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Original Research

People with patellofemoral pain have impaired functional performance, that is correlated to hip muscle capacity

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A B S T R A C T

Objective: To (i) compare objective function in a range of tasks between people with and without patellofemoral pain (PFP); and (ii) evaluate the relationship of objective function with hip muscle capacity and self-reported function in people with PFP.
Design: Cross-sectional.
Settings: Laboratory.
Participants: Thirty-two physically active people (16 with PFP and 16 controls).
Main outcome measures: Functional assessments included stair climbing (time), single-legged chair stand (repetitions), step down (repetitions), forward hop for distance and side hop (repetitions). Hip abductor and extensor capacity assessments included power, endurance, isometric and dynamic strength. Self-reported function included the Kujala scale and Patellofemoral sub-scale of the Knee injury and Osteoarthritis Outcome Score (KOOS-PF).
Results: The PFP group was 15% slower climbing stairs (effect size [ES] = 0.90), performed 12% fewer chair stands (ES = 0.62) and forward hopped 20% shorter (ES = 0.79) compared to controls. Lower hip muscle strength and power correlated with lower objective function (r = 0.52–0.78). Lower Kujala scores correlated with longer stair climbing time (r = −0.53).
Conclusion: People with PFP have objective functional impairments, that are associated with reduced hip muscle capacity, indicating progressive resistance training may be beneficial. Absence of a strong correlation between self-reported, and objective, function indicates assessment of both when treating people with PFP is warranted.

1. Introduction

Patellofemoral pain (PFP) is prevalent, affecting up to 23% of the general population annually (Smith et al., 2018). People with PFP usually report pain and difficulty with functional activities including stair climbing, standing from sitting, squatting and jumping/hopping (Crossley et al., 2016a,b; Witvrouw et al., 2014). Additionally, people with PFP exhibit impairments in objectively measured function (de Oliveira Silva et al., 2018; dos Reis et al., 2015; Loudon, Wiesner, Goist-Foley, Asjes, & Loudon, 2002). Deficits in the number of step downs (de Oliveira Silva et al., 2018; Loudon et al., 2002), but not squats (Loudon et al., 2002), and inconsistent findings related to hop for distance assessment (de Oliveira Silva et al., 2018; dos Reis et al., 2015), are evident in people with PFP when compared to asymptomatic people. To date, no study has objectively evaluated a range of functional tasks in people with PFP compared to asymptomatic individuals.

Self-reported measures of function using questionnaires are often used as a primary outcome measures when evaluating the effectiveness of interventions for PFP treatment (e.g., Kooiker, Van De Port, Weir, & Moen, 2014; Lack, Barton, Sohan, Crossley, & Morrissey, 2015; van der Heijden, Lankhorst, van Linschoten, Bierma-Zeinstra, & van Middelkoop, 2015). These patient-

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reported outcome measures (PROMs) reflect how people perceive their functional limitations, but may not reflect actual objectively measured functional performance (Hamilton, Giesinger, & Giesinger, 2018). Considering that subjective and objective measures of function may have different constructs (perception and performance, respectively), the measurement of both could be important (Hamilton et al., 2018). A greater understanding of the potential breadth of functional impairment may help guide rehabilitation and choice of outcome measures.

Isometric hip abduction and extension muscle strength are reported to be associated with the number of step down repetitions over 60 seconds (Burnham et al., 2016) and the hop for distance test (Kemp, Schache, Makdissi, Sims, & Crossley, 2013) in asymptomatic individuals. The relationship between hip muscle capacity (strength, power and endurance) (Nunes, Barton, & Serrão, 2018; Rathleff, Rathleff, Crossley, & Barton, 2014) and functional impairments in people with PFP is not known. This knowledge would allow clinicians to target the most important parameters of hip muscle capacity during rehabilitation to improve function in people with PFP.

The aims of this study were to (i) compare objectively measured functional performance in a range of tasks between people with and without PFP, and (ii) evaluate the relationship between objective function and hip muscle capacity (endurance, strength, and power) and PROMs of function in people with PFP.

2. Materials and methods

2.1. Participants

Thirty-two physically active people (16 with PFP and 16 asymptomatic controls) were enrolled in our study (Table 1). A minimum of 16 participants per group was required for an alpha of 0.05 and statistical power of 80% to identify a 15 cm difference in the hop for distance task, and to detect a correlation (r value) over 0.70 between two measures, alpha of 0.05 and power 80%.

Participants were recruited through advertisements at the University and via social media (Twitter and Facebook). The inclusion criteria for the PFP group were: (i) aged between 18 and 50 years old; (ii) insidious onset of symptoms unrelated to a traumatic event; (iii) presence of retropatellar or peripatellar pain (minimum 3/10 points on the visual analogue scale) in at least three of the following activities: using stairs, running, kneeling, squatting, prolonged sitting, jumping, and isometric contraction of quadriceps; and (iv) presence of pain for at least two months (Nunes et al., 2018). The control group had no participants with history of injury or pain in the knees, and were similar to the PFP group for age, height and body weight (see Table 1). The exclusion criteria for both groups were self-reported history of surgery in either knee; injury or pain in the hip; patellar instability; signs or symptoms of meniscal or knee ligament injuries,presence of Osgood-Schlatter and Sinding-Larsen-Johansson syndrome; or pain on palpation of the patellar tendon area, Hoffa's fat pad, iliotibial band, pes anserinus tendon or knee joint line (Nunes et al., 2018). This study was approved by the Human Research Ethics Committee of La Trobe University (registration number 16–141) and written informed consent was obtained from all participants.

Table 1
Participant characteristics [mean (SD)] for PFP and control groups.

	PFP group (n = 16)	Control group (n = 16)
Gender (women/men)	9/7	9/7
Age (years)	32 (9)	29 (7)
Height (m)	1.67 (0.12)	1.70 (0.10)
Body mass (kg)	67.3 (14.6)	66.4 (14.2)
Duration of symptoms (years)	2.3 (1.7)	N.A.
Worst pain (points)[a]	6.5 (1.8)	N.A.
Kujala score (points)	76.3 (12.5)	99.5 (1.1)
KOOS-PF (points)	67.3 (19.3)	98.9 (1.7)

[a] Worst pain during the previous week of the data collection using visual analogue scale (0 = no pain; 10 = unbearable pain). Both groups were similar in age, body mass and height (p > 0.05). N.A.: Not applied.

2.2. Procedures

An experienced physiotherapist (>7 years of clinical experience), blinded to group allocation, completed all participant evaluations. In the PFP group, the lower limb of the affected knee or the more painful knee was assessed. In the control group, the assessed lower limb was determined by tossing a coin. A researcher not directly involved in the data collection determined the lower limb to be tested in order to keep the assessor blinded.

The assessments were completed over two sessions separated by 2–7 days. In the first session: hip isometric strength, objective functional tests and endurance tests; and in the second session: hip dynamic strength (10 repetition-maximum) and hip power tests were included. The participants were asked to complete a warm-up for 5 min on a bicycle ergometer before starting each session.

2.3. Assessments

2.3.1. Patient-reported outcome measures (PROMs)

Participants completed the Kujala scale (Kujala et al., 1993) and Knee injury and Osteoarthritis Outcome Score for patellofemoral pain and osteoarthritis (KOOS-PF) (Crossley, Macri, Cowan, Collins, & Roos, 2017) to evaluate subjective function.

2.3.2. Objective function assessments

Participants had the opportunity to perform at least two trials of each objective test before the data collection as a familiarization procedure. All participants received 3 min of rest between each objective functional test. The participants were verbally encouraged to achieve maximum effort during all the tests.

Stair climbing test: Participants were asked to ascend and descend a standard flight of stairs (nine steps - 17 cm height each) as fast as possible, step by step, using the rail only if needed (Dobson et al., 2012; OARSI 2013). Each participant performed one trial and the time was recorded in seconds from the assessor's command to “go” until the participants return to the bottom landing touching both feet on the floor (Dobson et al., 2012; OARSI 2013).

Single-legged chair stand test: Participants were seated in a standard chair and were instructed to keep arms crossed over the chest, the foot of the assessed lower limb flat on the floor and the knee of the non-assessed lower limb extended for the whole test. The participants were also instructed to avoid touching the foot of the non-assessed lower limb on the floor, and if they did, these repetitions were not counted. On the assessor's command to “go”, the participants were asked to stand up to a single-legged stand position (hip and knee extended), then sit back down touching their back on the chair's backrest. The participants repeated the task as many times as possible in a 30-second period (Dobson et al., 2012; OARSI 2013). Each participant performed one trial and the maximum number of sit-to-stand repetitions was recorded (Dobson et al., 2012; OARSI 2013).

Step down test: Participants were instructed to keep their hands on their waist. On the assessor's command to “go”, participants stepped their non-assessed lower limb down from a 15 cm high step, tapped the floor with their heel and then returned that limb to the step. The assessed limb remained on the step for the duration of the test. The task was repeated as many times as possible in a 30-second period (Loudon et al., 2002). Each participant performed one trial and the maximum number of repetitions was recorded (Loudon et al., 2002).

Forward hop for distance test: Participants were instructed to keep their hands crossed behind their back throughout the test, to commence the test in single-legged stance on the assessed lower limb, and hop forward as far as possible landing on the same limb without extra hops or losing balance (i.e. non testing limb touching the ground) upon landing (Guney, Yuksel, Kaya, & Doral, 2016; Gustavsson et al., 2006). Three valid trials were collected with a minimum interval of 1 min between trials and the average of the three trials was used for statistical analysis.

Side hop test: Participants were instructed to keep their hands crossed behind their back throughout the test and hop from side to side on the assessed lower limb over two straps 40 cm apart in a 30-second period (Gustavsson et al., 2006). Each participant performed one trial and the maximum number of hops (each hop counted as 1 repetition, so over and back = 2) was recorded (Gustavsson et al., 2006).

Hip muscle capacity assessment: Strength, power and endurance for hip abduction and extension protocols were previously published for comparisons between people with and without PFP (Nunes et al., 2019). Briefly, hip muscle capacity was assessed using clinically applicable methods: strength was evaluated isometrically using a hand-held dynamometer (HHD; JTech Commander PowerTrack, JTech Medical Industries Inc., Midvale, USA) and dynamically using a gym cable machine (Nautilus Freedom Trainer, Nautilus Inc., Vancouver, Canada) evaluating a 10 repetition maximum test (10RM). Power was assessed using a linear position transducer (GymAware, Kinetic Performance Technology, Canberra, Australia) during the assessed movements in the cable machine; and endurance was assessed using maximum number of hip abduction and extension repetitions (Nunes et al., 2019). Additional details are presented in Supplementary material 1.

2.4. Statistical analysis

A test-retest reliability evaluation with six asymptomatic participants was completed to verify the intra-rater reliability ($ICC_{3,1}$) and standard error of measurement of the objective functional tests used (see Supplementary material 2). ICCs ranged from 0.81 to 0.98, indicating good to excellent reliability for all measures used (Portney & Watkins, 2009).

To compare participant characteristics and functional measures between groups, multiple independent t-tests were used. In order to avoid missing potentially clinically meaningful findings, no statistical correction was applied (Perneger, 1998). Effect size (ES; Hedges' g) was calculated using Review Manager (RevMan) (Version 5.2, Copenhagen, Denmark) for each comparison and significant differences were classified according to ES values as follows: small (>0.2), medium (>0.5), large (>0.8), and very large (>1.3) (Sullivan & Feinn, 2012). Pearson correlations were calculated to verify the association between PROMs, hip muscle strength and power with objective functional measures. Due to violations of normality in the endurance data, Spearman correlations were calculated to verify the association between hip muscle endurance and objective functional measures. Correlations were considered as weak (r = 0.0 to 0.3), moderate (r = 0.4 to 0.6), or strong (r = 0.7 to 1.0) (Dancey & Reidy, 2011). The confidence level was set at 5%. Data were analyzed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1. Objective function

The PFP group had medium to large (ES = 0.62–0.90) deficits in objective function compared to the control group (Table 2). They were 15% slower during the stair climbing (p = 0.02; ES = 0.90), performed 12% fewer repetitions single-legged chair stands (p = 0.04; ES = 0.62), and demonstrated 20% shorter forward hop for distance (p = 0.03; ES = 0.79) than the control group (Table 2). Although the PFP group completed 11% less step downs and 27% less side hops compared to the control, these differences were not statistically significant (Table 2).

3.2. Correlations

All correlations between hip muscle capacity (strength, power and endurance) and objective measures of function are shown in Table 3.

Isometric strength: Lower isometric hip abduction strength was moderately correlated with fewer step down repetitions and shorter forward hop for distance, explaining 28% and 34% of the variance respectively. No significant correlations between isometric hip extension and measures of objective functional performance were identified (Table 3).

Dynamic strength (10 RM): Lower dynamic hip abduction strength was strongly correlated with fewer step down repetitions and moderately correlated with shorter forward hop for distance, explaining 61% and 38% of the variance respectively. Lower dynamic hip extension strength was strongly correlated with fewer chair stand repetitions, explaining 59% of the variance; and moderately correlated with fewer step down repetitions, shorter forward hop for distance and fewer side hop repetitions, explaining 29%, 26% and 27% of the variance respectively.

Endurance: No significant correlations were identified between hip abduction or extension muscle endurance and any measure of objective functional performance (Table 3).

Power: Lower hip abduction power was moderately correlated with fewer step down repetitions and shorter forward hop for distance, explaining 38% of the variance for both tasks. Lower hip extension power was moderately correlated with fewer step down repetitions and shorter forward hop for distance, explaining 27% and 38% of the variance respectively.

Table 2
Objective functional tests measures for comparisons between groups [mean (SD)].

	PFP group (n = 16)	Control group (n = 16)	Mean difference (95% CI)	p value	Effect size
Stair climbing test (sec)	6.0 (0.7)	5.2 (1.0)	−0.8 (−1.4 to −0.1)	0.02[a]	0.90
Chair stand test (rep)	15 (4)	17 (2)	2 (0–4)	0.04[a]	0.62
Step down test (rep)	25 (5)	28 (5)	3 (−1 to 6)	0.15	0.58
Forward hop test (cm)	90 (29)	113 (28)	23 (2–43)	0.03[a]	0.79
Side hop test (rep)	25 (15)	34 (14)	9 (−2 to 19)	0.09	0.60

PFP: patellofemoral pain; rep: repetitions. [a]significant difference.

Table 3
Correlations values between functional tests with hip muscle capacity and patient-reported outcome measures (PROMs) for the PFP group.

	Stair Climbing test	Chair test	Step down test	Forward hop test	Side hop test
Isometric strength (%BW[a])					
Hip abduction	−0.03	0.03	**0.53**	**0.58**	0.37
Hip extension	−0.43	0.36	0.32	0.37	0.40
Dynamic strength (%BW[b])					
Hip abduction	−0.16	0.46	**0.78**	**0.62**	0.46
Hip extension	−0.40	**0.77**	**0.54**	**0.51**	**0.52**
Endurance (repetitions)					
Hip abduction	−0.29	−0.16	0.17	0.06	0.00
Hip extension	−0.19	0.01	−0.01	−0.10	−0.06
Power (W/kg)					
Hip abduction	−0.18	0.40	**0.62**	**0.62**	0.43
Hip extension	−0.32	0.48	**0.52**	**0.62**	0.47
PROMs (points)					
Kujala	**−0.53**	0.28	0.45	0.37	0.49
KOOS-PF	−0.42	0.09	0.07	−0.11	0.05

[a] %BM = (Nm/kg)x100.
[b] %BM = $(kg^{(10RM)}/kg^{(body\ mass)})$x100. Numbers in bold indicate significant correlations ($p < 0.05$).

Patient-reported outcome measures (PROMs): A lower Kujala score was moderately correlated with longer stair climbing time, explaining 28% of the variance.

4. Discussion

This study provides the most comprehensive evaluation of objectively measured functional performance in people with PFP. Findings indicate people with PFP have moderate to large impairments in stair climbing time, single-legged chair stand repetitions and forward hop for distance performance. Our study is the first to compare chair stand repetitions and stair climbing speed between people with and without PFP, with findings indicating both may be impaired. Previous studies report that people with knee osteoarthritis perform 40% fewer chair stand repetitions (Cavalcante et al., 2015), while people with hip osteoarthritis are 50% slower during stair climbing test (Judd, Thomas, Dayton, & Stevens-Lapsley, 2014) compared to controls. These deficits are substantially greater compared to those identified in our study (12–15%), possibly reflecting less chronicity and pain severity in our younger cohort.

Deficits in forward hop for distance in our PFP cohort (20%) is greater than reported by de Oliveira Silva et al. (2018) (up to 12%). A possible explanation may be the older mixed-sex population in our study compared to the younger female-only population evaluated by de Oliveira Silva et al. (2018). The impact of sex and age on functional performance impairments in people with PFP remains unknown. Nonetheless, forward hop for distance deficits found in both studies reinforce the impact of PFP on functional performance, and highlight a potential need for addressing this impairment as part of exercise-therapy.

Step down and side hop test performance were not impaired in our PFP group. However, medium effect sizes (0.58–0.60), alongside non-statistically significant *t*-test results, may reflect inadequate statistical power. Other studies do report deficits in these tests in people with knee pathologies. For example, the side hop test appears valuable in identifying functional deficits in people following anterior cruciate ligament injury (Gustavsson et al., 2006), and people with PFP have been reported to possess significant deficits in the number of step downs (14 to 22%) in previous research (de Oliveira Silva et al., 2018; Loudon et al., 2002).

Dynamic hip strength and power were moderately to strongly associated with four (chair, step down, forward hop and side hop) of the five objective functional tests. Therefore, targeting dynamic (10 RM) hip strength and power might improve objective function in people with PFP. Of note, dynamic hip extension was significantly associated with all four of these tests. Isometric hip abduction strength was moderately associated with step down and forward hop for distance tests. Relationships of objective measures of function with isometric hip muscle strength were generally found to be weaker than with dynamic strength and power. This indicates isometric strength, which is more commonly measured (Rathleff et al., 2014), has less relevance to functional performance in people with PFP. Additionally, neither hip abduction nor extension muscle endurance was associated with any functional test, suggesting these measures may have little relevance to functional performance in people with PFP.

Current evidence supports exercise-therapy programs targeting the hip in order to improve functional performance in people with PFP (Collins et al., 2018; Crossley et al., 2016a,b; Lack et al., 2015; Nascimento, Teixeira-Salmela, Souza, & Resende, 2017). However, published rehabilitation programs for PFP frequently include only exercise of sufficient dose for muscular endurance, and in some cases strength (Lack et al., 2015; Lack, Neal, Silva, & Barton, 2018). Exercises focusing on hip muscle power are rarely included (Lack et al., 2015). Considering the findings from this study, greater improvements in functional performance in people with PFP through exercise-therapy may be possible through more progressive resistance training programs targeting hip muscle power. We recently demonstrated the feasibility of delivering an exercise-therapy program targeting proximal muscle strength and power in people with PFP, with just one pain flare of short duration (1 week) occurring among the ten people completing the program. Hip strength and power increased significantly alongside large improvements in subjectively measured pain and function (Barton et al., 2019). Further research is needed to determine if such an approach might also improve objective functional impairments identified in this study, and the typically poor prognosis among people with PFP (Lankhorst et al., 2016).

Findings from this study indicate PROMs clearly measure different constructs to objectively measured function, with the only significant correlation being stair climb time with Kujala score. Interestingly, KOOS-PF did not relate to any objective function measure. Together, this may indicate that the Kujala score might better reflect functional performance than the KOOS-PF. Specifically, KOOS-PF questions encompass stiffness, pain during activities and quality of life (Crossley et al., 2017), while Kujala questions are more focused on difficulties during functional activities (Kujala et al., 1993). Regardless, our results highlight the need to consider both objective and subjective measures of function during assessment of people with PFP.

4.1. Limitations and future directions

Our findings should be interpreted with consideration to some limitations. The current study was powered to identify deficits in forward hop for distance, and may have been underpowered for some between group comparisons and correlations. Although hip muscle capacity explained 26–61% of the variability in functional performance in our cohort, other factors, such as kinesiophobia and pain severity (de Oliveira Silva et al., 2019; Priore et al., 2019) are likely to contribute to the remaining variance, and warrant consideration in future research. Ideally this research should focus on prospective designs to determine if functional performance impairments identified in this study are the result of persistent pain and/or kinesiophobia, or contribute to the development of PFP.

Our findings are limited to a mixed-sex population. Considering women with PFP have greater deficits in hip muscle strength than men (Rathleff et al., 2014), gender differences could influence our functional performance comparisons and correlation results. Further research with adequate power to subgroup for gender is encouraged. Our findings are also limited to those aged 18–50 years. Adolescent and older populations with PFP may present different muscle capacity and functional performance characteristics, and this requires consideration in future research. It is possible that some of our older participants (close to 50 years) could have had patellofemoral osteoarthritis (PF-OA). However, PFP is thought to be a continuum with PF-OA, and high prevalence (20–30%) of PF-OA signals were recently reported on imaging exams in a young population with PFP (26–50 years) (Collins, Oei, de Kanter, Vicenzino, & Crossley, 2018). Additionally, people with PFP and PF-OA seem to have similar deficits related to hip muscle capacity and function (Wyndow, Collins, Vicenzino, Tucker, & Crossley, 2016). Finally, the cross-sectional nature of our study does not allow our findings to clearly guide recommendations on intervention.

5. Conclusion

People with PFP have deficits in objective functional performance ranging between 12 and 20% when compared to people without pain. Objective and subjective functional measures were not strongly correlated for people with PFP, indicating evaluating both is needed to provide the full details of impairments in people with PFP. The association of impairments in objective function with lower hip strength and power highlight the possibility of including progressive resistance training to improve functional performance in people with PFP.

Conflicts of interest

None declared.

Ethical approval

This study was approved by the Human Research Ethics Committee of La Trobe University (registration number 16–141).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2019.08.010.

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