial or lateral face of the patella (14). Exclusion criteria for both PFP and pain-free controls included history of patella dislocation, lower limb surgery, meniscal or ligament injury of the knee in the past six months confirmed by a health professional, concomitant lower limb injury or hip pain in the last three months, as well as rheumatic, neurological or degenerative diseases and pregnancy (14). The present study was approved by the XXX (XXX registration number: XXX) and the Sectorial Rehabilitation and Social Integration Research Ethics Committee of the XXX (Registration number: XXX).

Sample size

An a priori sample size calculation was conducted to determine the minimum number of participants required to detect a clinically meaningful difference in hip abductor isometric strength with a statistical power of 80% and a significance level of 0.05. Based on data from previous studies (11, 25), it was estimated that at least 20 participants per group were necessary to achieve robust statistical power.

Procedures

Participants interested in this study were first screened by phone for eligibility. Eligibility was verified prior to the experiment by physiotherapists with over 15 years of clinical experience at the research laboratories of the Rehabilitation Sciences (XXX) and at the Centre for interdisciplinary Research in Rehabilitation and Social Integration (XXX). Participants were scheduled for an appointment, and, subsequently, the experiment was conducted. Prior to the experiment, all participants provided written informed consent. The experiment took place from February 2020 to March 2023.

Demographics and Self-Reported Function

Sociodemographic data were first collected, including age, weight, height, affected leg, dominant leg, participation and frequency of physical activity during the week, and duration of symptoms. Then, knee functional capacity was assessed using the French version of the AKPS questionnaire, a self-reported questionnaire that evaluates the impact of knee pain on various functional activities such as walking, running, and jumping (15). The reliability of the French version of the AKPS questionnaire is considered excellent (intraclass correlation coefficient [ICC] = 0.97) (16). The total score ranges from 0 to 100, with higher scores indicating lower levels of disability (15). The severity of pain was evaluated using the Numeric Pain Rating Scale (NPRS), ranging from “0” (no pain) to “10” (the most intense pain imaginable). Pain ratings were recorded for usual pain, worst pain, and worst pain experienced during physical activity, and the mean of these three scores was used for analysis (11).

Assessment of hip strength and endurance

After the general assessment, hip strength and endurance were assessed. The assessment began with participants viewing an explanatory video showing the different tests and completing a five-minute warm-up on a cycle ergometer at a perceived effort of 3-4 out of 10 on the Borg Rating of Perceived Exertion Scale (Borg RPE). The Borg RPE is a one-dimensional scale ranging from 1 ("No Effort") to 10 ("Maximum Effort") (17). Afterwards, in the PFP group, hip abductor function (isometric strength, isometric endurance and dynamic endurance) was assessed for the injured limb. In the case of bilateral symptoms, the most symptomatic limb was used. In the control group, the evaluated lower limb corresponded to the limb dominance observed in the PFP group. The dominant leg was identified by asking participants which leg they primarily used to kick a ball. Participants carried out the various tests in the same order: first the isometric strength test, then the isometric endurance test, and finally the dynamic endurance test. All tests were separated by a two-minute rest (11). Participants were instructed to report any pain during the tests, which would result in the immediate interruption of the procedure; however, no participant reported pain during or after the testing sessions.

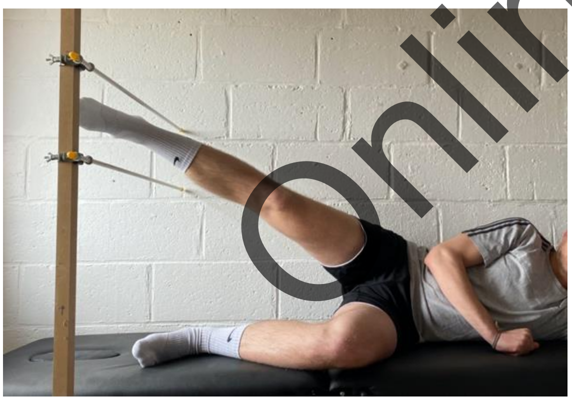
Isometric strength assessment

Figure 1 : Isometric strength assessment of hip abductors.

The maximum isometric strength of the hip abductors was measured with a hand-held dynamometer (BioFET, Dynamometer V3/ Bluetooth 4.0, Mustec, Muscle Dynamic

Technology BV), in a side-lying position on an examination table (11,18). An inelastic strap was placed around the waist to fix the trunk and avoid compensation of the upper body (19,20). A second strap was placed 5 cm above the external malleolus of the evaluated leg and was used for external fixation of the dynamometer (11). Participants were required to abduct against the dynamometer in a neutral hip position , ensuring no flexion, extension, or rotation of the hip, to standardize the testing procedure and minimize compensatory movements (19,20). After two sub-maximum trials, participants performed three trials at their maximum force. Each test was spaced by one minute of rest. Participants were asked to start the contraction slowly until they reach their maximum effort and hold the contraction for 3 to 4 seconds. For each of the three tests, a Newton value representing the maximum force performed by the participant was recorded. The highest value was then be multiplied by the lever arm (distance between the greater trochanter and the external malleolus) to give the moment of force. The result was averaged and normalized to the participant's body weight (Nm/kg) x 100 = % BM (20). This procedure has been shown to be reliable (ICCs ranging from 0.86 to 0.94) (21).

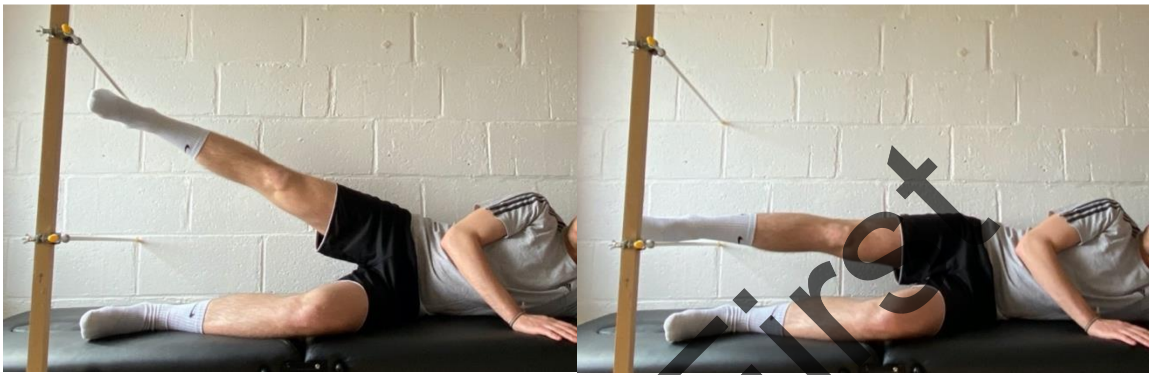
Isometric endurance assessment



<u>*Figure 2 :*</u> *Isometric endurance assessment of hip abductors.*

Isometric endurance was assessed in a side-lying position, with the non-evaluated limb positioned at 45° of hip and knee flexion and the trunk stabilized against a wall (22). Based on previous studies, the evaluated side was placed at 30° of hip abduction and full extension of the knee (23). During the isometric endurance test, the participant was asked to hold the evaluated lower limb in 30° of hip abduction for as long as possible, with an extended knee, while keeping the pelvis, shoulders, and head against the wall. A height-adjustable device with two rods was placed next to the participant at the ankle level to mark the 30° of hip abduction position. During the test, the foot of the evaluated limb had to remain in-between the two rods at the same distance from the floor. The test ended when the participant could no longer control the initial position of the limb and stepped over the lower rod. Isometric endurance performance was determined by the maximum holding time (in seconds) (23). The test demonstrates good test retest reliability (ICC = 0.73) (23).

Dynamic endurance assessment



<u>Figure 3 :</u> Dynamic endurance of hip abductors.

Dynamic endurance was also assessed in a side-lying position with the non-evaluated limb positioned at 45° of hip and knee flexion (the same position as for the isometric endurance assessment; see fig.2). The same height-adjustable device with two was placed next to the participant at the ankle level. The upper rod was adjusted to correspond to 30° of hip abduction, whereas the lower rod was placed to correspond to 10° of hip abduction. Participants were asked to perform the maximum number of hip abduction repetitions between 10° and 30°, guided by the pace of a metronome (one abduction every two seconds: 1 second of concentric movement and 1 second of eccentric movement) (23). Dynamic endurance was determined as the maximum number of hip abductions that the participant could perform. As in the isometric endurance assessment, participants were asked to indicate their subjective exertion every 30 seconds using the Borg scale (17). The test was stopped if participants were unable to perform the test in the rhythm of the metronome, or could no longer maintain the initial position of the lower limb, or if their back was no longer against the wall (23). The maximal number of successful repetitions was obtained and used for statistical analysis. The dynamic endurance test demonstrates good test retest reliability (ICC = 0.78) (23).

<u>Statistical analysis</u>

Data were collected in a Microsoft Excel (2013) spreadsheet and analysed using RStudio (Version 2023.03.1, Boston). Demographics, self-reported outcomes, isometric strength, isometric endurance, and dynamic endurance were compared between the PFP group and the pain-free group. A Shapiro-Wilk test was employed to assess the normal distribution of the variables. As data were normally distributed, independent Student t-tests for continuous variables were performed. Chi-square tests were performed for dichotomous variables.

To analyse the effect of symptom duration on muscular strength and endurance, the PFP group was divided twice into two subgroups: duration of symptoms < 12 months and ≥ 12 months, and duration of symptoms ≤ 6 months and > 24 months. This approach enabled the investigation of four distinct symptom periods while ensuring a sufficient number of participants in each subgroup. A priori sample size calculation was performed to determine the number of participants required to detect a clinically meaningful difference in [outcome] with a power of 80% and an alpha of 0.05. Based on previous studies (reference), a minimum of X participants per group was required. One-way analyse of variance (ANOVA) and Tukey-Kramer post hoc tests were performed to compare the subgroups with each other and with the healthy group. The significance level was set at 0.05.

Results

Participant demographics

Ninety-seven participants were included in the study (68 with PFP, 29 healthy). Means and standard deviations of the demographics and clinical characteristics of all participants are presented in Table 1. PFP group had an average symptom duration of 45 months (SD = 38.50) and a mean AKPS score of 78.60 (SD = 10.78). Participants with PFP and healthy controls were similar except for height (p = 0.035) and limb length (p < 0.01).

Table 1** **Baseline characteristics of PFP group and healthy group

	PFP group (n=68)	*Pain-free group (n=29)*	*P Value*
Sex (female), n(%)	48 (70)	14 (48)	0,303
Age (years)	24.15 (5.55)	23.45 (3.15)	0.527
Symptoms duration (months)	45.22 (38.50)	N/A	N/A
Weight (kg)	66.34 (13.81)	68.43 (11.50)	0.475

Height (cm)	170.10 (9.09)	174.31 (8.40)	0.035*
Limb length (meter)	0.88 (0.06)	0.94 (0.05)	< 0.01*
Sport per week (hours)	4.15 (2.24)	3.74 (2.15)	0.411
AKPS (/100)	78.60 (10.78)	N/A	N/A
NPRS	3.6 (1.1)	N/A	N/A

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; *: significant (p<0,05); AKPS: Anterior Knee Pain Scale ; NPRS : Numeric Pain Rating Scale ; N/A : not applicable*

Symptoms duration

Participants' demographics are presented in subgroups in Tables 2 and 3. Subgroups PFP >12 months and PFP >24 months were significantly different for height. Borg score for isometric and dynamic endurance were not significatively different between groups.

Table 2 Participants demographic categorized by symptoms duration (≤ 12 months and > 12 months)

	Group		
	PFP duration		
	PFP ≤ 12 months (n=21)	PFP > 12 months (n=47)	Pain-free control (n=29)
Sex (female), n(%)	11 (52)	37 (78)	14 (48)
Age (years)	25.19 (7.09)	23.68 (4.72)	23.45 (3.45)
Weight (kg)	71.00 (11.23)	64.25 (14.44)	68.43 (11.50)
Height (cm)	173.67 (9.15)	168.49 (8.69)*	174.31 (8.40)
Limb length (meter)	0.89 (0.06)*	0.87 (0.07)*	0.94 (0.05)
Sport per week (hours)	4.86 (2.41)	3.83 (2.11)	3.74 (2.15)
AKPS Score (/100)	77.43 (13.14)	79.13 (9.66)	N/A
NPRS	3.5 (1.3)	3.3 (1.3)	N/A

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; AKPS: Anterior Knee Pain Scale ; NPRS : Numeric Pain Rating Scale; N/A : not applicable; *: significant (p<0,05).*

Table 3 Participants demographic categorized by symptoms duration (≤ 6 months and > 24 months)

	Group		
	PFP duration		
	PFP ≤ 6 months (n=16)	PFP > 24 months (n=42)	Pain-free control (n=29)
Sex (female), n(%)	8 (50)	34 (79)	14/15 (48)
Age (years)	26.44 (7.74)	23.81 (4.81)	23.45 (3.15)
Weight (kg)	70.52 (10.67)	63.01 (12.01)	68.43 (11.50)
Height (cm)	172.59 (8.89)	168.00 (8.57)*	174.31 (8.40)
Limb length (meter)	0.88 (0.06)*	0.87 (0.06)*	0.94 (0.05)
Sport per week (hours)	4.75 (2.43)	3.58 (1.92)	3.74 (2.15)
AKPS Score (/100)	77.12 (14.56)	79.12 (9.82)	N/A
NPRS	4.2 (1.2)	3.2 (1.1)	N/A

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; AKPS: Anterior Knee Pain Scale ; NPRS : Numeric Pain Rating Scale ; N/A : not applicable ; *: significant (p<0,05).*

Comparison between PFP group and pain-free control group

Hip abductor isometric strength (%BM) of the PFP group was significantly lower compared to the pain-free control group ($p < 0.01$, mean difference (95% [CI]) = -50.83 [-83.89; -17.77]). Isometric endurance and dynamic endurance were not significatively different between the two groups (Table 4).

Table 4 **Strength, isometric and dynamic endurance measures of PFP group and healthy group**

	Group			
	PFP (n = 68)	*Healthy group (n = 29)*		*P Value*
	Mean (SD)		**Mean difference (95% CI)**	
% BM	203.79 (46.79)	254.62 (60.28)	-50.83 [-83.89 ; -17.77]	P < 0.01*
Isometric endurance (sec)	178.10 (58.59)	198.48 (67.21)	- 20.38 [-58.77; 18.01]	0.136
Dynamic endurance (reps)	62.25 (27.41)	76.14 (40.33)	-13.89 [-35.08; 7.30]	0.052

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; %BM = (N.m / Kg) x 100; Reps: repetitions; *: significant (p<0,05).*

Comparison between PFP subgroup (≤ 12 months), PFP subgroup (> 12 months) and healthy group

The two PFP subgroups (≤ 12 months and >12 months) had lower hip abductors maximal strength (% BM = 203.92 [56.97] and 203.73 [42.16], respectively) than the pain-free control group (% BM = 254.62 [60.28]) ($p < 0.01$), but there was no significant difference between the two subgroups. Isometric endurance and dynamic endurance were not significatively different between the subgroups and between the subgroups and the pain-free controls (Table 5).

Table 5 **Strength, isometric and dynamic endurance measures categorized by pain duration (≤ 12 months and > 12 months)**

	Group			
	PFP duration			P-Value
	PFP ≤ 12 months (n=21)	PFP > 12 months (n=47)	Healthy control (n=29)	
% BM	203.93 (56.97)	203.73 (42.16)	254.62 (60.28)	P < 0.01*
Isometric endurance	175.43 (61.64)	179.23 (57.82)	198.48 (67.21)	0.322

(sec)				
Dynamic endurance (reps)	60.24 (29.24)	63.15 (26.83)	76.14 (40.33)	0.143

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; %BM = (N.m / Kg) x 100; Reps: repetitions; *: significant (p<0,05).*

Comparison between PFP subgroups (≤ 6 months and > 24 months) and healthy group

Compared to the pain-free control group (% BM = 254.62 [60.28]), both PFP subgroups (≤ 6 months and > 24 months) had lower hip abductor maximal strength (% BM = 205.12 [59.61] and 207.67 [41.92], respectively) ($p < 0.01$). However, there was no significant difference in hip abductor maximal strength between the two PFP subgroups. Isometric endurance and dynamic endurance were not significatively different between the subgroups and the healthy controls (Table 6).

***Table 6* Strength, isometric and dynamic endurance measures of PFP subgroup (≤ 6 months), PFP group (>24 months) and healthy control group**

	Group			
	PFS duration			P-Value
	PFS ≤ 6 months (n=16)	PFS > 24 months (n=42)	Healthy control (n=29)	
% BM	205.12 (59.61)	207.67 (41.92)	254.62 (60.28)	P < 0.01*
Isometric endurance (sec)	163.19 (47.55)	180.74 (59.00)	198.48 (67.21)	0.301
Dynamic endurance (reps)	56.16 (25.49)	63.35 (26.56)	76.14 (40.33)	0.199

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; %BM = (N.m / Kg) x 100; Reps: repetitions; *: significant (p<0,05).*

Discussion

Summary of the findings

The aim of this study was to determine the potential impact of pain duration on hip abductor function (strength, isometric, and dynamic endurance). Firstly, our findings revealed that individuals with PFP exhibited significantly weaker hip abductor maximal strength compared to healthy individuals. This result aligns with prior research highlighting hip abductor strength deficits in individuals with PFP (6,7,9,14). These differences were evident across all symptom duration subgroups (≤6 months, ≤12 months, >12 months, and >24 months), indicating that hip abductor strength deficits appear early in the course of PFP and remain stable over time, even up to 2 years after the onset of symptoms. Finally, no differences in isometric or dynamic endurance were detected between individuals with PFP and pain-free controls, nor among the subgroups based on symptom duration. These results indicate that while strength deficits are evident, endurance does not seem to be affected by PFP duration or presence.

Hip abductor strength deficit

Previously, Rathleff et al. (9) hypothesized that decreased isometric muscle strength of the lower extremity in individuals with PFP could be a consequence of longstanding PFP. This assumption was verified in a recent cross-sectional study concerning quadriceps muscle strength (24). The authors reported that both severity and duration of anterior knee pain were inversely associated with quadriceps function and self-reported function. Moreover, a combination of high severity and long duration of symptoms caused further deficits in quadriceps function. In light of our results, it does not seem to be the case for the hip abductor muscles. While Van Cant et al. (11) reported that hip abductor strength deficits are more pronounced in individuals with PFP who present with higher pain severity and frequency, we found that the duration of symptoms does not influence hip abductor muscle function. Studies, involving patients with PFP, spanning both severe and less severe symptoms, are needed to determine whether the interplay between symptom severity and duration influences strength and endurance, or whether only symptom severity influences hip abductor strength. In our study, functional capacity was assessed using the AKPS questionnaire and was similar between subgroups, which may suggest that symptoms severity was comparable despite different durations of symptoms.

Hip abductors endurance in individuals with PFP

Although the aims of the present study did not specifically target this question, our results restart the debate on the presence or not of a lack of hip muscle endurance in individuals with PFP. Contradictory findings are reported in the literature. Several authors found no difference in hip abduction endurance between individuals with and without PFP (25,26), while others reported that females with PFP have lower hip abduction endurance (22). The cause of the current discrepancies among studies is unclear, but could stem from interindividual variability in the performance of muscular endurance testing (27). For example, a coefficient of variation around 50% was reported for static performance (27). Such substantial variability would require larger samples in order to limit the type 1 error. In addition, as Nunes et al. (25)

argued, inconsistencies among studies may underscore the multifactorial nature of PFP and the possibility of subgroups within individuals with PFP, some exhibiting hip abductors muscle endurance deficits while other do not. In this respect, our results emphasize that PFP subgrouping based on symptoms duration do not allow to report differences in isometric and dynamic endurance across subgroups.

Clinical perspectives

Clinical practice guidelines for PFP management recommend multimodal intervention programme including gluteal and quadriceps strengthening, patellar taping and an emphasis on education and activity modification (28,29). Concerning gluteal strengthening, a systematic review highlighted that in the early stages of rehabilitation (first 6 months), hip focused exercise may improve pain and function to a greater extent than knee targeted exercise, particularly in patients where knee targeted exercises may exacerbate symptoms (30). Our results support the notion that exercise prescription in the early stage (< 6 months) should prioritize proximal rehabilitation to enhance hip strength, as deficits are evident within the initial months following symptom onset. Moreover, literature reports that a substantial proportion of people with PFP experience an unfavorable outcome over 12 months and that longer duration of PFP symptoms (>4 months) is the most consistent prognostic factor of poor outcome (31). The present study highlights that hip abductor deficits are present at an early stage of the onset of PFP symptoms, which suggests it might be important to target these deficits as quickly as possible in order to decrease the risk of recurrent or persistent PFP symptoms. Additional studies are needed to better understand this specific period of the condition.

Limitations

The present study has some limitations. Firstly, the assessors were not blinded to participants' symptom duration, which may have introduced biases during the evaluations. However, bias might have been minimized by using standardized protocols and external fixation. Secondly, recruitment of individuals with recent PFP was more complicated than recruiting patients with longstanding PFP. These small sample sizes in recent PFP subgroups (n = 16 and 21 for PFP ≤ 6 months and ≤ 12 months, respectively) compared to longstanding PFP subgroups (n= 47 and 43 for PFP > 12 months and > 24 months, respectively) may have influenced our results. Additionally, the inclusion criterion of a minimum symptom duration of 4 weeks was selected to capture participants at the early stages of PFP while avoiding variability associated with very acute symptoms. However, this choice may have influenced the subgroup analyses, as it remains unclear how early deficits in hip abductor function develop or evolve over time. Future studies using a longitudinal design could provide deeper insights into these aspects. Lastly, this study included mixed-sex samples, and although different muscle groups were assessed, sex differences in neuromuscular function have been reported in PFP research (6,7,9,14). This factor may have introduced variability into our findings and should be further investigated in future studies with sex-stratified analyses.

Conclusion

Although individuals with PFP presented with lower hip abductor strength compared to pain-free controls, the present study did not find significant differences in hip abductor strength between individuals with recent and long-standing PFP. These findings suggest that hip abductors strength deficits are present early in the course of PFP.However, further studies are needed to understand the relationship between PFP and hip abductor endurance.

References

1. Smith BE, Selfe J, Thacker D, Hendrick P, Bateman M, Moffatt F, et al. Incidence and prevalence of patellofemoral pain: A systematic review and meta-analysis. Screen HR, editor. PLOS ONE. 2018 Jan 11;13(1):e0190892.
2. Thomeé R, Augustsson J, Karlsson J. Patellofemoral Pain Syndrome: A Review of Current Issues. Sports Med. 1999;28(4):245–62.
3. Thomeé R, Renström P, Karlsson J, Grimby G. Patellofemoral pain syndrome in young women. I. A clinical analysis of alignment, pain parameters, common symptoms and functional activity level. Scand J Med Sci Sports. 1995 Aug;5(4):237–44.
4. Glaviano NR, Kew M, Hart JM, Saliba S. DEMOGRAPHIC AND EPIDEMIOLOGICAL TRENDS IN PATELLOFEMORAL PAIN. Int J Sports Phys Ther. 2015 Jun;10(3):281–90.
5. Boling M, Padua D, Marshall S, Guskiewicz K, Pyne S, Beutler A. Gender differences in the incidence and prevalence of patellofemoral pain syndrome: Epidemiology of patellofemoral pain. Scand J Med Sci Sports. 2010 Oct;20(5):725–30.
6. Van Cant J, Pineux C, Pitance L, Feipel V. Hip muscle strength and endurance in females with patellofemoral pain: a systematic review with meta-analysis. Int J Sports Phys Ther. 2014 Oct;9(5):564–82.
7. Powers CM, Witvrouw E, Davis IS, Crossley KM. Evidence-based framework for a pathomechanical model of patellofemoral pain: 2017 patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester, UK: part 3. Br J Sports Med. 2017 Dec;51(24):1713–23.
8. Prins MR, van der Wurff P. Females with patellofemoral pain syndrome have weak hip muscles: a systematic review. Aust J Physiother. 2009;55(1):9–15.
9. Rathleff MS, Rathleff CR, Crossley KM, Barton CJ. Is hip strength a risk factor for

patellofemoral pain? A systematic review and meta-analysis. Br J Sports Med. 2014 Jul;48(14):1088–1088.

10. Herbst KA, Barber Foss KD, Fader L, Hewett TE, Witvrouw E, Stanfield D, et al. Hip Strength Is Greater in Athletes Who Subsequently Develop Patellofemoral Pain. Am J Sports Med. 2015 Nov;43(11):2747–52.

11. Van Cant J, Declève P, Garnier A, Roy JS. Influence of symptom frequency and severity on hip abductor strength and endurance in individuals with patellofemoral pain. Phys Ther Sport. 2021 May;49:83–9.

12. Blønd L, Hansen L. Patellofemoral pain syndrome in athletes: a 5.7-year retrospective follow-up study of 250 athletes. Acta Orthop Belg. 1998 Dec;64(4):393–400.

13. Canu MH, Fourneau J, Coq JO, Dannhoffer L, Cieniewski-Bernard C, Stevens L, et al. Interplay between hypoactivity, muscle properties and motor command: How to escape the vicious deconditioning circle? Ann Phys Rehabil Med. 2019 Mar;62(2):122–7.

14. Nunes GS, Barton CJ, Serrão FV. Hip rate of force development and strength are impaired in females with patellofemoral pain without signs of altered gluteus medius and maximus morphology. J Sci Med Sport. 2018 Feb;21(2):123–8.

15. Kaux JF, Buckinx F, Borheim S, Van Beveren J, Dardenne N, Bruyère O. Adaptation interculturelle du questionnaire Kujala Anterior Knee Pain Scale pour les patients francophones. J Traumatol Sport. 2018 Mar;35(1):62.

16. Buckinx F, Bornheim S, Remy G, Van Beveren J, Reginster Jy, Bruyère O, et al. French translation and validation of the "Anterior Knee Pain Scale" (AKPS). Disabil Rehabil. 2019 Apr 24;41(9):1089–94.

17. Muyor JM. Exercise Intensity and Validity of the Ratings of Perceived Exertion (Borg and OMNI Scales) in an Indoor Cycling Session. J Hum Kinet. 2013 Dec 18;39:93–101.

18. Waiteman MC, Garcia MC, Briani RV, Norte G, Glaviano NR, De Azevedo FM, et al. Can Clinicians Trust Objective Measures of Hip Muscle Strength From Portable Dynamometers? A Systematic Review With Meta-analysis and Evidence Gap Map of 107 Studies of Reliability and Criterion Validity Using the COSMIN Methodology. J Orthop Sports Phys Ther. 2023 Nov;53(11):655–72.

19. Ireland ML, Willson JD, Ballantyne BT, Davis IM. Hip strength in females with and without patellofemoral pain. J Orthop Sports Phys Ther. 2003 Nov;33(11):671–6.

20. Bazett-Jones DM, Cobb SC, Huddleston WE, O'Connor KM, Armstrong BSR, Earl-Boehm JE. Effect of Patellofemoral Pain on Strength and Mechanics after an Exhaustive Run. Med Sci Sports Exerc. 2013 Jul;45(7):1331–9.

21. Kollock RO, Onate JA, Van Lunen B. The reliability of portable fixed dynamometry during hip and knee strength assessments. J Athl Train. 2010 Aug;45(4):349–56.

22. Van Cant J, Pitance L, Feipel V. Hip abductor, trunk extensor and ankle plantar flexor endurance in females with and without patellofemoral pain. J Back Musculoskelet Rehabil. 2017 Mar 2;30(2):299–307.

23. Van Cant J, Dumont G, Pitance L, Demoulin C, Feipel V. TEST-RETEST RELIABILITY OF TWO CLINICAL TESTS FOR THE ASSESSMENT OF HIP ABDUCTOR ENDURANCE IN HEALTHY FEMALES. Int J Sports Phys Ther. 2016 Feb;11(1):24–33.

24. Kim S, Park J. Influence of Severity and Duration of Anterior Knee Pain on Quadriceps Function and Self-Reported Function. J Athl Train. 2022 Aug 1;57(8):771–9.

25. Nunes GS, de Oliveira Silva D, Pizzari T, Serrão FV, Crossley KM, Barton CJ. Clinically measured hip muscle capacity deficits in people with patellofemoral pain. Phys Ther Sport Off J Assoc Chart Physiother Sports Med. 2019 Jan;35:69–74.

26. McMoreland A, O'Sullivan K, Sainsbury D, Clifford A, McCreesh K. No deficit in hip isometric strength or concentric endurance in young females with mild patellofemoral

pain. Isokinet Exerc Sci. 2011 May 6;19(2):117–25.
27. El Ahrache K, Imbeau D, Farbos B. Percentile values for determining maximum endurance times for static muscular work. Int J Ind Ergon. 2006 Feb;36(2):99–108.
28. Willy RW, Hoglund LT, Barton CJ, Bolgla LA, Scalzitti DA, Logerstedt DS, et al. Patellofemoral Pain: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability and Health From the Academy of Orthopaedic Physical Therapy of the American Physical Therapy Association. J Orthop Sports Phys Ther. 2019 Sep;49(9):CPG1–95.
29. Bolgla LA, Boling MC, Mace KL, DiStefano MJ, Fithian DC, Powers CM. National Athletic Trainers' Association Position Statement: Management of Individuals With Patellofemoral Pain. J Athl Train. 2018 Sep 1;53(9):820–36.
30. Lack S, Barton C, Sohan O, Crossley K, Morrissey D. Proximal muscle rehabilitation is effective for patellofemoral pain: a systematic review with meta-analysis. Br J Sports Med. 2015 Nov;49(21):1365–76.
31. Lankhorst NE, van Middelkoop M, Crossley KM, Bierma-Zeinstra SMA, Oei EHG, Vicenzino B, et al. Factors that predict a poor outcome 5–8 years after the diagnosis of patellofemoral pain: a multicentre observational analysis. Br J Sports Med. 2016 Jul;50(14):881–6.

Table 1 **Baseline characteristics of PFP group and healthy group**

	PFP group (n=68)	*Pain-free group (n=29)*	*P Value*
Sex (female), n(%)	48 (70)	14 (48)	0,303
Age (years)	24.15 (5.55)	23.45 (3.15)	0.527
Symptoms duration (months)	45.22 (38.50)	N/A	N/A
Weight (kg)	66.34 (13.81)	68.43 (11.50)	0.475
Height (cm)	170.10 (9.09)	174.31 (8.40)	0.035*
Limb length (meter)	0.88 (0.06)	0.94 (0.05)	< 0.01*
Sport per week (hours)	4.15 (2.24)	3.74 (2.15)	0.411
AKPS (/100)	78.60 (10.78)	N/A	N/A
NPRS	3.6 (1.1)	N/A	N/A

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; *: significant (p<0,05); AKPS: Anterior Knee Pain Scale ; NPRS : Numeric Pain Rating Scale ; N/A : not applicable*

Table 2 Participants demographic categorized by symptoms duration (≤ 12 months and > 12 months)

	Group		
	PFP duration		
	PFP ≤ 12 months (n=21)	PFP > 12 months (n=47)	Pain-free control (n=29)
Sex (female), n(%)	11 (52)	37 (78)	14 (48)
Age (years)	25.19 (7.09)	23.68 (4.72)	23.45 (3.45)
Weight (kg)	71.00 (11.23)	64.25 (14.44)	68.43 (11.50)
Height (cm)	173.67 (9.15)	168.49 (8.69)*	174.31 (8.40)
Limb length (meter)	0.89 (0.06)*	0.87 (0.07)*	0.94 (0.05)
Sport per week (hours)	4.86 (2.41)	3.83 (2.11)	3.74 (2.15)
AKPS Score (/100)	77.43 (13.14)	79.13 (9.66)	N/A
NPRS	3.5 (1.3)	3.3 (1.3)	N/A

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; AKPS: Anterior Knee Pain Scale ; NPRS : Numeric Pain Rating Scale; N/A : not applicable; *: significant (p<0,05).*

Table 3 Participants demographic categorized by symptoms duration (≤ 6 months and > 24 months)

	Group		
	PFP duration		
	PFP ≤ 6 months (n=16)	PFP > 24 months (n=42)	Pain-free control (n=29)
Sex (female), n(%)	8 (50)	34 (79)	14/15 (48)
Age (years)	26.44 (7.74)	23.81 (4.81)	23.45 (3.15)
Weight (kg)	70.52 (10.67)	63.01 (12.01)	68.43 (11.50)
Height (cm)	172.59 (8.89)	168.00 (8.57)*	174.31 (8.40)
Limb length (meter)	0.88 (0.06)*	0.87 (0.06)*	0.94 (0.05)
Sport per week (hours)	4.75 (2.43)	3.58 (1.92)	3.74 (2.15)
AKPS Score (/100)	77.12 (14.56)	79.12 (9.82)	N/A
NPRS	4.2 (1.2)	3.2 (1.1)	N/A

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; AKPS: Anterior Knee Pain Scale ; NPRS : Numeric Pain Rating Scale ; N/A : not applicable ; *: significant (p<0,05).*

Table 4** **Strength, isometric and dynamic endurance measures of PFP group and healthy group

	Group			
	PFP (n = 68)	*Healthy group (n = 29)*		*P Value*
	Mean (SD)		**Mean difference (95% CI)**	
% BM	203.79 (46.79)	254.62 (60.28)	-50.83 [-83.89 ;-17.77]	P < 0.01*
Isometric endurance (sec)	178.10 (58.59)	198.48 (67.21)	- 20.38 [-58.77; 18.01]	0.136
Dynamic endurance (reps)	62.25 (27.41)	76.14 (40.33)	-13.89 [-35.08; 7.30]	0.052

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; %BM = (N.m / Kg) x 100; Reps: repetitions; *: significant (p<0,05).*

***Table 5** Strength, isometric and dynamic endurance measures categorized by pain duration (≤ 12 months and > 12 months)*

	Group			
	PFP duration			P-Value
	PFP ≤ 12 months (n=21)	PFP > 12 months (n=47)	Healthy control (n=29)	
% BM	203.93 (56.97)	203.73 (42.16)	254.62 (60.28)	P < 0.01*
Isometric endurance (sec)	175.43 (61.64)	179.23 (57.82)	198.48 (67.21)	0.322
Dynamic endurance (reps)	60.24 (29.24)	63.15 (26.83)	76.14 (40.33)	0.143

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; %BM = (N.m / Kg) x 100; Reps: repetitions; *: significant (p<0,05).*

***Table 6** Strength, isometric and dynamic endurance measures of PFP subgroup (≤ 6 months), PFP group (>24 months) and healthy control group*

	Group			
	PFS duration			P-Value
	PFS ≤ 6 months (n=16)	PFS > 24 months (n=42)	Healthy control (n=29)	
% BM	205.12 (59.61)	207.67 (41.92)	254.62 (60.28)	P < 0.01*
Isometric endurance (sec)	163.19 (47.55)	180.74 (59.00)	198.48 (67.21)	0.301
Dynamic endurance (reps)	56.16 (25.49)	63.35 (26.56)	76.14 (40.33)	0.199

*Participant characteristics[mean (SD)] SD: Standard Deviation; PFP: patellofemoral pain; %BM = (N.m / Kg) x 100; Reps: repetitions; *: significant (p<0,05).*