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Anteromedial versus posterolateral hip musculature strengthening with dose-controlled in women with patellofemoral pain: A randomized controlled trial

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A B S T R A C T

Objective: To compare the effectiveness of adding anteromedial versus posterolateral hip musculature strengthening to knee strengthening in women with patellofemoral pain (PFP).
Design: Randomized controlled trial.
Setting: University physiotherapy clinic.
Participants: Fifty-two women with PFP were randomized to receive either anteromedial (AMHG) or posterolateral (PLHG) hip musculature strengthening.
Main outcome measures: The primary outcomes were pain intensity by the numeric pain rating scale and function by the Anterior Knee Pain Scale in six weeks. Secondary outcomes were pain and function at six months, global perceived effect at six weeks and six months, pain in step down, isometric torque of abductors, adductors and hip rotators measured with hand-held dynamometer, and dynamic knee valgus by step down in six weeks.
Results: Both groups showed improvement in primary outcomes; however, no differences were found between groups in pain intensity and function in six weeks and the secondary outcomes. Group x time interaction found superior gains in abductor strength in the PLHG and increase in the strength of the adductors and internal rotators in AMHG.
Conclusion: There was no difference between the addition of anteromedial or posterolateral hip musculature strengthening to knee strengthening in improving pain and function in women with PFP.

Introduction

Patellofemoral pain (PFP) is characterized by peripatellar or retropatellar pain, exacerbated in activities that increase the compressive loads on the patellofemoral joint, such as running, going up and down stairs, and squatting (Crossley et al., 2016). The prevalence is around 22.7% in the general population, and women are more often affected than men (Smith et al., 2018). The etiology of PFP is not well defined and is described as multifactorial (Powers, Witvrouw, Davis, & Crossley, 2017; Willy et al., 2019).

Alteration of the tibiofemoral and patellofemoral kinematics with consequent reduction of the patellofemoral contact area, patellar maltracking, and increased patellofemoral stress are the main biomechanical factors associated with PFP (Almeida et al., 2016; Chen & Powers, 2014; Dos Reis et al., 2015; Powers et al., 2017; Salsich & Perman, 2007). The weakness of the hip muscles, especially abductors, extensors, and external rotators, underlies these changes (Almeida et al., 2016; Earl & Hoch, 2011; Rathleff, Rathleff, Crossley, & Barton, 2014). But previous research has found that hip muscles weakness could actually be a consequence rather than a cause for PFP (Neal et al., 2019; Rathleff et al., 2014).

Exercises are widely recommended for patients with PFP (Collins et al., 2018; van der Heijden, Lankhorst, van Linschoten, Bierma-Zeinstra, & van Middelkoop, 2015; Willy et al., 2019),

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highlighting the benefits of combining the strengthening of the hip and knee muscles to improve pain and functional capacity (Collins et al., 2018; Lack, Barton, Sohan, Crossley, & Morrissey, 2015; Nascimento, Teixeira-Salmela, Souza, & Resende, 2018; Willy et al., 2019). The preference for selectively strengthening the posterolateral hip musculature theoretically aims to reduce excessive adduction and medial rotation of the hip during activities, which contributes to improving the tibiofemoral and patellofemoral joint kinematics and decreases stress in the patellofemoral joint; however, studies have failed to prove this theory (Esculier et al., 2018; Ferber, Kendall, & Farr, 2011; Rabelo et al., 2017). A recent systematic review (Nascimento et al., 2018) verified the effects of adding hip strengthening to knee strengthening on PFP and included 14 clinical trials. All performed abductor, extensor, and external rotator (posterolateral) hip strengthening and showed more effective than knee strengthening alone for decreasing pain and improving activity. But only one study (Razeghi, Etemadi, Taghizadeh, & Ghaem, 2010) also included adductor, flexor, internal rotator (anteromedial) and posterolateral hip strengthening plus knee strengthening; the latter also found results superior to isolated knee strengthening.

To date, there are no studies verifying the effects of selective addition of flexor, adductor, and internal rotator hip strengthening to knee strengthening in patients with PFP, which raises the question of whether the reported clinical improvement occurred by selectively adding the posterolateral hip musculature or as a result of the summation effect of exercises (Lack et al., 2015; Nascimento et al., 2018; Willy et al., 2019). Therefore, the aim of this study was to compare the effects of adding anteromedial versus posterolateral hip musculature strengthening to knee strengthening in women with patellofemoral pain.

Materials and methods

Design

This study was a randomized controlled trial, two-arm, parallel group, with a blinded assessor, carried out between May 2017 and March 2018. This study was approved by the Research Ethics Committee with protocol number 2.055.614 and registered prospectively in the ClinicalTrials.gov database (NCT03163290). All participants signed the written consent form. Data were reported following the guidelines of the Consolidated Standards of Reporting Trials (Schulz, Altman, Moher, & CONSORT Group, 2010), Template for Intervention Description and Replication (Hoffmann et al., 2014) and Consensus on Exercise Reporting Template (Slade, Dionne, Underwood, & Buchbinder, 2016).

Settings and participants

The data were collected at the University Physiotherapy Clinic of the Physiotherapy Department, Federal University of Ceará. The participants were recruited from the university hospital and orthopedic and rheumatology clinics. This study included women, aged 18–35 years, practicing physical activity at least three days per week and 30 min per day, with patellofemoral pain characterized by peri- or retropatellar pain and reproduced in at least two of the following criteria: ascending or descending stairs, crouching, kneeling, sitting for a long time, isometric contraction of the quadriceps, jumping, running, or palpation of the lateral and/or medial facet of the patella; with insidious onset and lasting at least three months; measuring at least three on the numerical pain scale (NPS) during the last week (maximum = 10 points); and a maximum of 86 points on the Anterior Knee Pain Scale (AKPS; maximum = 100 points) (Watson, Propps, & Ratner, 2005). For patients with bilateral pain, the worst knee was included. Exclusion criteria were previous surgery on the hip, knee, ankle, and/or spine; a history of patellar dislocation; clinical evidence of knee instability; evidence of edema; or other muscle, tendon, or joint injuries to the lower limb with an effect on the presenting clinical condition or to perform the prescribed exercises.

Randomization

A researcher not involved in the data collection generated randomization codes using Random Allocation Software (1.0.0 version) in the proportion of 1:1. These codes were placed in sealed and opaque envelopes and numbered consecutively. Patients were divided into two groups: posterolateral hip muscle strengthening group (PLHG) and anteromedial hip muscle strengthening group (AMHG).

Interventions

The therapeutic protocol was performed individually, supervised, with an average duration of 60 min and a frequency of twice a week for 6 weeks at the university physiotherapy clinic. Four physiotherapists with 1–5 years of experience were responsible for the interventions. There were four initial meetings for training and standardization. The materials for the interventions were ergometric bicycles, ankle weight cuffs (1–15 kg), elastic bands, flex ring, stretchers, and chairs.

Table 1 presents the intervention protocols in the PLHG and AMHG. Both groups performed a warm-up via a stationary bike, lower limb muscle stretching and knee extension, and squat exercise. The exercise in open kinetic chain (knee extension) and closed kinetic chain (squat exercise) were allowed in the full range of motion (0–90°); however, in the presence of knee pain (NPS > 3 during exercise), we reduced the amplitude in the open kinetic chain by avoiding the terminal extension (45–90°) and closed kinetic chain by avoiding the deeper knee flexion (0–45°). The progression of amplitude was achieved, mediated by pain (Holden, Rathleff, Jensen, & Barton, 2018; Powers, Ho, Chen, Souza, & Farrokhi, 2014).

The PLHG added three strengthening exercises: hip abduction in a side-lying position, clam with elastic resistance, and hip external rotation with elastic resistance (Fukuda et al., 2012; Selkowitz, Beneck, & Powers, 2013). The AMHG added three strengthening exercises: hip adduction in a side-lying position, flex ring squeeze in a side-lying position, and hip internal rotation with elastic resistance (Delmore, Laudner, & Torry, 2014).

The exercise intensity was monitored by the physical therapist, as determined by the participants' ability to complete three sets of 8–12 repetitions for a given exercise and a Borg Rating of Perceived Exertion (RPE) of 60–80% (American College of Sports Medicine, 2009). The load was increased by 2%–10% in a single session when the patients were able to perform 14 or more complete repetitions in the last sets or presented perceived exertion less than 60% in the RPE (American College of Sports Medicine, 2009). If the patient reported a worsening of symptoms with increased load, we increased the number of repetitions in each set without increasing the load, with the ultimate goal of reaching 60–80% in the RPE. A resting period was established of 30 s between sets and 2 min between exercises (Holden et al., 2018). The total workload (TW) in arbitrary units was calculated in each exercise with the following formula: TW = sets x repetitions x load x RPE, for exercises using weights (knee extension, squat, and hip abduction and adduction in a side-lying position); and TW = sets x repetitions x RPE for exercises with elastic and flex ring (clam, flex ring squeeze, and hip external and internal rotation). The TW of the posterolateral and

Table 1
Intervention protocols.

Both groups
•Warm-up via a stationary bike, 5 min
• Supine hamstring stretch passive, 1 × 45 s
• Supine abductors and adductors stretch passive, 1 × 45 s
• Side-lying quadriceps stretch passive, 1 × 45 s
• Standing wall stretch for triceps surae, 1 × 45 s
• Seated knee extension strengthening, 3 x 8–12* with 60–80% in RPE
• Squatting, 3 × 8–12* with 60–80% in RPE
Posterolateral Hip Group (PLHG)
• Hip abduction in side-lying, 3 × 8–12* with 60–80% in RPE
• Clam with elastic resistance, 3 × 8–12* with 60–80% in RPE
• Hip external rotation with elastic resistance, 3 × 8–12* with 60–80% in RPE
Anteromedial Hip Group (AMHG)
• Hip adduction in side-lying, 3 × 8–12* with 60–80% in RPE
• Flex ring squeeze in side-lying, 3 × 8–12* with 60–80% in RPE
• Hip internal rotation with elastic resistance, 3 × 8–12* with 60–80% in RPE

Abbreviations: RPE, Borg Rating of Perceived Exertion.
*If the patient reported a worsening of symptoms with increased load, we increased the number of repetitions in each set without increasing the load, with the ultimate goal of reaching 60–80% in the RPE.

anteromedial hip musculature was calculated by summing the TW of the three hip exercises in each group (Singh, Foster, Tod, & McGuigan, 2007).

Adherence to treatment was assessed by the total number of treatment sessions performed in six weeks with 12 sessions equaling 100%.

Outcome measures

Two physiotherapists, each one with seven years of experience, were responsible for the assessments. Both were blinded to the distribution of the treatment groups.

Primary outcomes were NPS and AKPS after six weeks. Secondary outcomes were NPS and AKPS after six months, global perceived effect (GPE), in six weeks' and six months' follow-up, frontal plane projection angle (FPPA), NPS during the step-down test, and hip muscle strength (abductors, adductors, and external and internal rotators) in a six-week follow-up.

Pain intensity was assessed by the mean of the last week by the NPS ranging from 0 (no pain) to 10 (maximum possible pain) (Crossley, Bennell, Cowan, & Green, 2004). Function was assessed by the Brazilian version of the AKPS, which ranges from 0 (worst possible) to 100 (best possible) (Da Cunha et al., 2013). The GPE has 11 points ranging from negative five points (extremely worse), zero (no change) to five points (fully recovered) (Kamper, Maher, & Mackay, 2009).

The dynamic knee valgus was assessed by the FPPA during the forward step-down test filmed with a digital camera (60 fps) (Almeida et al., 2016). FPPA was measured by the angle formed by the intersection of the lines between the anterior superior iliac spine at the center of the femoral condyles and the center of the malleoli at the center of the femoral condyles. The step height was normalized to 10% of the height of each participant (Almeida et al., 2016). All participants performed two training tests and three valid tests, with a 5-s cadence for each test. The FPPA was calculated at the time of the heel touch on the ground by the Kinovea® Video Editor program. We considered a positive value as dynamic valgus and a negative value as dynamic varus (Almeida et al., 2015, 2016). Pain intensity was also collected during the forward step-down test.

Hip muscle strength was assessed using an hand-held dynamometer (Nicholas Manual Muscle Test, Lafayette® Instrument Company). A belt was used to stabilize the hip and a dynamometer to eliminate the interference of the evaluator's strength, and maximum strength was measured for 5 s, with 30 s of rest between repetitions and 1 min between muscle groups. The strength of the abductor, adductor, and external and internal rotator hip muscles was evaluated in this sequence, following parameters published in previous studies (Almeida, Rodrigues, De Freitas, & De Paula Lima, 2017; Magalhães et al., 2010). Peak isometric torque was measured by multiplying force, gravity acceleration, and lever arm and normalized by body weight (Nm/kg): [force (kg) x 9.81 x lever arm (m)]/body mass (kg). The lever arm length was measured from the superior aspect of the greater trochanter to 5 cm above the lateral joint line of the knee for abduction and adduction; lateral joint line of the knee to 5 cm above the lateral malleolus for internal rotation, and medial joint line of the knee to 5 cm above the medial malleolus for external rotation. Previously, an intra-rater reliability analysis was performed to assess the strength of the four hip muscles in 10 women with no knee complaints. The tests showed excellent reliability, with an intraclass correlation coefficient of 0.94–0.97.

Sample size

The sample size calculation was performed *a priori* considering a difference of two points for the pain intensity measured by the NPS, with an estimated standard deviation of 1.8 points (Khayambashi, Fallah, Movahedi, Bagwell, & Powers, 2014), and a difference of 10 points in the AKPS, with an estimated standard deviation of 11.7 points (Fukuda et al., 2010). A statistical power of 80%, α of 5%, and possible sample loss of 15% were considered for the sample size: $n = [2 \text{ x } DP^2 \text{ x } (Z\alpha_{/2} + Z_\beta)^2]/d^2$ (http://www.sample-size.net/sample-size-means/). Therefore, 26 patients were required in each group, or 52 patients combined.

Statistical analysis

The normality of distribution of the data was determined by using the Shapiro-Wilk test. Participants characteristics were reported using descriptive statistical tests. The independent *t*-test were used to treatment adherence.

The between-group differences and their respective confidence intervals were calculated using mixed linear models. These longitudinal models of analyses incorporate terms for treatment groups (PLHG and AMHG), time (baseline, six weeks, and six months), and interactions terms of group versus time. The regression coefficients from the interaction group versus time were equivalent to the estimates of the between group differences of the effects of interventions. The analysis adjusted the between-group differences considering all moments of evaluation. Statistical analysis was performed following the principles of the intention-to-treat analysis, and multiple imputation was used for missing data.

Between-group differences in terms of TW were also calculated via mixed linear models that utilized the interaction of time (each of the 12 sessions) versus group (PLHG and AMHG).

For all statistical analyses, SPSS 20.0 software (Statistical Package for the Social Sciences Inc., Chicago, IL, USA) was used, with a significance of $\alpha \leq 0.05$.

Results

Seventy-eight potential participants were contacted, but 26 did not meet the eligibility criteria (Fig. 1). Of the 52 participants selected and assessed in baseline, 46 (88.5%) completed the assessments at the six-week and six-month follow-up. All losses in the follow-up occurred due to the lack of response in attempts to contact patients via telephone, messaging services, and email.

Table 2 shows the anthropometric, demographic, and clinical characteristics of the two groups at baseline. Treatment adherence was high in both groups. Of the 12 proposed sessions, the PLHG had an average of 10.3 ± 3 sessions, and the AMHG had an average of 11.3 ± 2.3 sessions (mean difference = −1.0, 95% CI = −2.5 − 0.52, P = 0.19).

Table 3 presents the clinical outcomes of the two groups assessed at baseline, six weeks, and six months and the adjusted mean difference and confidence intervals.

Both groups showed improvement in primary outcomes; however, no significant between-group differences were found in pain intensity (mean difference = 0.53, 95% CI = −0.55 − 1.63, P = 0.33) and function (mean difference = −0.34, 95% CI -1.16 − 1.01, P = 0.89) in six weeks (Table 3).

In secondary outcomes, no significant between-group differences were found in pain intensity and function after six months, GPE at six weeks and six months, and dynamic knee valgus and pain during the step-down test in six weeks (Table 3).

Difference was found in the group × time interaction in favor of PLHG for abductor strength and in favor of AMHG for adductor and internal hip rotator strength (Table 3).

In the within-group comparison, AMHG showed significant improvement in all variables analyzed, except for dynamic knee valgus. The PLHG group did not show a significant improvement in adductor strength and dynamic knee valgus (Table 4).

Table 2
Demographic and anthropometric characteristics.

	PLHG (N = 26)	AMHG (N = 26)
Age (years)	24.9 ± 4.6	24.9 ± 5.0
Body Mass (kg)	61.2 ± 9.6	63.9 ± 9.6
Height (m)	1.63 ± 0.7	1.60 ± 0.7
Body Mass Index (kg/m^2)	23.0 ± 3.5	24.8 ± 3.6
Unilateral/Bilateral symptoms	8/18	11/15
Symptoms duration (months)	50.8 ± 38.9	47.3 ± 39.6
Analgesic use in last month (%)	Yes 6 (23%) No 20 (77%)	Yes 5 (19%) No 21 (81%)

Abbreviations: PLHG, posterolateral hip group; AMHG, anteromedial hip group.

The TW was similar in the two groups during the sessions (Fig. 2), with no significant differences between the groups (Table 5). No adverse events occurring during the exercise sessions.

Discussion

This is the first randomized controlled trial to verify the effects of adding selective strengthening of the anteromedial versus posterolateral hip musculature to knee strengthening in women with PFP. The results demonstrate that the two groups showed improvement in pain intensity, function, GPE, and muscle strength; however, there were no differences between groups. The two

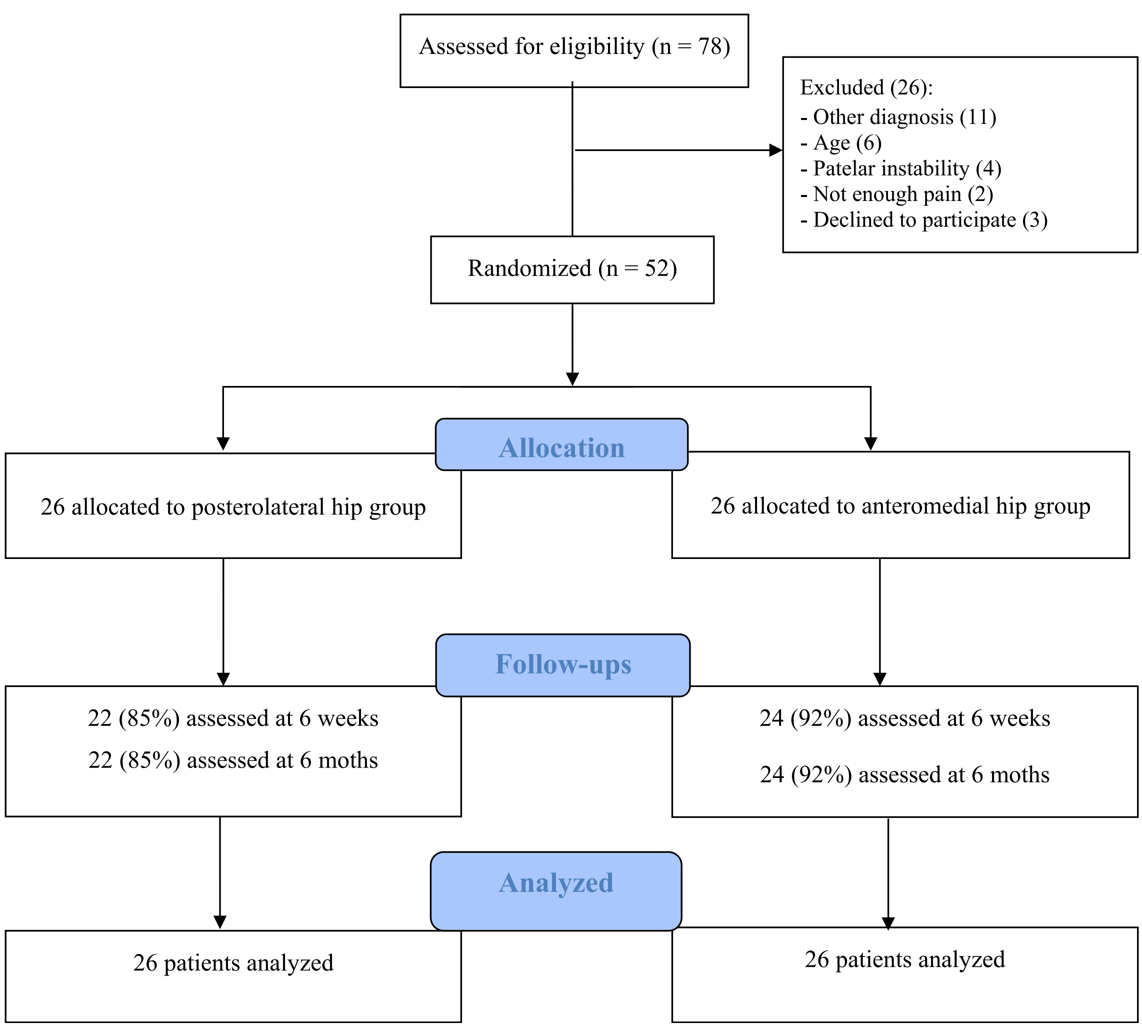

Fig. 1. Participant flow diagram.

Table 3
Primary and secondary outcomes at baseline, 6 weeks and 6 months.

Outcomes	PLHG N = 26	AMHG N = 26	Adjusted Differences between Groups (CI 95%)	P Value Between Groups	P Value - Group by Time Interaction
Pain Intensity (0–10)					
Baseline	5.27 (2.01)	5.04 (1.58)	0.23 (−0.85–1.32)	0.67	0.71
6 Weeks*	1.15 (2.32)	0.57 (1.17)	0.53 (−0.55–1.63)	0.33	
6 Months	2.76 (2.12)	2.84 (2.37)	−0.07 (−1.16–1.01)	0.89	
AKPS (0–100)					
Baseline	68.50 (8.21)	65.96 (10.03)	2.53 (−2.80–7.87)	0.34	0.47
6 Weeks*	79.11 (9.73)	79.46 (9.44)	−0.34 (−5.68–4.99)	0.89	
6 Months	80.31 (9.51)	78.69 (10.99)	1.61 (−3.72–6.95)	0.55	
Global Perceived Effect (-5/+5)					
Baseline	−1.03 (2.56)	1.11 (2.42)	0.07 (−1.01–1.16)	0.88	0.68
6 Weeks	2.73 (1.92)	3.15 (1.22)	−0.50 (−1.59–0.59)	0.36	
6 Months	1.81 (1.72)	2.19 (1.76)	−0.38 (−1.47–0.71)	0.48	
Pain - Step Down (0–10)					
Baseline	2.46 (2.5)	2.11 (2.30)	0.34 (−0.69–1.38)	0.51	0.77
6 Weeks	0.53 (1.02)	0.38 (1.13)	0.15 (−0.88–1.19)	0.77	
Hip Abductor Strength (Nm/kg)					
Baseline	1.01 (0.21)	1.05 (0.28)	−0.03 (−0.16–0.10)	0.62	0.02
6 Weeks	1.26 (0.23)	1.18 (0.22)	0.09 (-.06–0.20)	0.29	
Hip Adductor Strength (Nm/kg)					
Baseline	0.57 (0.17)	0.50 (0.19)	0.07 (−0.3–0.17)	0.17	<0.001
6 Weeks	0.61 (0.20)	0.70 (0.17)	−0.09 (−0.19–0.01)	0.07	
Hip External Rotation Strength (Nm/kg)					
Baseline	0.42 (0.12)	0.41 (0.09)	0.01 (−0.05–0.07)	0.69	0.21
6 Weeks	0.52 (0.14)	0.47 (0.08)	0.04 (−0.02–0.10)	0.17	
Hip Internal Rotation Strength (Nm/kg)					
Baseline	0.53 (0.13)	0.45 (0.14)	−0.07 (−0.001–0.15)	0.52	0.01
6 Weeks	0.57 (0.12)	0.58 (0.13)	−0.01 (−0.08–0.07)	0.83	
Frontal Plane Projection Angle (°)					
Baseline	7.59 (6.53)	7.0 (5.18)	0.58 (−2.61–3.79)	0.71	0.91
6 Weeks	7.09 (5.50)	6.72 (5.99)	0.37 (−2.83–3.57)	0.82	

*Primary outcomes.
Abbreviations: PLHG, posterolateral hip group; AMHG, anteromedial hip group; AKPS, anterior knee pain scale; CI, Confidence Interval.

proposed interventions did not change the dynamic knee valgus assessed by FPPA.

The relationship between hip strength and patellofemoral pain has been investigated for approximately 20 years (Clark et al., 2000; Ireland, Willson, Ballantyne, & Davis, 2003) and concentrated mainly on the influence of the strength of the hip abductors, extensors, and external rotators, also called "posterolateral hip musculature" (Nascimento, Teixeira-Salmela, Souza, & Resende, 2017; Rathleff et al., 2014). A systematic review (Rathleff et al., 2014) verifying the association of the hip musculature with patellofemoral pain found 21 cross-sectional studies that evaluated the posterolateral hip musculature strength and only five studies that evaluated the anteromedial hip musculature (flexors, adductors, and internal rotators). These cross-sectional studies showed lower posterolateral and anteromedial hip muscles strength in women with PFP compared to pain-free individuals (Rathleff et al., 2014). However, the weakness of both muscle groups has not been associated as a risk factor for PFP in prospective cohorts (Neal et al., 2019; Rathleff et al., 2014).

The evidence is consistent for adding hip strengthening to knee strengthening on pain and function in PFP (Collins et al., 2018; Nascimento et al., 2018; van der Heijden et al., 2015; Willy et al., 2019). However, it is not clear what mechanisms underlie these results. Studies (Powers et al., 2017; Salsich & Perman, 2007) may have focused on the idea that posterolateral hip musculature strengthening could improve lower limb alignment and consequently the patellofemoral kinematics, which would reduce the patellofemoral compression loads and improve pain. However, this theory has not been supported by previous studies (Earl & Hoch,

Table 4
Within-group comparisons.

	PLHG (n = 26) Adjusted Difference (CI 95%)	AMHG (n = 26) Adjusted Difference (CI 95%)
Pain Intensity (0–10)		
6 weeks - *Baseline*	- 4.15* (−5.20 - -3.10)	−4.46* (−5.51 - -3.41)
6 months - *Baseline*	−2.5* (−3.54 - -1.45)	−2.19* (−3.24 - -1.14)
AKPS (0–100)		
6 weeks - *Baseline*	10.61* (7.22–14.0)	13.5* (10.11–16.89)
6 months - *Baseline*	11.81* (8.41–15.19)	12.73* (9.34–16.12)
Global Perceived Effect (-5/+5)		
6 weeks - *Baseline*	3.69* (−2.71 – 4.67)	4.26* (3.29–5.24)
6 months - *Baseline*	−2.84* (1.86–3.82)	3.31* (2.32–4.28)
Pain - Step Down (0–10)		
6 weeks - *Baseline*	−1.92* (−2.86 – -0.98)	−1.73* (−2.66 - -0.79)
Hip Abductor Strength (Nm/kg)		
6 weeks - *Baseline*	0.24* (0.17–0.31)	0.13* (0.07–0.20)
Hip Adductor Strength (Nm/kg)		
6 weeks - *Baseline*	0.04 (−0.01–0.09)	0.20* (0.15–0.26)
Hip External Rotation Strength (Nm/kg)		
6 weeks - *Baseline*	0.09* (0.06–0.13)	0.06* (0.03–0.10)
Hip Internal Rotation Strength (Nm/kg)		
6 weeks - *Baseline*	0.05† (0.002–0.09)	0.13* (0.08–0.17)
Frontal Plane Projection Angle (°)		
6 weeks - *Baseline*	−0.50 (−3.57–2.56)	−0.28 (−3.35–2.78)

Abbreviations: PLHG, posterolateral hip group; AMHG, anteromedial hip group; AKPS, anterior knee pain scale; CI, Confidence Interval.
*P < 0,001.
†P < 0,05.

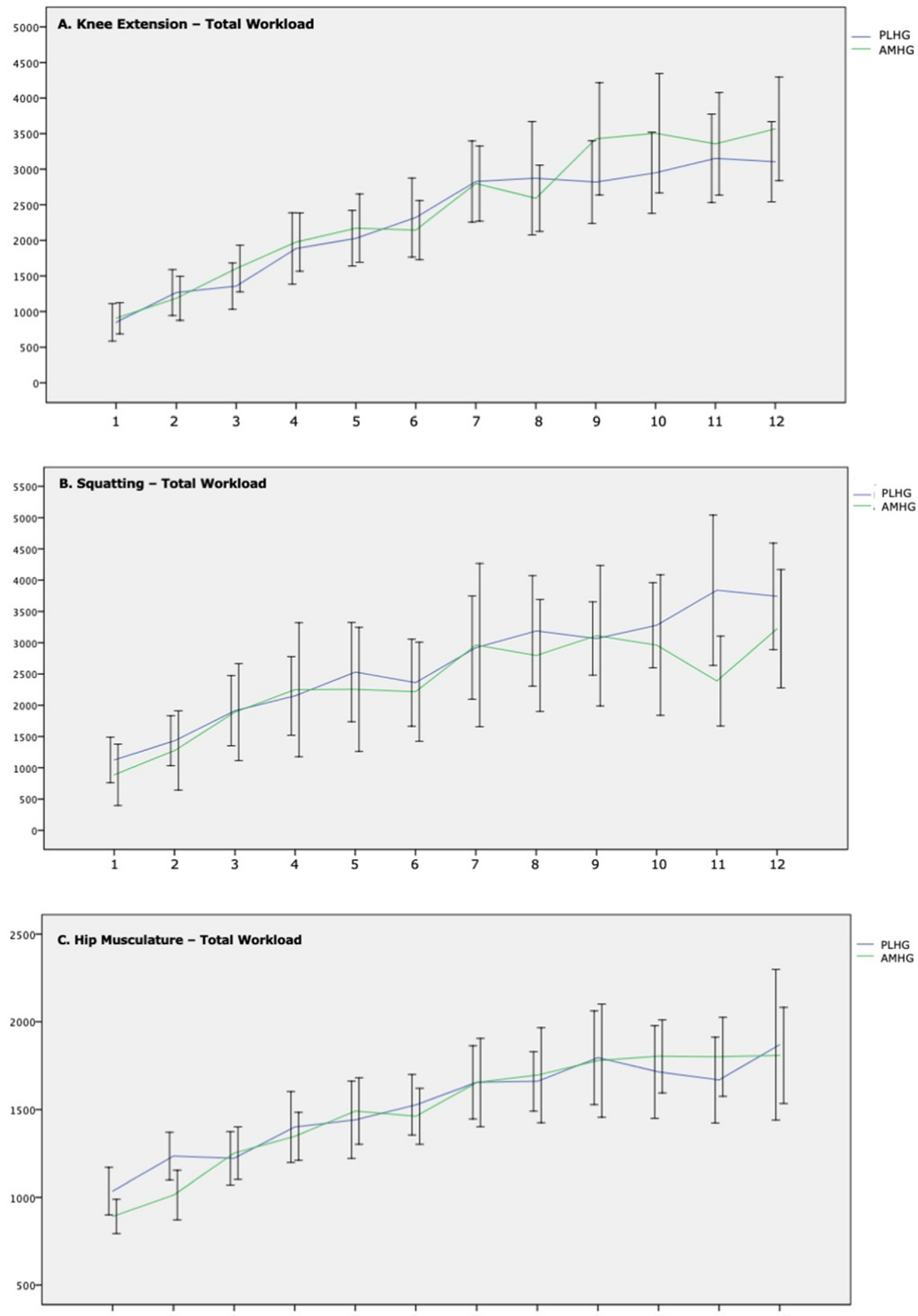

Fig. 2. Total workload in each session.

Table 5
Knee extension, squatting and hip musculature total workload.

	PLHG (N = 26)	AMHG (N = 26)	Adjusted Differences between Groups (CI 95%)	P-Value
Knee extension (AU)	2279.9 (1925.2–2634.5)	2456.9 (2105.2–2808.6)	−176.9 (−676.4–3222.49)	0.48
Squatting (AU)	2582.7 (1911.1–3254.3)	2326.5 (1656.3–2996.7)	256.2 (−692.6–1205.1)	0.59
Hip musculature (AU)	1520.8 (1383.5–1658.0)	1497.8 (1361.9–1633.75)	22.9 (−170.2–216.1)	0.81

Abbreviations: PLHG, posterolateral hip group; AMHG, anteromedial hip group; AU, arbitrary units; CI, confidence interval.

2011; Esculier et al., 2018; Ferber et al., 2011; Palmer, Hebron, & Williams, 2015; Rabelo et al., 2017) in which patients had improved pain and function after hip strengthening but no changes found in the lower limb kinematics.

Corroborating these findings, the two groups in our research showed improvements in pain intensity, function, GPE and pain during the step down but no changes in the dynamic knee valgus. The relationship between posterolateral hip strength and dynamic knee valgus is conflicting and may be conditional to task demand. A systematic review (Dix, Marsh, Dingenen, & Malliaras, 2019) showed no relationship between weaker posterolateral hip strength and greater dynamic knee valgus for single leg squat and double leg landing tasks, but lower dynamic knee valgus was associated with greater posterolateral hip strength.

The dose of the most frequent PFP exercises was 20–60 min, performed three times a week, for eight consecutive weeks (range 3–16) and 24–36 visits (range 12–146) (Young, Rhon, Cleland, & Snodgrass, 2018). Our intervention protocol was performed with an average duration of 60 min, twice a week, for six consecutive weeks and 12 sessions. This dose was lower than the average of previous studies (Young et al., 2018), but the ideal exercise dose of PFP is still not well established. Although a study (Young et al., 2018) found that the highest exercise dose was not associated with greater therapeutic effects on PFP, Nascimento et al. (2018) report that strengthening three times a week for six consecutive weeks would be necessary to achieve greater benefits. However, our study was the first to control the TW over the sessions.

The internal and external load are important variables for adjusting the exercise dose for patients with PFP (Holden et al., 2018), since hip and knee strengthening has shown good results for pain and function but without concomitant increase in muscle strength (Nascimento et al., 2018). Monitoring these variables ensured standardization of exercise doses in groups and increased strength over time for abductors in PLHG (24%) compared to AMGH (13%), and strength of the adductors and internal rotators in AMHG (20% and 13%, respectively) compared to PLHG (4% and 9%, respectively).

The anteromedial or posterolateral hip muscles strengthening plus knee strengthening achieves the same clinical benefits in six weeks and six months follow-up in women with patellofemoral pain. Our results question whether the focus on selective strengthening of posterolateral hip muscles for decreasing pain and improving activity patellofemoral pain; clinicians should also consider strengthening of flexors, adductors, and internal rotators hip muscles in PFP.

Study limitations

This study had some limitations. We did not collect all clinical outcomes at the six-month follow-up; only women were included, so we are not sure that these results can be extrapolated to men; and we did not monitor exercise continuity between six weeks and six months of follow-up.

Conclusion

Our study demonstrated that there is no difference between adding posterolateral or anteromedial hip muscle strengthening to quadriceps strengthening in improving pain, function, and dynamic knee valgus in women with patellofemoral pain. The results suggest that the two interventions are equally effective.

Ethical statement

This study was approved by Federal University of Ceará Ethics Committee with protocol number 2.055.614. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. Informed consent was obtained from all patients for being included in the study.

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Declaration of competing interest

None declared.

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