PhJPT

The Philippine Journal of Physical Therapy
Official Journal of the Philippine Physical Therapy Association

VOLUME 3, ISSUE 2

August 2024

Philippine Journal of Physical Therapy
ISSN: 2766-3086
Original Research Article

Patellofemoral Pain: Correlations Between Hip Strength, Pain Severity, and Function

James R. Burns*[1], Jennifer L. Kennedy[1], Amy D. Parker[1]

[1]William Carey University, MS, USA

*Address all correspondence to Rolando T. Lazaro at: rburns@wmcarey.edu

To cite this article: Burns, J.R., Kennedy, J.L., and Parker, A.D. (2024). Patellofemoral Pain: Correlations Between Hip Strength, Pain Severity, and Function. *Philippine Journal of Physical Therapy. 3*(2), 4-14. https://doi.org/10.46409/002.KPNU3996

Abstract

Introduction. Patellofemoral pain is a common condition that results in anterior knee pain and frequently affects a wide range of the population, from adolescents to older adults. The etiology of patellofemoral pain is multifactorial and usually results in peripatellar or retropatellar pain. The purpose of this study is to determine whether a correlation exists between the strength of the posterolateral hip musculature and the severity of pain or level of function experienced by individuals with patellofemoral pain.

Methods. The participants rated pain and functional levels with the Numeric Pain Rating Scale and the Lower Extremity Functional Scale, respectively. The strength of the participants' posterolateral hip musculature was assessed with a handheld dynamometer. This study used a quantitative, cross-sectional, correlational design to determine the nature of the correlations between these variables.

Results. A total of 30 participants met the inclusion criteria and participated in the study. Posterolateral hip strength and pain severity ratings were found to be significantly negatively correlated at the .05 level, r (28) = -.375, p=.041. Posterolateral hip strength and the participants' level of function were significantly positively correlated at the .01 level, r (28) = .541, p = .002. Pain severity ratings and the participants' level of function were also significantly negatively correlated at the .001 level, r (28) = - .526, p = .003.

Discussion. Due to the multifactorial nature of PFP, the most evidence-based treatment approach is a thorough assessment followed by the development and implementation of an individualized, comprehensive treatment plan. Based on the findings of the study, however, weakness of the posterolateral hip musculature may indeed be present in a significant percentage of individuals with PFP.

Keywords: patellofemoral pain, anterior knee pain, chondromalacia patella, runner's knee

Received: *October 15, 2023.* ***Revised:*** *January 17, 2024.* ***Accepted:*** *May 05, 2024*
Published by ***University of St. Augustine for Health Sciences*** *on behalf of the Philippine Physical Therapy Association. ISSN: 2766-3086*

Introduction

Patellofemoral pain (PFP) is one of the most common orthopedic problems involving the knee, especially in more active individuals from adolescents to older adults (Hott et al., 2019). Patellofemoral pain is thought to result from a combination of biomechanical, anatomical, psychological, and behavioral factors. Common aggravating activities include squatting, running, jumping, and ascending or descending stairs. According to Hott et al. (2019), the primary complaint in individuals with PFP is retropatellar or peripatellar pain that is increased with activities, such as squatting, that increase pressure at the patellofemoral joint (PFJ). Peripatellar tenderness is also commonly present. Common terminology used synonymously with PFP includes PFP syndrome, anterior knee pain, runner's knee, or chondromalacia patella. Diagnosing someone with PFP requires a thorough clinical examination, but there is no conclusive special test to clinically diagnose PFP (Crossley et al., 2016).

According to Capin and Snyder-Mackler (2018), the annual incidence of PFP is reported to be 23% in the general population, with increased incidence in females compared to males. Individuals with PFP typically reported persistent symptoms, and 57% reported poor outcomes 5 to 8 years after being initially diagnosed. Ramskov et al. (2015) reported that PFP has poor long-term outcomes and that between 71% and 91% of individuals have chronic symptoms up to 20 years following onset. Therefore, the recommended goal should be to provide optimal care and individualized rehabilitation protocols based on the specific needs of the patient, as there may be subgroups of patients that would benefit from varied treatment approaches (Capin & Snyder-Mackler, 2018; Earl-Boehm et al., 2018).

Despite significant research attempting to identify the causative factors of PFP, the underlying etiology remains a mystery (Bolgla et al., 2018). According to Souza and Powers (2009), the concept of hip weakness contributing to the development of PFP has gained traction more recently, with an increasing number of studies investigating this mechanism. The authors reported that dysfunction in the PFJ could be caused by influences from proximal in the kinetic chain, especially the hip. Weakness in the hip abductors and external rotators could lead to abnormal mechanics in the PFJ due to a lack of control of femoral adduction and internal rotation in a closed chain activity, such as squatting or descending stairs. Conversely, in a recent prospective study conducted to determine factors predictive of PFP development, Herbst et al. (2015) found that adolescent female athletes with greater hip abduction strength were more likely to develop PFP. Furthermore, Crossley et al. (2016) reported in the 2016 Consensus Statement on PFP that the likelihood of weakness from the hip leading to the development of PFP remained unknown. The purpose of this study is to determine whether there is a correlation between the strength of the posterolateral hip musculature and the severity of pain or level of function experienced by individuals with PFP.

Methods

Research Design

This study used a quantitative, cross-sectional, correlational design. Participants for this study were from the southeastern United States. The participants were assessed, and data was collected in a university laboratory or physical therapy clinic environment.

Sampling and Population

Study participants were recruited from the local community via flyers placed in high-traffic locations at local community colleges, universities, gyms, and healthcare facilities. Participants were also recruited from referrals from local healthcare providers, including physicians and physical therapists. The inclusion and exclusion criteria were determined to reduce the likelihood of other variables presenting as anterior knee pain. The inclusion criteria were (a) 18-45 years old; (b) history of unilateral or bilateral peripatellar or retropatellar pain for at least 1 month; (c) pain with three or more of the following: prolonged sitting, ascending or descending stairs or inclines, squatting, running, hopping, jumping, or palpation of patellar borders. The exclusion criteria were (a) other musculoskeletal hip or knee conditions, including iliotibial band syndrome, patellar tendonitis, ligament injuries, Osgood-Schlatter or Sinding Larsen Johansson Syndrome, acetabular labrum tear, or fracture of the hip or knee within the previous two years; (b) systemic or neurological conditions that could cause pain or weakness of the hip or knee; (c) pregnancy. Participants that volunteered from the community without a referral from a medical provider were screened for inclusion by an experienced, licensed physical therapist other than the principal investigator (PI).

The PI performed a power analysis and determined that the minimum sample size needed for this study was 30 participants. Sampling was conducted via a sample of convenience. Participation in this study was strictly voluntary, and no coercion took place. The PI obtained Institutional Review Board approval and provided informed consent to the participants in a written format. Written permission from the medical or physical therapy clinics to perform data collection was also obtained.

Outcome Measurements

Participants completed forms and questionnaires that included an informed consent form, pain ratings using the Numeric Pain Rating Scale (NPRS), and the current level of function using the Lower Extremity Functional Scale (LEFS). The NPRS is an 11-point scale with zero corresponding to no pain and 10 corresponding to the worst pain imaginable. The NPRS is a reliable and valid assessment of pain for individuals with PFP

(Piva et al., 2009). The PI collected the participants' worst pain ratings. The LEFS is a questionnaire of self-reported functional ability for individuals with lower extremity injuries (Binkley et al., 1999). Scores range from zero to 80, with 80 being the highest functional level. The LEFS has been shown to be valid and reliable for individuals with knee injuries (Watson et al., 2005). The PI performed all of the data collection, including the strength testing for all participants in a university laboratory or physical therapy clinic setting.

A Health-o-meter® digital scale was used to measure the participants' weight. Posterolateral hip strength was measured using a microFET® 2 handheld dynamometer (Hoggan Scientific, LLC., Salt Lake City, UT, USA) with the Hip Stability Test (HipSIT), which was shown to be valid and reliable for assessing posterolateral hip strength (Almeida et al., 2017). The HipSIT was chosen based on previously reported findings that the clam exercise produced the most electromyographic activation of the gluteal complex in relation to the tensor fascia lata (Almeida et al., 2017; Selkowitz et al., 2013). The microFET® 2 handheld dynamometer records strength measurements in 0.1-pound increments to improve accuracy. Handheld dynamometers have been shown to have excellent reliability and validity compared to isokinetic dynamometers, which are considered the gold standard (Mentiplay et al., 2015). Participants were guided through the appropriate movement pattern for the HipSIT. Then the PI applied manual resistance with the dynamometer without using a strap (Appendix A). A three-trial average of posterolateral hip strength was taken for each lower extremity with a 30-second rest break between trials. The average of the three trials was converted to a percentage of bodyweight specific to the individual participant. These measurements were taken bilaterally since the PI was blinded to which limb was involved until after data collection was completed. Once the involved limb was determined, only the data for the involved limb were analyzed for a correlation to pain severity ratings and the level of function of the participant.

Data Gathering Procedure

The PI obtained a signed informed consent form and instructed the participant to fill out the various questionnaires, including the NPRS (Appendix B), LEFS (Appendix C), and demographic data such as name, age, gender, duration of symptoms, and designation of involved lower extremity. For the NPRS, the worst pain rating was used for data analysis. If PFP was present bilaterally, the most symptomatic limb was designated as the involved lower extremity. Participants placed the completed forms in an envelope so that the PI was blinded to the information until the completion of the data collection. Upon completing the questionnaires, the participant's weight was recorded. Next, strength measurements of the posterolateral hip musculature were taken bilaterally using a handheld dynamometer with the participant lying on a standard plinth. Verbal instructions were given before the initiation of strength testing to ensure participant understanding, and verbal encouragement was provided during testing to ensure maximal effort was given. A three-trial average was calculated and recorded for each lower extremity and converted to a percentage of bodyweight specific to the individual participant. Statistical analysis was performed using SPSS. A Pearson's correlation coefficient (r) was used to determine the nature of the relationship between posterolateral hip strength and pain and posterolateral hip strength and the level of the participant's function.

Results

Ultimately, 30 participants met the inclusion criteria and participated in the study. Eighty percent of the participants were female (n = 24), while 20% of the participants were male (n = 6). The mean age of the participants was 24.6 years, with a range of 18-43 years (SD = 6.2). The involved limbs consisted of 53.3% left limbs (n = 16) and 46.7% right limbs (n = 14). When analyzed by gender, females had left limbs as the involved limb 54.2% of the time (n = 13) and right limbs as the involved limb 45.8% of the time (n = 11). Males had the left limb as the involved limb 50% of the time (n = 3) and the right limb as the involved limb 50% of the time (n = 3). The mean bodyweight of the participants was 165.5 pounds, with a range of 102 pounds to 319.4 pounds (SD = 47.8). When analyzed by gender, the mean bodyweight of the female participants was 154 pounds, with a range of 102-216.8 pounds and a standard deviation of 32.2 pounds. The mean bodyweight of the male participants was 211.4 pounds, with a range of 127.4-319.4 pounds and a standard deviation of 73 pounds. Table 1 displays the demographic characteristics of the participants, and Table 2 lists the involved limbs of the participants

Table 1. Demographic Characteristics (N = 30)

Variable	n	%
Gender		
Male	6	20.00
Female	24	80.00
Age		
18-24	20	66.67
25-31	6	20.00
32-38	2	6.67
39-43	2	6.67

Note: Mean age = 24.6 years old (SD = 6.2)

Table 2. Involved Limbs (N = 30)

Variable	n	%
Involved limb		
Right	14	46.70
Left	16	53.30
Involved limb (Male)		
Right	3	50.00
Left	3	50.00
Involved limb (Female)		
Right	11	45.80
Left	13	54.20

Table 3 contains the strength test in pounds of the involved limb, the bodyweight of the participant, and the percentage of bodyweight of the strength test results. The participants provided a pain rating indicating the worst pain level experienced using the NPRS. Table 4 contains the participants' worst pain ratings and LEFS scores converted to a percentage of function.

Table 3. Posterolateral Hip Strength (N = 30)

Participant Code	Strength (lbs.)	BW (lbs.)	Strength as % BW
1	62.2	118.8	52.4
2	111.4	192.6	57.8
3	63.4	119.4	53.1
4	62.9	133.4	47.2
5	73.5	177	41.5
6	71.5	145.6	49.1
7	44.5	104.4	42.6
8	56	127.4	44
9	136.8	319.4	42.8
10	39.3	145.2	27.1
11	87.5	184.2	47.5
12	67.7	161.4	42
13	43.4	102	42.6
14	93.3	153.4	60.8
15	86.6	190.2	45.5
16	45.4	129.4	35.1
17	69.1	143.2	48.3
18	62.8	150.2	41.8
19	69.4	165.6	41.9
20	84.5	212	39.9
21	54.5	144.8	37.6
22	86.9	216.8	40.1
23	108.7	223.4	48.7
24	77.4	118.6	65.3
25	76.7	177.8	43.1
26	78.8	142.6	55.3
27	87.3	201.2	43.4
28	46.5	167.4	27.8
29	91.7	263.2	34.8
30	63.6	133.6	47.6

Legend: Bodyweight (BW)
Note: Average % BW strength = 44.9 (SD = 8.5)

Table 4. Pain Ratings and Function Scores (N = 30)

Participant Code	Pain Rating (0-10)	LEFS (% of Function)
1	7	56
2	7	90
3	7	94
4	10	53
5	5	83
6	8	85
7	9	60
8	6	80
9	8	29
10	8	46
11	8	68
12	8	93
13	7	53
14	3	94
15	8	34
16	9	55
17	5	91
18	8	76
19	9	55
20	7	79
21	7	64
22	8	70
23	6	76
24	5	89
25	8	65
26	10	91
27	4	99
28	8	44
29	9	61
30	8	66

Table 4. Pain Ratings and Function Scores (N = 30)

Note: LEFS scores were converted to a percentage of function (score/80 x 100). Average pain rating = 7.3 (SD = 1.7); Average % of Function=70 (SD = 19)

SPSS software was used to perform a Pearson's r to examine the nature of the correlation between posterolateral hip strength and pain severity ratings and between posterolateral hip strength and the level of function of the participants. Posterolateral hip strength and pain severity ratings were found to be significantly negatively correlated at the .05 level, r (28) = -.375, p=.041. Posterolateral hip strength and the participants' level of function were significantly positively correlated at the .01 level, r (28) = .541, p = .002. Pain severity ratings and the participants' level of function were also significantly negatively correlated at the .001 level, r (28) = -.526, p = .003. Table 5 presents the findings of the statistical analysis.

Table 5. Correlations (N=30)

Variables	Pearson Correlation	Significance (2-tailed)
Hip strength & pain rating	-.375	.041
Hip strength & level of function	.541	.002
Pain ratings & level of function	-.526	.003

Data analysis revealed the majority of study participants were females between 18 and 31 years old, and the involved limbs had nearly equal representation of right and left among all participants. However, regardless of age, gender, or involved limb, there was a significant negative correlation between posterolateral hip strength and pain severity ratings and a significant positive correlation between posterolateral hip strength and the level of function of the participants.

Discussion

Patellofemoral pain is often thought to develop from abnormal patellar tracking, but until recently, the focus has been on controlling the patella itself and not the underlying femur (Tyler et al., 2006). If there is a lack of strength or neuromuscular control in the posterolateral hip musculature, the femur could be allowed to move into excessive adduction and internal rotation, which leads to an increase in dynamic knee valgus during closed chain activities, such as squatting. As more research has been done in recent years, the concept of correcting the biomechanics at the knee by strengthening the hip has gained traction (Bolgla et al., 2008; Mascal et al., 2003; Robinson & Nee, 2007; Souza & Powers, 2009; Tyler et al., 2006; Villafane et al., 2019). However, most current research on the etiology of PFP points to the multifactorial nature of the potential causes of the condition and that no single underlying cause has been identified. The two most recent consensus statements by the leading experts on PFP concluded that the likelihood of hip weakness leading to the development of PFP remains unknown and that uncertainty still exists as to the best exercise interventions for PFP (Bolgla et al., 2018; Collins et al., 2018; Crossley et al., 2016).

Previous studies have examined hip and knee strength in a group of individuals with PFP compared to a healthy control group and how these factors influence lower extremity biomechanics (Almeida et al., 2017; Baellow et al., 2020; Ferriera et al., 2019; Hoglund et al., 2018). However, to the knowledge of the PI, no study has attempted to correlate the amount of posterolateral hip strength expressed as a percentage of body weight with the severity of pain or the level of function in a group of individuals with PFP. This study helps fill the gap in the literature by utilizing a cross-sectional study design to examine the nature of the relationship between these variables. Participants were not asked about exercise routines or physical activity levels at the time of the study. Some of the participants could have previously been to formal physical therapy for rehabilitation of PFP and actively continuing a home exercise program that included hip strengthening exercises, while others may have been sedentary. However, because of this study's design, this information would not affect inclusion in the study. Instead of comparing to a healthy control group, this study utilized a single data collection to determine whether higher or lower levels of posterolateral hip strength were correlated with higher or lower pain ratings and functional levels within a group of individuals with PFP at a given moment in time.

The results of this study showed a significant negative correlation between posterolateral hip strength and pain severity ratings in individuals with PFP. For the participants in this study, findings indicated that higher strength levels in the posterolateral hip musculature were significantly correlated with lower pain severity ratings, and lower strength levels in the posterolateral hip musculature were significantly correlated with higher pain severity ratings. This study's results also showed a significant positive correlation between posterolateral hip strength and the level of function in individuals with PFP. Higher strength levels in the posterolateral hip musculature were significantly correlated with higher levels of function, and lower strength levels in the posterolateral hip musculature were significantly correlated with lower levels of function. Pain severity ratings and functional levels were also significantly positively correlated, in that, participants with better pain ratings had better functional levels. Study participants that reported higher pain severity ratings also reported lower levels of function, and those that reported lower pain severity ratings also reported higher levels of function. This finding suggests that the participants provided truthful subjective information when reporting pain ratings on the NPRS and functional information on the LEFS, as it would be expected to see lower functional levels in those with more pain and higher functional levels in those with less pain. This finding also supports previous researchers' findings that the LEFS and NPRS are effective subjective tools to identify pain and functional level in individuals with PFP (Piva et al., 2009; Watson et al., 2005).

This study provides evidence to support the need for assessing the entire kinetic chain, beyond just the knee, for patients with PFP. Although this study's results cannot be seen as proving that hip weakness causes PFP, a significant negative correlation between posterolateral hip strength and pain severity in adults with PFP was found. Additionally, a significant positive correlation was found between posterolateral hip strength and the participants' level of function. This research adds to the literature to help physical therapists with clinical decision-making when assessing and treating people with PFP.

There were no conflicts of interest to report in this study. A limitation of this study was the cross-sectional design. A one-time data collection was convenient, but limited the impact of the findings because despite significant correlations being found, causation could not be inferred. The possibility that posterolateral hip weakness results from having PFP must also be considered. Likewise, correlating higher posterolateral hip strength with those with less pain and higher functional levels could be coincidental. Another potential limitation was the limited age range of the majority of participants. Since the minimum age for inclusion in this study was 18, adolescents were not included despite the relatively common occurrence of PFP in the adolescent population (Hott et al., 2019). Additionally, while the target population was adults between 18 and 45 years old, over 86% of the participants were in the lower half of the targeted age range, potentially limiting the generalizability of the findings to the entire target population.

Future research should consider a prospective form of this study, in which baseline posterolateral hip strength assessments are performed in asymptomatic individuals, such as a group of athletes on a sports team prior to the beginning of the season. The athletes could be followed through the season and monitored for the development of PFP. Future researchers should attempt to identify a cutoff, such as a certain percentage of bodyweight for posterolateral hip strength, that could predict those that would or would not develop PFP. If these cutoffs could be successfully identified, coaches could have preseason goals for each athlete's posterolateral hip strength to aid in the prevention of developing PFP. Future researchers could then explore ways to generalize those findings to the general population. Additionally, expanding the target population to include the adolescent population would be beneficial, as PFP is also common in those younger than 18

(Hott et al., 2019). Future research should also continue attempting to identify subgroups of people that present with PFP. If subgroups could be accurately identified, the treatment process could be individualized accordingly, potentially leading to more efficient care and better outcomes for patients with PFP.

Conclusion

In a previous study by Baellow et al. (2020), the researchers examined a group of individuals with PFP and compared hip and knee strength with a healthy control group. The average pain rating for the PFP group was 4.4, and the minimum pain rating to be included in the study was three out of 10 on a VAS. The authors did not find a significant difference in strength but stated that could have been because the subjects had relatively low pain ratings. The authors stated that more significant strength differences might have been found if pain ratings had been higher. The current study by the PI helps fill this gap in the literature, as the participants had an average pain rating of 7.3 on a zero to 10 scale. This study also supported the findings of Baellow et al. because lower pain ratings were correlated with higher amounts of strength in the posterolateral hip musculature and vice versa.

While the results of this study cannot prove causation, a logical assumption would be to surmise that someone with PFP could decrease pain and improve function by increasing strength in the posterolateral hip musculature. However, other researchers have used hip strengthening as an intervention in individuals with PFP with mixed results across the literature. In some studies, strengthening the hip musculature, or improving hip neuromuscular control, was effective at treating PFP (Earl-Boehm et al., 2018; Emamvirdi et al., 2019; Ferber et al., 2015; Sahin et al., 2016; Villafane et al., 2019). However, in other studies, hip strengthening was no more effective than knee strengthening, stretching, or in some cases, free physical activity (Hott et al., 2019; Saad et al., 2018). The participants in these studies were randomly placed into specific intervention groups without considering the individual deficits that each participant may have had, such as weakness of other muscle groups, or lack of flexibility. Hott et al. (2019) acknowledged this and stated that if the intervention groups had been selected based on the specific needs of each participant, the outcomes might have been different. Therefore, in clinical practice, when treating someone with PFP, the recommendation is to perform a thorough assessment of the entire limb and look for any deficits that may contribute to the development of PFP.

Patellofemoral pain has a multifactorial etiology; therefore, the most evidence-based treatment approach seems to be a thorough assessment of the individual patient followed by developing and implementing an individualized, comprehensive treatment plan (Willy et al., 2019). The study findings suggest, however, that weakness of the posterolateral hip musculature may be present in a significant percentage of individuals with PFP. The PI recognizes that no specific deficits should be assumed, and every patient should be examined thoroughly. Physical therapists must have an open mind and a good understanding of biomechanics to effectively identify deficits in the lower extremity kinetic chain that could lead to the development of PFP in a given patient. Physical therapists should also consider the potential combination of anatomical, psychological, and behavioral factors that could also contribute to the development of PFP. With an individualized, thorough assessment leading to a specific, unique treatment plan for each patient, physical therapists can more effectively treat patients with PFP and decrease the likelihood of chronic pain and poor outcomes often associated with this condition.

Conflict of interest statement

The authors declare no competing interests.

References

Almeida, G. P. L., das Neves Rodrigues, H. L., de Freitas, B. W., & de Paula Lima, P. O. (2017). Reliability and validity of the hip stability isometric test (HipSIT): A new method to assess hip posterolateral muscle strength. *Journal of Orthopaedic and Sports Physical Therapy, 47(12)*, 906-913. https://doi:10.2519/jospt.2017.7274

Baellow, A., Glaviano, N. R., Hertel, J. H., & Saliba, S. A. (2020). Lower extremity biomechanics during a drop-vertical jump and muscle strength in women with patellofemoral pain. *Journal of Athletic Training, 55(6)*, 615-622. https://doi:10.4085/1062-6050-476-18

Binkley, J. M., Stratford, P. W., Lott, S. A., & Riddle, D. L. (1999). The Lower Extremity Functional Scale (LEFS): Scale development, measurement properties, and clinical application. *Physical Therapy, 79(4)*, 371-383. https://academic.oup.com/ptj/article/79/4/371/2857730

Bolgla. L. A., Malone, T. R., Umberger, B. R., & Uhl, T. L. (2008). Hip strength and hip and knee kinematics during stair descent in females with and without patellofemoral pain syndrome. *Journal of Orthopaedic and Sports Physical Therapy, 38(1)*, 12-18. https://www.jospt.org/doi/10.2519/jospt.2008.2462

Bolgla, L. A., Boling, M. C., Mace, K. L., DiStefano, M. J., Fithian, D. C., & Powers, C. M. (2018). National Athletic Trainer's Association position statement: Management of individuals with patellofemoral pain. *Journal of Athletic Training, 53(9)*, 820-836. https://doi:10.4085/1062-6050-231-15

Capin, J. J., & Synder-Mackler, L. (2018). The current management of patients with patellofemoral pain from the physical therapist's perspective. *Annals of Joint, 40(3)*, 1-14. https://doi:10.21037/aoj.2018.04.11

Collins, N. J., Barton, C. J., van Middelkoop, M., Callaghan, M. J., Rathleff, M. S., Vicenzino, B. T., Davis, I. S., Powers, C. M., Macri, E. M., Hart, H. F., de Oliveira Silva, D., & Crossley, K. M. (2018). 2018 Consensus statement on exercise therapy and physical interventions (orthoses, taping, and manual therapy) to treat patellofemoral pain: Recommendations from the 5th International Patellofemoral Pain Research Retreat, Gold Coast, Australia, 2017. *British Journal of Sports Medicine, 52*, 1170-1178. https://doi:10.1136/bjsports-2018-099397

Crossley, K. M., Stefanik, J. J., Selfe, J., Collins, N. J., Davis, I. S., Powers, C. M., McConnell, J., Vicenzino, B., Bazett-Jones, D. M., Esculier, J. F., Morrissey D., & Callaghan, M. J. (2016). 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis, and patient-reported outcome measures. *British Journal of Sports Medicine, 50*, 839-843. https://doi:10.1136/bjsports-2016-096384

Earl-Boehm, J. E., Bolgla, L. A., Emory, C., Hamstr-Wright, K. L., Tarima, S., & Ferber, R. (2018). Treatment success of hip and core or knee strengthening for patellofemoral pain: Development of clinical prediction rules. *Journal of Athletic Training, 53(6)*, 545-552. https://doi:10.4085/1062-6050-510-16

Emamvirdi, M., Letafatkar, A., & Tazji, M. K. (2019). The effect of valgus control instruction exercises on pain, strength, and functionality in active females with patellofemoral pain syndrome. *Sports Health, 11(3)*, 223-237. https://doi:10.1177/1941738119837622

Ferber, R. Bolgla, L. Earl-Boehm, J. E., Emery, C., & Hamstra-Wright, K. (2015). Strengthening of the hip and core versus knee muscles for the treatment of patellofemoral pain: A multicenter randomized controlled trial. *Journal of Athletic Training, 50(4)*, 366-377. https://doi:10.4085/1062-6050-49.3.70

Ferriera, A. S., de Oliveira Silva, D., Ferrari, D., Magalhaes, F. H., Pappas, E., Briani, R., V., Pazzinatto, M. F., & de Azevedo, F. M. (2019). Knee and hip isometric force steadiness are impaired in women with patellofemoral pain. *The Journal of Strength and Conditioning Research, 35(10)*, 2878-2885. https://doi:10.1519/JSC.0000000000003215

Herbst, K. A., Barber Foss, K. D., Fader, L., Hewett, T. E., Witvrouw, E., Stanfield, D., & Myer, G. D. (2015). Hip strength is greater in athletes who subsequently develop patellofemoral pain. *The American Journal of Sports Medicine, 43(11)*, 2747-2752. https://doi.org/10.1177/0363546515599628

Hoglund, L. T., Burns, R. O., & Stepney, A. L. (2018). Do males with patellofemoral pain have posterolateral hip muscle weakness? *The International Journal of Sports Physical Therapy, 13(2)*, 160-170. https://doi:10.26603/ijspt20180160

Hott, A., Brox, J. I., Pripp, A. H., Juel N. G., Paulsen, G., & Liavaag, S. (2019). Effectiveness of isolated hip exercise, knee exercise, or free physical activity for patellofemoral pain: A randomized controlled trial. *The American Journal of Sports Medicine, 47(6)*, 1312-1322. https://doi:10.1177/0363546519830644

Mascal, C. L., Landel, R., & Powers C. (2003). Management of patellofemoral pain targeting hip, pelvis, and trunk muscle function: 2 case reports. *Journal of Orthopaedic and Sports Physical Therapy, 33(11)*, 647-660. https://www.jospt.org/doi/10.2519/jospt.2003.33.11.647

Mentiplay, B. F., Perraton, L. G., Bower, K. J., Adair, B., Pua, Y. H., Williams, G. P., McGaw, R., & Clark, R. A. (2015). Assessment of lower limb muscle strength and power using hand-held and fixed dynamometry: A reliability and validity study. *PLoS One, 10(10)*, 1-18. https://doi:10.1371/journal.pone.0140822

Piva, S. R., Gil, A. B., Moore, C. G., & Fitzgerald, G. K. (2009). Responsiveness of the activities of daily living scale of the knee outcome survey and numeric pain rating scale in patients with patellofemoral pain. *Journal of Rehabilitation Medicine. 41(3)*, 129-135. https://doi:10.2340/16501977-0295

Ramskov, D. Barton, C. Nielson, R. O., & Rasmussen, S. (2015). High eccentric hip abduction strength reduces the risk of developing patellofemoral pain among novice runners initiating a self-structured running program: A 1-year observational study. *Journal of Orthopaedic & Sports Physical Therapy, 45(3)*, 153-161. https://doi:10.2519/jospt.2015.5091

Robinson, R. L., & Nee, R. J. (2007). Analysis of hip strength in females seeking physical therapy treatment for unilateral patellofemoral pain syndrome. *Journal of Orthopaedic and Sports Physical Therapy, 37(5)*, 232-238. https://doi:10.2519/jospt.2007.2439

Saad, M. C., de Vasconcelos, R. A., de Oliveria, L. V., de Barros Munno, M. S., Liporaci R., F., & Grossi, D. B. (2018). Is hip strengthening the best treatment option for females with patellofemoral pain? A randomized controlled trial of three different types of exercises. *Brazilian Journal of Physical Therapy, 22(5)*, 408-416. https://doi:10.1016/j.bjpt.2018.03.009

Sahin, M., Ayhan, F. F., Borman, P., & Atasoy, H. (2016). The effect of hip and knee exercises on pain, function, and strength in patients with patellofemoral pain syndrome: A randomized controlled trial. *Turkish Journal of Medical Sciences, 46*, 265-277. https://doi:10.3906/sag-1409-66

Selkowitz, D. M., Beneck, G. J., & Powers, C. M. (2013). Which exercises target the gluteal muscles while minimizing activation of the tensor facia lata? Electromyographic assessment using fine-wire electrodes. *Journal of Orthopaedic and Sports Physical Therapy, 43(2)*, 54-64. https://doi:10.2519/jospt.2013.4116

Souza, R. B., & Powers, C. M. (2009). Differences in hip kinematics, muscle strength, and muscle activation between subjects with and without patellofemoral pain. *Journal of Orthopaedic and Sports Physical Therapy, 39(1)*, 12-19. https://www.jospt.org/doi/10.2519/jospt.2009.2885

Tyler, T. F., Nicholas, S. J., Mullaney, M. J., & McHugh, M. P. (2006). The role of hip muscle function in the treatment of patellofemoral pain syndrome. *The American Journal of Sports Medicine, 34(4)*, 630-636. https://doi:10.1177/0363546505281808

Villafane, J. H., Bissolotti, L., La Touche, R., Pedersini, P., & Negrini, S. (2019). Effect of muscle strengthening on perceived pain and static knee angles in young subjects with patellofemoral pain syndrome. *Journal of Exercise Rehabilitation, 15(3)*, 454-459. https://doi.org/10.12965/jer.1938224.112

Watson, C. J., Propps, M., Ratner, J., Zeigler, D. L., Horton, P., & Smith, S. S. (2005). Reliability and responsiveness of the lower extremity functional scale and the anterior knee pain scale in patients with anterior knee pain. *Journal of Orthopaedic and Sports Physical Therapy, 35(3)*, 136-146. https://www.jospt.org/doi/10.2519/jospt.2005.35.3.136

Willy, R. W., Hoglund, L. T., Barton, C. J., Bolgla, L. A., Scalzitti, D. A., Logerstedt, D. S., Lynch, A. D., Snyder-Mackler, L., & McDonough, C. M. (2019). 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. *Journal of Orthopaedic and Sports Physical Therapy, 49(9)*, CPG1-CPG95. https://doi:10.2519/jospt.2019.0302

Appendix A

Photos of Dynamometer and HipSIT Technique

Figure 1. microFET® 2 handheld dynamometer


Figure 2. Hip Stability Test (HipSIT)

Appendix B

Numeric Pain Rating Scale

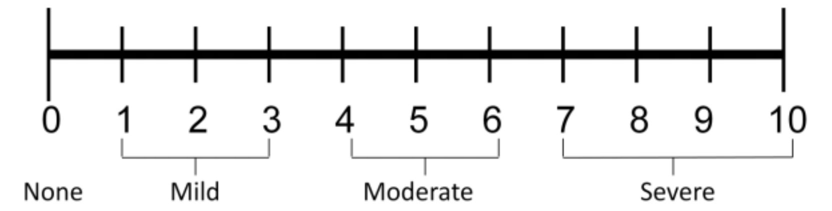
The Numeric Pain Rating Scale Instructions

General Information:

- The patient is asked to make three pain ratings, corresponding to current, best and worst pain experienced over the past 24 hours.
- The average of the 3 ratings was used to represent the patient's level of pain over the previous 24 hours.

Patient Instructions (adopted from (McCaffery, Beebe et al. 1989):

"Please indicate the intensity of current, best, and worst pain levels over the past 24 hours on a scale of 0 (no pain) to 10 (worst pain imaginable)"



Reference:
McCaffery, M., Beebe, A., et al. (1989). Pain: Clinical manual for nursing practice, Mosby St. Louis, MO.

Appendix C

Lower Extremity Functional Scale

The Lower Extremity Functional Scale

We are interested in knowing whether you are having any difficulty at all with the activities listed below **because of your lower limb problem** for which you are currently seeking attention. Please provide an answer for **each** activity.

Today, *do you* or *would you* have any difficulty at all with:

	Activities	Extreme Difficulty or Unable to Perform Activity	Quite a Bit of Difficulty	Moderate Difficulty	A Little Bit of Difficulty	No Difficulty
1	Any of your usual work, housework, or school activities.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
2	Your usual hobbies, re creational or sporting activities.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
3	Getting into or out of the bath.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
4	Walking between rooms.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
5	Putting on your shoes or socks.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
6	Squatting.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
7	Lifting an object, like a bag of groceries from the floor.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
8	Performing light activities around your home.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
9	Performing heavy activities around your home.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
10	Getting into or out of a car.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
11	Walking 2 blocks.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
12	Walking a mile.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
13	Going up or down 10 stairs (about 1 flight of stairs).	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
14	Standing for 1 hour.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
15	Sitting for 1 hour.	0 ☐	1 ☐	2 ☐	3 ☐	4
16	Running on even ground.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
17	Running on uneven ground.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
18	Making sharp turns while running fast.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
19	Hopping.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
20	Rolling over in bed.	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
	Column Totals:		0	0	0	0

Minimum Level of Detectable Change (90% Confidence): 9 points **SCORE:** 0 **/ 80 (fill in the blank with the sum of your responses)**

Source: Binkley et al (1999): The Lower Extremity Functional Scale (LEFS): Scale development, measurement properties, and clinical application. Physical Therapy. 79:371-383.