Analyzing the Effects of Hip and Knee Exercises on Patellofemoral Joint Pain Recovery

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AP Research

April 2018

Word Count: 4997

Abstract

The effects of knee and hip exercises on the pain severity and occurrence in patellofemoral joint pain (PFP) patients over various time intervals were analyzed to determine whether or not there is a correlation between various exercise treatments and quicker reductions in PFP symptoms. Papers included in this systematic review reported patient pain levels when patients participated in a hip and knee exercise therapy program and a knee-only exercise therapy program. Pain reports were examined, and results of the data analysis indicate lower pain levels among the combined exercise group compared to the knee-only group, as well as decreased pain in a shorter amount of time. Considering these findings, performing the combination of hip and knee exercises may be more beneficial to injury recovery than performing knee exercise only.

Keywords: patellofemoral joint pain syndrome, prevention, exercise, exercise therapy

Introduction

Patellofemoral joint pain (PFP) is described as any type of peripatellar (behind the kneecap) or retropatellar (around the kneecap) pain unrelated to trauma (Smith et al., 2018). It comprises about 25-40% of all knee problems seen in sports injury clinics, making it one of the primary knee injuries in humans (Witvrouw et al., 2014).

While the source of the injury is unknown due to its multifactorial nature, knee abnormalities in which there is deviation in the location of the patella can cause PFP. As cited by Okonnen (2015), researchers Wiburg and Baumgartl identified six types of patella configurations, with types I and II being most stable and least likely to cause pain. As the patella shifts away from the middle of the knee, as seen in types III, II/III, IV, and "Jägerhut," the knee becomes more unstable, causing knee pain (Figure 1).

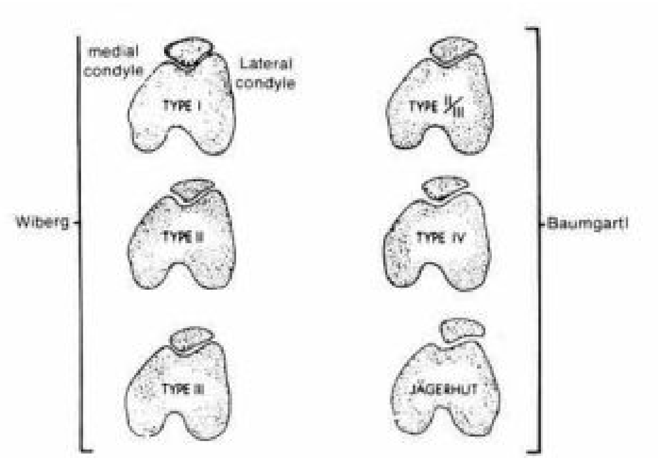

Figure 1. *Unstable configurations of the patella (Okkonen, 2015). Instability in the knee joint is caused by the patella shifting away from the midline of the knee, and this leads to PFP.*

The injury can also be caused by overuse and repetitive strain put on the patella. PFP symptoms arise and worsen when performing activities that aggravate the knee joint. Such activities often include the following: running/jogging, hopping/jumping, stair ambulation, rising from sitting after prolonged amounts of time, or squatting. These activities induce stress on the knee because the knee repeatedly absorbs the body's shock and faces increased impact forces (Mølgaard et al., 2018; Halabchi, Abolhasani, Mirshahi & Alizadeh, 2017; Crossley et al., 2016; Okonnen, 2015).

Terminology

Throughout the literature, PFP has been given various terms. Some authors refer to it as patellofemoral pain syndrome, patellofemoral arthralgia, patellalgia, lateral patellar compression syndrome, chondromalacia patellae, anterior knee pain/syndrome, or “runner’s knee” (Halabchi et al., 2017). However, in 2016, the Fourth International Patellofemoral Pain Research Retreat recommended PFP as the preferred term (Crossley, et al., 2016). While this term applies to those affected under the age of forty, in people over forty, the injury is referred to as “patellofemoral osteoarthritis” (van Middelkoop, van der Heijden & Bierma-Zeinstra, 2017).

Risk Factors

PFP can affect people of various ages and activity levels. The injury typically affects adolescents, active adults, professional athletes, and military recruits, but it can also affect less active people (Smith et al., 2018; Hart, Barton, Khan, Riel & Crossley, 2017). Certain intrinsic factors, which deal with anthropometrics (factors within the body), and extrinsic factors (factors outside the body) determine which groups are most likely to be affected.

Intrinsic factors affecting PFP include age, gender, and body shape. Although PFP affects all ages under forty, adolescents and young adults are more susceptible to this injury because of their increased participation in activities that involve running, jumping, and pivoting (Halabchi et al., 2017). While both sexes are affected by PFP, women specifically are more likely to develop the injury. In fact, 33% of knee injuries in female athletes and 18% of knee injuries in male athletes are identified as PFP (Halabchi et al., 2017). One potential reason females are more likely to suffer from this injury is due to their body shape and the pathomechanics of their q-angle, or quadriceps angle. The angle is formed by tracing a line from the anterior superior iliac spine (the anterior part of the hip) to the patellar tendon (Figure 2) (Tsakoniti, Stoupis & Athanasopoulos, 2008; Okonnen, 2015). Women tend to have a greater q-angles, as they typically have wider hips, and as a result, they are more likely to have valgus, or “knock” knee, in which the knee caves inward and pain occurs (Figure 3) (Okonnen, 2015; Nguyen, Boling, Levine & Shultz, 2009).

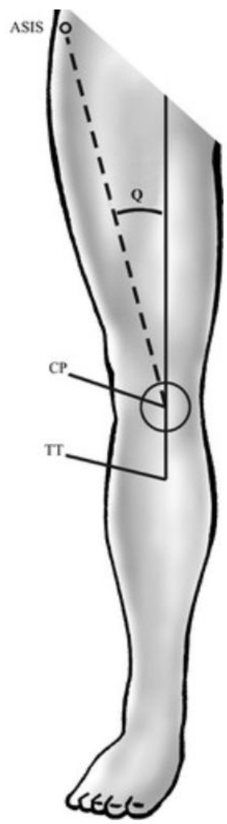

Figure 2. *Image showing the location of the q-angle (Q). The angle is formed by the line tracing the quadriceps muscle from the anterior superior iliac spine (ASIS) to the center of the patella (CP), which connects to the tibial tubercle (TT) (Tsakoniti et al., 2008).*

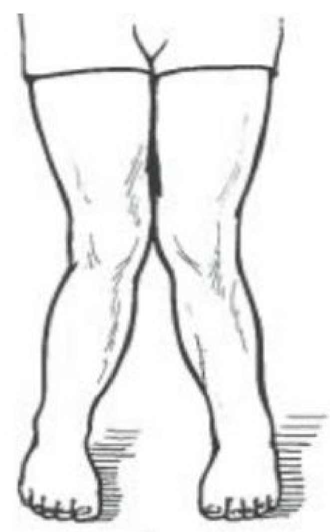

Figure 3. *Valgus knee (“knock knee”) occuring as a result of having a larger q-angle (Okonnen, 2015).*

Pain may also be caused by hip weakness because hip weakness triggers pelvic (or hip) drop, resulting in the knee shifting towards the body. This leads to internal rotation of the femur and tibia and more stress being placed on the patella (Figure 4) (Okonnen, 2015).

Other misalignments in the body can provoke PFP. The inward rotation, or overpronation, of the ankle, for example, may cause the patella to shift and knee pain to arise (Figure 4) (Okonnen, 2015; Barton, Lack, Hemmings, Tufail & Morrissey, 2015).

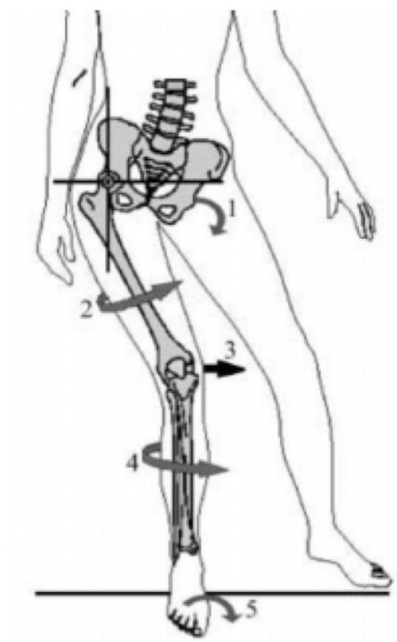

Figure 4. *Image detailing the multifactorial conditions causing PFP. Intrinsic causes regarding body shape include: 1) pelvic drop, 2) internal femoral rotation, 3) knee valgus, 4) internal tibial rotation, and 5) overpronation of the foot. When there is a pelvic drop or overpronation, the knee caves inwards towards the body as a result of internal rotation of the femur and tibia (Okkonen, 2015).*

Extrinsic factors affecting PFP include activity level. People who tend to be more active and participate in sports involving the lower extremities—typically comprised of six main regions: the pelvis, thigh, knee, lower leg, ankle, and foot (Howard, et al., 2014)— are more likely to suffer from this injury because of the stress they place on their knees (Halabchi et al., 2017; Bonanno, Murley, Munteanu, Landorf & Menz, 2017).

Common Effects on Humans

PFP affects those diagnosed with it and those who are affiliated with the affected. Individuals affected suffer not only from mass amounts of pain, but also from difficulty of treatments and increased risk for other health issues including cardiovascular disease, diabetes, osteoporosis, osteoarthritis, and ACL injury (Collins et al., 2013; Halabchi et al., 2017). Other people are indirectly affected by the implications of the injury. Rathleff and Vicenzino (2016) indicated that people with PFP reported having a lower quality of life than people without it and are more depressed, hostile, stressed, aggressive, and anxious. In addition, people with the injury were more susceptible to pain catastrophizing, which may make it harder for people to cooperate with them. The injury may also lead to absence in the workplace, resulting in lower productivity (Smith et al., 2018). There is a need for PFP management to improve because of these implications, and as a result of PFP's complex nature, it is extremely challenging to treat and can affect the patient for up to twenty years (Collins et al., 2013).

Symptom Management

The main treatment method for this injury today is exercise therapy or muscle strengthening. This method may be accompanied by the use of external aids, such as orthotics or taping and has been proven to effectively reduce pain and support long-term recovery (Rathleff & Vincenzo, 2016; van der Heijden et al., 2015).

The earliest study of PFP was done in 1979 by researchers Dehaven, Dolan and Mayer, who analyzed one hundred diagnosed athletes and their body's response to a controlled pain management program, and since then, it has been widely studied. Throughout the years, studies have examined PFP patients under various interventions to determine what interventions are most effective in improving PFP conditions. Many researchers have compared the recovery of patients with PFP who went through exercise therapy and those who had no exercise intervention (Clark et al., 2000; Abrahams et al., 2003; Taylor et al., 2003; Loudon et al., 2004; Lun et al., 2005; Herrington et al, 2007; Song et al., 2009; Van Linschoten et al., 2009; Fukuda et al., 2010; and Moyano et al., 2013). These studies together suggest that undergoing exercise therapy is more effective than no exercise intervention because it decreases overall pain and pain severity, and increases functionality and recovery. This conclusion was determined by measuring pain over various intervals of time ranging from weeks to years.

Further research has been done to study the effects of exercising certain areas and muscle groups in the lower extremity. The most studied area is the knee, as the majority of research on the relationship between exercise therapy and PFP pain has been on the effects of knee/quadricep exercises. However, research has also analyzed the outcomes of hip exercises on PFP. The data collected regarding these two types of exercises were compared in published systematic reviews to see which most effectively decreased symptoms of PFP, and findings suggested hip exercises were more favorable than knee/quadricep exercises, and the combination of hip and knee exercise were more effective in decreasing pain and increasing functionality (van der Heijden et al., 2015; Nascimento, Teixeira-Salmela, Souza & Resende, 2018).

Throughout the literature, researchers have also studied the effects of exercising muscle groups outside of the lower extremity. Chevidikunnan et al. (2016) examined the result of core area exercises on PFP. This was in response to work by Chuter and Janse de Jonge (2012), which indicated that knee pain is often caused by core instability. Chevidikunnan et al. analyzed the patients' pain and ability to balance after intervention and found that performing core exercises decreased PFP pain intensity and significantly improved balance. To contribute further to this line of research, Ferber et al. (2015) compared the effects of combining hip and core exercises to knee exercises on the intensity and occurrence of PFP pain and found that the combination of exercises resulted in a similar decrease in the amount of patient pain and increase in functionality and strength. The hip and core protocol group, however, experienced significant decreases in pain by the third week of the exercise program, while the knee group felt pain reduction by the fourth week, suggesting that the combination of hip and core exercise reduced pain faster.

Researchers have also examined the effects of external aids, such as orthotics or kinesiology tape, to manage PFP symptoms. Collins et al. (2013) analyzed the correlation between length of exercise therapy and pain with and without shoe inserts and orthoses. Results showed the use of foot orthoses and inserts do not consistently reduce pain among patients, as some patients experienced worsening pain, while others felt improvements. Similarly, Mølgaard et al. (2018) researched the outcomes of foot exercises and foot orthoses on PFP pain. Findings from this study suggested that foot intervention helps decrease pain. However, this study included only PFP patients with excessive calcaneal inversion, a foot condition occurring in only a small percentage of individuals. Therefore, this study has limited generalizability. Bracing and taping are other methods being implemented in PFP prevention and treatment, but they are inconsistent in reducing pain and improving performance among patients (Smith, Drew, Meek & Clark, 2015; Aytar et al., 2011).

Despite these methods of treatment, people often still fail to fully recover. According to Collins et al. (2013), who studied the relationship between those affected with PFP and their recovery rates with various treatment methods, 55% of patients have an unfavorable recovery after three months and 40% have an unfavorable recovery after one year. Unfavorable recovery meant patients felt moderate to no improvement in pain levels and function, while favorable recovery was characterized by patients feeling completely or strongly recovered, or having marked improvement in pain and function.

Finding an effective way to manage PFP is necessary due to the high occurrence and implications of the injury. There is a need to identify new methods or improve current methods to prevent PFP because it is painful and may prevent people from completing everyday tasks, such as walking up stairs or participating in activities they enjoy, such as sports. Studies show that 74% of PFP patients are limited in their movement and may have to quit athletics (Chevidikunnan et al., 2016; Halabchi et al., 2017).

Purpose

The purpose of this study is to identify the most effective exercise therapy treatment method. Exercises are a favorable treatment method because they are free to perform and accessible to all. In addition, current literature suggests they are more effective in invariably reducing pain than external aids. To date, there are no systematic reviews analyzing the recovery times of PFP. This study attempts to identify which exercise therapy treatments result in the quickest and longest-lasting reduction of pain, making this research unique. This paper will compare the effectiveness of hip and knee versus knee-only exercise protocols and determine whether one group consistently experiences reductions in pain sooner than another.

Research Question

This study will consider several questions developed after reviewing the P. I. C. O. format, a format used to develop specific research questions. Each question following this format addresses the: population involved (P), intervention/treatment on the patient (I), comparative intervention (C), and potential outcome of the interventions (O) (Kung et al., 2010). The questions used for this study include the following: Does the combination of hip and knee exercises simultaneously decrease pain severity among patients? Does the combination of hip and knee exercise result in accelerated recovery for PFP patients compared to knee-only exercise?

Alternative Hypothesis

Considering exercise protocols that include the hip—hip and core or just hip—have been demonstrated to help alleviate PFP pain more effectively than knee exercises alone, hip exercise is hypothesized to consistently help quicken the recovery rates of PFP and lower overall pain suffered. Therefore, a combination of hip and knee exercises concurrently will reduce pain and speed up the recovery process in PFP patients more than will knee exercises, alone.

Null Hypothesis

A combination of hip and knee exercises is no better at reducing pain and speeding up the recovery process in PFP patients than knee exercises, alone.

Methods

Data Sources

Google Scholar, Elsevier, PUBMED-NCBI, ResearchGate, ScienceDirect, Wiley Interstate Journals, SAGE Publications, PLOS, etc. was searched to gather studies analyzing the effects of hip and knee exercise therapy treatments on patients with PFP. Keywords, such as "patellofemoral joint pain syndrome," "patellofemoral joint pain syndrome prevention," "patellofemoral joint pain exercise," "patellofemoral joint pain exercise therapy," etc. were used to collect relevant articles. Additional literature was collected by searching the reference sections of articles already gathered.

Inclusion and Exclusion Criteria

All papers used in this analysis were current, full-text clinical trials. Papers were excluded if they were not published within ten years from 2018 in order to keep information as pertinent as possible. In addition, papers were not included in the study if they were systematic reviews, meta-analyses, or study protocols.

Papers were also excluded from this study if patient pain was not measured using the visual analog scale (VAS). The VAS, first introduced in 1921 by Hayes and Patterson, is an instrument used for clinical and research purposes that can measure pain among people when they perform activities or are at rest (Marsh-Richard, Hatzis, Mathias, Venditti & Dougherty, 2009). The scale resembles a ruler, as it is a horizontal line which patients mark their pain levels on. Clinicians or researchers then measure where the patients marked their pain to be, allowing them to know how intense the pain patients are experiencing is. This measurement can either be calculated using a pencil, paper, and ruler or through digital programs, and the length of the scale varies, as it can range from a few centimeters to five inches (Marsh-Richard et al., 2009). However, in this study, authors of all papers measuring pain with the VAS used a 10-centimeter scale.

Figure 5. *Image of the 10 cm visual analogue scale (VAS). Patients mark their pain level at a given time, and this mark is measured in cm or mm to determine the VAS score, depending on the evaluator (Crellin et al., 2017).*

This paper only analyzes the results of trials using the VAS because the VAS was the most commonly used scale throughout the gathered articles. Papers using the VAS would provide the most data, thus allowing for comparisons and trends to be identified. The VAS also provides accurate results, as its test-retest reliability ranges from r=0.62–0.91 (Hawker, Mian, Kendzerska & French, 2011). Papers were also excluded if VAS scores did not represent the patient’s worst pain throughout daily life and instead, measured pain after patients performed various activities or exercises.

Furthermore, this study was limited to examining studies comparing the effects of hip and knee to knee-only exercise among PFP patients. Papers were excluded if they did not have both a hip and knee and knee-only exercise group in order to obtain pain data from the same groups of people. This allowed for more reliable and unbiased data because all of the reported pain in the study were gathered from the same group of patients, meaning the results of the overall study were based on the same pain spectrum.

The final exclusion factor considered in this study was the use of braces, orthotics, or taping. Neither of the groups was taped or used orthotics or braces.

Data Extraction

The research design, number of patients, patient characteristics, exercise protocols, and patients’ pain levels after the exercises after a certain duration of time were recorded and examined for each study included in this paper.

Statistical Analysis

The patient pain in both hip and knee (combination) and knee-only exercise groups for each gathered study was compared to determine whether or not one exercise protocol was significantly more effective than another. One-tailed, paired sample t-tests were run using Microsoft Excel's Data Analysis Toolpak to calculate the significance of the pain reduction between the two groups. This analysis contributes to previous research because no systematic review analyzed this significance using t-tests.

The VAS scores from studies analyzing pain during the same intervals of time were then grouped and averaged in order to reveal what the general relationship between pain levels and length of treatment was. This was used to hypothesize how long each treatment group would take to experience no pain. Another t-test was conducted to determine the validity of these findings.

In all t-tests, p-values $\leq .05$ were considered to be significant, meaning if a p-value was $\leq .05$, the null hypothesis was rejected.

Quality

The credibility of the included papers was measured by the Physiotherapy Evidence Database (PEDro) scale, which was accessed by visiting www.pedro.org.au. The PEDro scale measures the internal validity, or "believability," and statistical validity of a paper by scoring ten items: 1) random allocation, 2) concealed allocation, 3) baseline comparability, 4) blind subjects, 5) blind therapists, 6) blind assessors, 7) adequate follow-up, 8) intention-to-treat analysis, 9) between-group comparisons, and 10) point-estimates and variability. The paper gets one point for each item included, thus the highest score for each paper is ten. The more points the paper includes, the less risk of bias it is considered to have. The average score of all papers included in the database is 5.1 ± 1.6, and scores ≥ six suggest papers are "moderate to high quality" (Physiotherapy Evidence Database, 2018).

The PEDro scale has been utilized by many researchers publishing systematic reviews (e.g., Nascimento et al., 2018). The oldest article recorded was in 1929, but it is still used today, suggesting it is a valid scale to measure the quality of papers.

In this study, the titles of each article included were searched on the site, and the PEDro scores corresponding to each paper was recorded.

Results

Study Selection

The search results from provided over sixteen thousand studies on PFP, and after screening each study's title and abstract, sixteen were identified eligible for this study, and nine were used. Strict inclusion criteria resulted in a large number of excluded studies.

Out of the total results, only sixteen studies were clinical trials comparing pain between both combination and knee-only exercise groups, making them eligible for the study. From those articles, two were excluded due to pain not being measured by the VAS. These studies were done by Fukuda et al. (2010) and Fukuda et al. (2012) who reported pain using the Numeric Pain Rating Scale. Three were excluded because they were published before 2008 (Avraham et al., 2007; Lun et al., 2005; Clark et al., 2000). Furthermore, one study analyzed pain levels after patients performed specific activities, rather than analyzing pain levels overall, therefore it was not included in the review (Sahin et al., 2016).

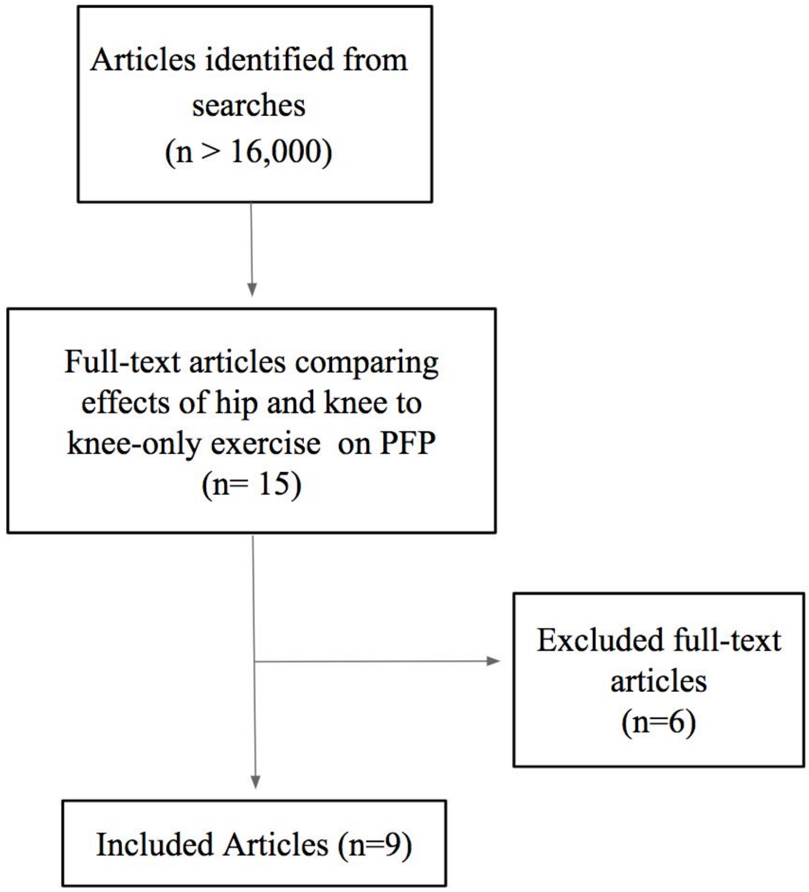

Figure 6. *Diagram of the flow of studies throughout data collection.*

Quality of Studies

The PEDro scores of the trials ranged from four to eight out of ten. The average score of the studies was six (Table 1).

Table 1. *PEDro score results of each study. "Y" indicates that the study included the factor being looked at, and a blank box means the study did not. A higher score suggests the study is less biased and more reliable.*

Study	**Design**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Bolgla et al (2016)	RCT	Y		Y			Y		Y	Y	Y	6
de Marche Baldon et al (2014)	RCT	Y	Y					Y		Y	Y	5
Dolak et al (2011)	RCT	Y		Y			Y		Y	Y	Y	6
Ferber et al (2015)	RCT	Y	Y	Y					Y	Y	Y	6
Ismail et al (2013)	RCT	Y	Y	Y	Y			Y	Y	Y	Y	8
Khayambashi et al (2014)	CT	Y		Y				Y		Y	Y	5
Nakagawa et al (2008)	RCT	Y	Y	Y			Y	Y	Y		Y	6
Razeghi et al (2010)	RCT	Y						Y		Y	Y	4
Song et al (2009)	RCT	Y	Y	Y			Y	Y	Y	Y	Y	8

Abbreviations: *RCT: randomized clinical trial; CT: controlled trial; Y: yes*

Factors considered in scoring: *1- Random Allocation; 2- Concealed Allocation; 3- Baseline Comparability; 4- Blind Subjects; 5- Blind Therapists; 6- Blind Assessors; 7- Adequate Follow-up; 8- Intention-to-Treat Analysis; 9- Between-group Comparisons; 10- Point-Estimates and Variability*

Characteristics of Included Trails

All studies examined populations with PFP, specifically. Each study recognized the occurrence of PFP as anterior or retropatellar pain in the knee when or after performing common movements associated with the injury, such as kneeling, squats, jumps, running, and getting up after prolonged sitting. Participants in all studies had no pain due to traumatic injuries. Patients were excluded if they had meniscal or ligament tears, ligament laxity, patellar dislocation or subluxation, or history of knee surgery. Other excluded participants may have had tenderness in their pes anserinus or patellar tendons, or iliotibial band, hip or lumbar pain, pes planus or cavus, uneven leg lengths or misaligned lower limbs, history of a knee effusion, rheumatoid arthritis, knee plica, Osgood–Schlatter disease, Sinding–Larsen–Johansson syndrome, or Hoffa's syndrome. Furthermore, some researchers excluded patients if they were pregnant, used steroidal or nonsteroidal medication or injections, or went to physical therapy within a certain time before the study was conducted.

Participants

Six-hundred fifteen participants were involved across all papers, with four hundred and two being female (65.37%), one hundred and eighty-one being male (29.43%), and thirty-two participants being unspecified in gender (5.20%). Five hundred fifteen participants were active (83.74), sixty-eight were sedentary (11.06%), and thirty-two had unidentified activity levels (5.20%). Participants ranged from sixteen to forty years of age, and the average age of participants was 26.71.

Table 2. *Characteristics of participants in the included trials.*

Study	Number of Participants	Gender Breakdown	Participants per Group	Age Range; Average Age (years)	Activity Level
Bolgla et al (2016)	185	124 F, 61 M	CG: 105 KG: 80	18-35; 29.35	active
de Marche Baldon et al (2014)	31	31 F	31 F CG: 15 KG: 16	18-30; 22 ± 3	active
Dolak et al (2011)	27	27 F	CG: 14 KG: 13	16-35; 26 ± 6	n/a
Ferber et al (2015)	199	133 F, 66 M	CG: 111 KG: 88	n/a; 29 ± 7	active
Ismail et al (2013)	32	16 F, 16 F	CG: 16 KG: 16	18-30; 21 ± 3	n/a
Khayambashi et al (2014)	36	18 F, 18 M	CG: 18 KG: 18	n/a; 28 ± 7	sedentary
Nakagawa et al (2008)	14	10 F, 4 M	CG: 7 KG: 7	17-40; 23.6 ± 5.9	n/a
Razeghi et al (2010)	32	n/a	CG: 16 KG: 16	18-30; 23 ± 3	sedentary
Song et al (2009)	59	43 F, 16 M	CG: 29 KG: 30	n/a; 39.4	n/a

Abbreviations: *F: females; M: males; CG: hip and knee (combination) treatment group; KG: knee-only treatment group*

Exercise Protocols

All papers included data detailing patient pain among those undergoing hip and knee exercises and knee-only exercise. Hip and knee exercises were characterized by any exercise done to target the hip muscle. Hip abduction and hip external rotation were the most common hip exercises prescribed to patients in this group (n=7). Knee exercises were characterized by any exercise that targets the knee only. This included more quadricep-focused exercise, such as squats (n=4), straight leg raises (n=3), etc.

Table 3. *Summarized exercise protocols for the combination and knee-only treatment groups in each study.*

Study	**Type of Exercise Program (frequency/week)**	**Combination Treatment Group**	**Knee-only Treatment Group**	**Exercises Both Groups Perform**
Bolgla et al (2016)	supervised (≤3), home (as many sessions needed to reach a total of 6 days/week)	- hip abduction - hip ER/IR - SL and DL balance - hip extension	- quadriceps setting - KE - SL and DL squats - TKE - lunge - step-downs	n/a
de Marche Baldon et al (2014)	supervised (3)	- core training - trunk extension - hip abduction - hip extension - clamshell - pelvic drop - hip lateral rotation - SL deadlift - SL squat - forward lunge - knee flexion	- quadriceps, lateral retinaculum, hamstrings, soleus, gastrocnemius, and IT band S - SLR - leg press - wall squat - step-ups/downs	- KE - SL balance

Dolak et al (2011)	supervised (1), home (2)	- hip abduction and ER - quadruped hydrant	- quadriceps sets - short arc quads - SLR - TKE	-hamstring, quadriceps, triceps surae S - SL balance - wall slides - step-downs - SL and DL calf raises - SL mini-squats - SL balance - lunges
Ferber et al (2015)	supervised (≤3), home (as many sessions needed to reach a total of 6 days/week)	- hip abduction - hip ER/IR - SL and DL balance - hip extension	- quadriceps sets - KE - SL and DL squats - TKE - lunge - step-downs	n/a
Ismail et al (2013)	supervised (3)	- hip abduction - hip ER	n/a	-hamstring, gastrocnemius, quadriceps, IT band S - wall squat -step-downs - TKE
Khayambashi et al (2014)	supervised (3)	- hip abduction - hip ER	- KE - sit to stand	- 5-minute warm-up/cool-down walk
Nakagawa et al (2008)	supervised (1), home (4-5)	- core training - hip abduction - pelvic drop - forward lunge w resistance to target hip muscles	- hamstring, quadriceps, calf, IT band S - patellar mobilization - quadriceps setting	n/a

			- SLR - mini squat - wall slides - step-ups/downs - lunges - SL balance - walking/running	
Razeghi et al (2010)	n/a	- resistive exercises for the hip muscles (not specified in study) - KE - mini squat	- quadriceps exercise (not specified in study)	n/a
Song et al (2009)	n/a	- SL leg press w resistance to target hip muscles	- SL leg press	-quadriceps, hamstring, IT band, calf muscle S

*** Type of exercise was noted as "supervised" or "home." "Supervised" exercise meant that patients were supervised by a physical therapist, athletic trainer, or investigator, while "home" exercise meant patients were assigned by physical therapists to follow a home exercise program.*

Abbreviations: *S: stretch; SL: single leg; DL: double leg; ER: external rotation; IR: internal rotation; KE: knee extension; IT: iliotibial TKE: terminal knee extension; SLR: straight leg raise*

Pain Outcomes

Patient pain was measured at different time intervals within trials. Researchers investigated pain after 4 weeks of intervention (n=2), 6 weeks (n=4), 8 weeks (n=3), and 2 months (n=1). After the interventions were completed, some researchers recorded patient pain after 3 months (n=2) and 6 months (n=1). There was a significant difference in the pain reduction between the combination and knee-only group (p=.03).

Table 4. *Reported patient pain between trials (mean ± SD). All pain was measured by the visual analog scale (VAS). Initial and during-treatment pain was measured, and the significance of the reductions of pain at the end of all treatments combined was calculated. Values recorded in this table were rounded to two decimal places.*

		Average VAS Scores		
Study	**Time When Pain Measured**	**Combination Treatment Group**	**Knee-only Treatment Group**	**Total p-value**
Bolgla et al (2016)	baseline: 6 wk:	5.20 ± 1.70 2.47 ± 2.26	5.00 ± 1.62 2.54 ± 2.26	
de Marche Baldon et al (2014)	baseline: 2 mos: 3 mos follow up:	6.60 ± 1.10 1.40 ± 1.40 0.90 ± 1.50	6.10 ± 1.80 3.10 ± 3.20 2.50 ± 2.70	
Dolak et al (2011)	baseline: 4 wk: 8 wk: 3 mos follow up:	4.60 ± 2.50 2.40 ± 2.00 2.40 ± 2.80 2.10 ± 2.50	4.20 ± 2.30 4.10 ± 2.50 2.60 ± 2.00 2.40 ± 2.30	
Ferber et al (2015)	baseline: 6 wk:	5.12 ± 1.66 1.96 ± 1.92	4.96 ± 1.66 1.99 ± 2.05	
Ismail et al (2013)	baseline: 6 wk:	5.30 ± 1.60 2.00 ± 1.10	4.50 ± 1.80 2.30 ± 1.10	
Khayambashi et al (2014)	baseline: 8 wk: 6 mos follow up:	7.63 ± 1.79 2.11 ± 1.60 2.00 ± 1.97	6.91 ± 1.94 3.27 ± 2.19 4.00 ± 2.44	
Nakagawa et al (2008)	baseline: 6 wk:	5.00 ± 2.10 1.40 ± 1.30	5.50 ± 1.50 3.40 ± 1.90	
Razhegi et al (2010)	baseline: 4 wk:	6.68 ± 1.62 3.37 ± 1.50	6.31 ± 1.25 4.81 ± 1.79	
Song et al (2009)	baseline: 8 wk:	4.80 ± 2.26 2.62 ± 2.51	4.85 ± 2.49 2.26 ± 2.20	p=.03

Abbreviations: *wk: weeks; mos: months*

When all VAS scores were averaged, throughout treatment, both groups overall experienced decreases in pain. However, the combination treatment group experienced greater decreases in pain and accelerated recovery. Although the combination treatment group initially reported having more pain than the knee-only treatment group (approximately 5.66 level pain compared to 5.37), as the exercise intervention continued, the combination treatment group's reported pain decreased more in less time. After four weeks of treatment, the combination treatment group reported their pain level to be approximately 2.89, while the knee-only treatment group reported theirs to be 4.46. At six weeks, pain between the combination and knee-only treatment group was around 1.96 and 2.56; at eight weeks, 2.38 and 2.77; and at two months (8.69 weeks), 1.40 and 3.10, respectively (Table 5).

The data points were plotted in a scatter plot, and a best-fit regression line was drawn for each group's pain trends to reveal the slope and R-squared value for each line. The combination treatment group line's slope was -.4435, and its R-squared value was .8759. The knee-only treatment group had a slope of -.3095 and R-squared value of .7984 (Figure 7).

After running a paired t-test to determine the significance of the overall pain reductions between groups, the p-value was calculated. There was a significant difference in the pain reductions between the combination treatment group and knee-only treatment group ($p=.05$) (Table 6).

Table 5. *Reported average patient pain measured by the visual analog scale (VAS) when patients undergo hip and knee or knee-only exercise after 0, 4, 6 and 8 weeks, and 2 months. Values are measured in centimeters and in a 10 cm scale. Higher scores indicate more pain when completing tasks. Values recorded in this table were rounded to two decimal places.*

	Average VAS Scores	
Time (weeks) When Pain is Measured	**Combination Treatment Group**	**Knee-Only Treatment Group**
0	5.66	5.37
4	2.89	4.46
6	1.96	2.56
8	2.38	2.77
8.69	1.40	3.10

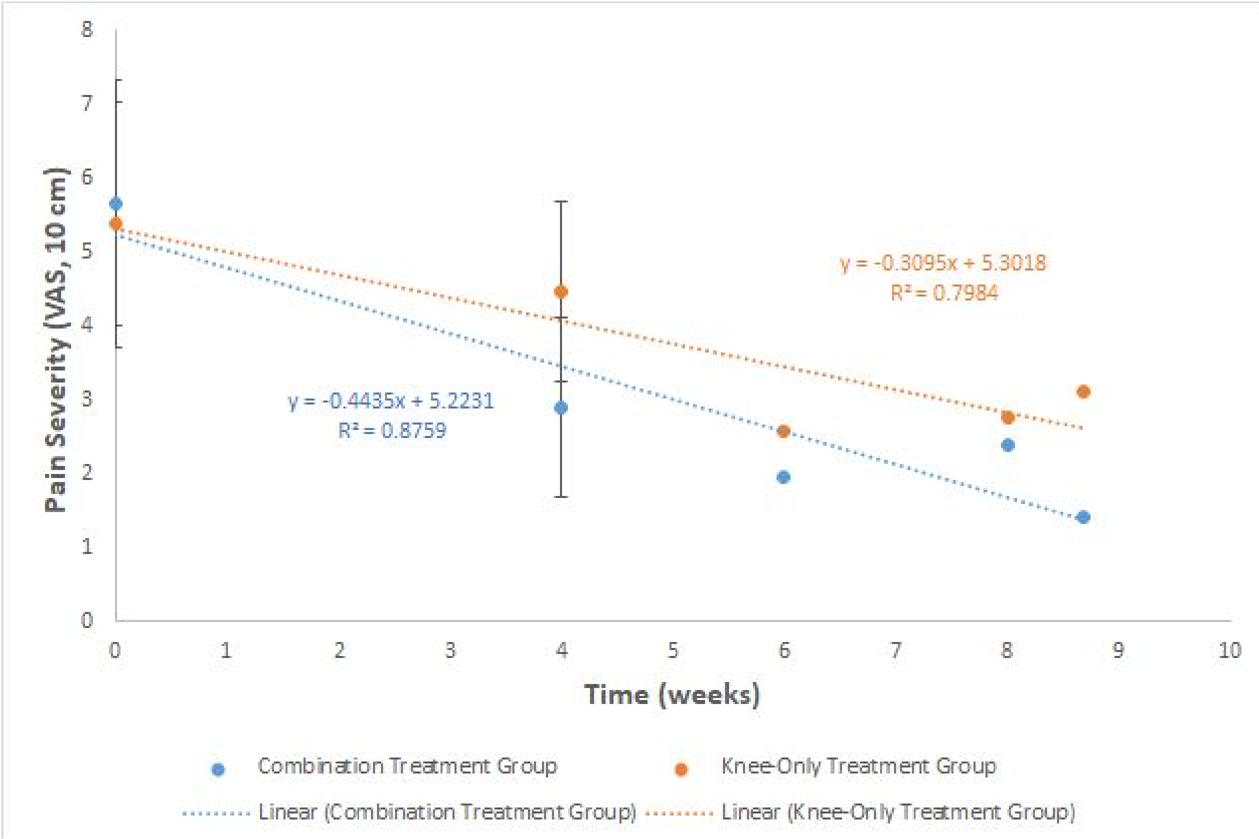

Figure 7. *Average pain severity (measured by the visual analog scale, VAS) of PFP patients throughout various exercise interventions after 0, 4, 6 and 8 weeks, and 2 months.*

Table 6. *t-test results for average pain severity of PFP patients throughout various exercise interventions after 0, 4, 6 and 8 weeks, and 2 months.*

t-test: Paired Two Sample for Means

	Combination Treatment Group	*Knee-Only Treatment Group*
Mean	2.855611111	3.6495
Variance	2.753506266	1.47142625
Observations	5	5
Pearson Correlation	0.875738381	
Hypothesized Mean Difference	0	
df	4	
t Stat	-2.122567927	
P(T<=t) one-tail	0.050524736	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	0.101049472	
t Critical two-tail	2.776445105	

Subsequent to gathering data from the collected articles, it was noted that some papers included data on patient pain after the exercise protocols to examine whether or not pain returned to one group quicker than another. This supplementary information was included in this review, addressing another gap in the research. No systematic review has been seen to examine the trends of pain post-intervention. The times when pain levels were recorded post-treatment was three months after an eight-week intervention program (21.04 weeks), three months after a two-month program (21.73 weeks), and six months after an eight-week program (34.07 weeks). As the papers indicated, three months after eight weeks of treatment, PFP pain levels were 2.10 and 2.40; three months after the two-month program, pain levels were .90 and 2.50, and six months after the eight-week program, pain levels were 2.00 and 4.00 for the combination treatment group and knee-only treatment group, respectively (Table 7).

After plotting the data points for the combination treatment group and the knee-only group onto a scatter plot and drawing a line of best fit for each group, the slopes and R-squared values for each trendline were calculated. The combination treatment group line had a slope of .1222 and R-squared of .99992. The knee-only group line's slope was .0355, and its R-squared value was .15262 (Figure 8).

The t-test results for this data suggested there was no significant difference in the changes in pain ($p=0.06$) (Table 8).

Table 7. *Reported average patient pain measured by the VAS after patients complete hip and knee or knee-only exercise protocols. Pain is recorded at 21.04 weeks (indicating a 3 month follow up after 8 weeks of exercise intervention as done in some studies), 21.73 weeks (3 months after 2 months of intervention), and 34.07 weeks (6 months after 8 weeks of intervention). Values are measured in centimeters and in a 10 cm scale. Higher scores indicate more pain when completing tasks. Values recorded in this table were rounded to two decimal places.*

	Average VAS Scores	
Number of Weeks After Beginning of Treatment	**Combination Treatment Group**	**Knee-Only Treatment Group**
21.04	2.10	2.40
21.73	0.90	2.50
34.07	2.00	4.00

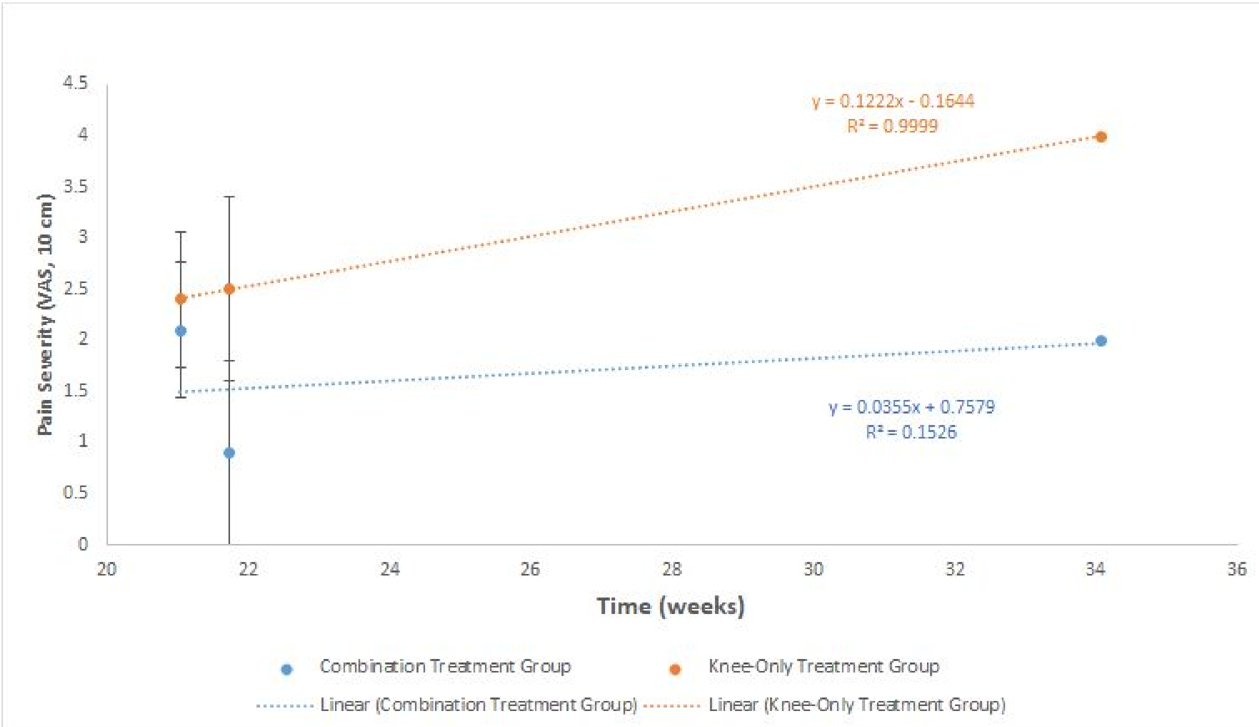

Figure 8. *Average pain severity (measured in VAS) among patients at their follow-up appointment (weeks), as called for in three studies.*

Table 8. *t-test results for average pain severity (measured in VAS) among patients at their follow-up appointment (weeks).*

t-test: Paired Two Sample for Means		
	Combination Treatment Group	*Knee-Only Treatment Group*
Mean	1.666666667	2.966666667
Variance	0.443333333	0.803333333
Observations	3	3
Pearson Correlation	0.382609923	
Hypothesized Mean Difference	0	
df	2	
t Stat	-2.53332223	
P(T<=t) one-tail	0.063420679	
t Critical one-tail	2.91998558	
P(T<=t) two-tail	0.126841357	
t Critical two-tail	4.30265273	

Discussion

When comparing the combination and knee-only group pain, it is clear that patients experience less pain, on average, when undergoing hip and knee exercise therapy, as shown in Table 1. As shown in Figure 3, patients in both groups experienced pain reductions after 0, 4, 6 and 8 weeks, and 2 months. The combination group reported greater reductions in pain after the times studied compared to the knee group, however, indicating that the combination of hip and knee exercises simultaneously more effectively decreases pain severity than knee exercises alone. According to the trendline equations for hip and knee exercise (y=-0.4435x+5.2231) and knee-only exercise (y=-0.3095x+5.3018), pain is projected to completely diminish at 11.777 weeks and 13.577 weeks respectively, supporting the hypothesis that the combination of exercises relieves pain sooner than knee-only exercise. This is a likely prediction considering the R-squared values for both groups are close to one. Because of the close R-squared values, the data points lie close to the best-fit regression line, suggesting the line is fairly accurate and can be used to predict values. Furthermore, pain severity levels and overall pain decreases as exercise therapy continues among both groups, meaning that although exercise therapy may not result in instant decreases in PFP pain, exercise ultimately reduces pain.

As shown in Table 2, patients who performed hip exercises in conjunction with knee exercises reported lower follow-up pain scores in all three included trials— three months post-eight-week intervention, three months post-two-month intervention, and six months post-eight-week intervention— suggesting hip and knee exercise allows for longer-lasting PFP pain reduction. Three months after the eight-week exercise treatment, patients in the combination group experienced, on average, 2.10-level pain, while those in the knee group felt 2.40-level pain. Similarly, three months after the two-month treatment, the combination group reported their pain level to be 0.90, while the knee reported pain to be at 2.50, and six months after eight-weeks of intervention, combination exercise patients reported 2.00-level pain, while their knee group counterparts felt 4.00-level pain. The reported pain levels in both groups, however, increased over time. The trendline equations for the combination treatment group (y=.0355x+0.7579) and the knee-only treatment group (y=.1222x-.1644) indicate that PFP pain after hip and knee exercise will come back slower than after knee-only exercise, but the overall findings suggest that once pain levels lower as a result of exercise among PFP patients, the pain will return. A likely cause for this is fewer muscle groups working to support the lower extremity and help treat malalignment in the body, making the patella more likely to shift. Another likely cause for pain returning at the post-treatment follow-ups is muscle atrophy/degeneration occurring among the exercised muscles, as a result of the muscles no longer being used. The muscles may get weaker because they are not regularly trained, decreasing stability among the lower extremity, ultimately causing PFP. These suggestions and findings also provide insight into why pain decreased during exercise intervention.

Sources of Error

Sources of error in this study include the unreliability of certain trials, lack of focus on the trials' populations, and lack of trials. Even though the mean PEDro score of the included trials was six out of ten, some papers received a score of four, meaning they were below moderate quality and may have presented bias. Furthermore, participant characteristics were gathered to examine what types of people were most affected by PFP, but no statistical tests were done comparing pain between genders or age, and the average VAS scores in Table 5 and Table 7 were not weighted averages, resulting in potentially less accurate data. Additionally, there was a small number of trials included in the study, and of the nine included trials, only three reported follow-up pain.

Conclusion

This systematic review provides evidence supporting the hypothesis proposed in this study that the combination of hip and knee exercise speeds up PFP pain reduction. The p-values gathered from the t-tests suggest that performing hip and knee exercise when treating PFP is more favorable than performing knee exercise alone because patients feel less intense pain, and their pain is alleviated sooner. In addition, this review indicates that discontinuing exercise intervention results in pain returning, but pain is predicted to return slower after performing hip and knee exercise compared to performing knee-only exercise.

Further Work

To further contribute to this study, research analyzing the specific durations of knee and hip versus knee-only exercise therapy could be conducted. PFP pain occurrence and severity is measured at various time intervals in the current literature, depending on the researcher conducting the study. Some researchers measure pain over a span of a short duration of time, such as weeks, while others measure it over a longer duration of time, such as months or years. More reliable information could be gathered by conducting studies that analyze PFP pain over the same intervals of time.

Furthermore, comparisons of the effects of hip-only and knee-only exercise on PFP pain should be conducted on the same population because it would more accurately indicate how effective hip exercise alone is. Current research has been done on each group individually, but no research has compared the intervention's effects on the same sample. Comparing the results of hip-only and knee-only exercise with the current research would not be as accurate as having a comparison done within the same population of people because there are variances in people's age, activity levels, etc. making people report pain differently. With the same population, pain tolerance and the causes of PFP pain would be most similar. As a result of this research, one type of exercise—hip or knee— could be suggested to be more effective at reducing pain and speeding up PFP recovery than another.

Further examining the effects of exercise on other muscle groups, such as the abdominals, and combinations of different muscle groups would expand this study by providing more evidence supporting or refuting the idea that different combinations of exercises are superior to performing one type of exercise to minimize PFP pain. This would help researchers determine what types and combinations of exercises most effectively decrease pain and what types of exercise, if any, have zero or negative effect on pain.

Analyzing the effects of various treatment durations for the same exercise group would also be valuable to enhancing this study because it could provide information on how long the effects of the treatments last. As suggested by PFP pain increasing post-treatment in Table 7, exercise may have to be performed consistently in order for PFP symptoms to be effectively treated. Research must be done to identify whether or not prolonged exercise programs will help keep pain levels down for an extended period of time compared to shorter programs. This research would help provide information regarding the rate at which pain returns after treatment and determine if pain will always return no matter how long the treatment lasts.

If the research proposed above were to be conducted, it would also be valuable to investigate the muscle atrophy rates of the quadriceps and hip muscles in PFP patients. Data showing how fast each muscle group atrophies will provide information that can increase the understanding of why the combination group in this study was predicted to have pain come back slower than the knee-only group. If data regarding the atrophy rates were collected and the results showed that hip muscles take longer to weaken than knee/quadricep muscles, there would be one possible explanation for why pain returned slower to the combination exercise group.

Acknowledgments

I would like to thank physical therapist Rebecca Guinn for supporting me in conducting this research, Dr. Jared Sinn for helping me develop my research question and providing expert advice on the topic, Dr. Karen Givvin for editing my paper and helping me with my data collection, and Dr. Zin Htway for help with my data collection and statistical analyses. Lastly, I would like to thank Michelle Magnusson and Dr. Nikki Malhotra for their time, guidance, support, and effort in helping me manage my time and develop my project.

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