# Effect of Lumbopelvic Manipulation Versus Tibiofemoral Mobilization on Pain and Quality of Life in Patellofemoral Pain Syndrome

**R Mukesh Kumar[1], Benazir Shereief[2], R Vasanthan[3]**

*[1]Student, [2]Professor, [3]Principal, The Oxford College of Physiotherapy, Karnataka, India*

## Abstract

**Background:** Patellofemoral pain syndrome is a common source of anterior knee pain which accounts for 25-40 percent of all knee problems seen in sports injuries. It is a sharp or dull pain in anterior or retro patellar knee pain that can be aggravated by sustained sitting, squatting, step up and step down. Therapeutic exercise, bracing, taping and orthotics have shown improvement in the treatment of PFPS. Manual therapy also shows little evidence in the management of PFPS.

**Objective:** The objective of this is to find the effectiveness of Lumbopelvic manipulation versus Tibiofemoral mobilization on pain and quality of life on Patellofemoral pain syndrome.

**Methodology:** This clinical trial was conducted 50 subjects with patellofemoral pain syndrome. The subjects were selected based on inclusion and exclusion criteria. Baseline assessment was taken and participants were allocated to either Group A LPM (n=25) or Group B TFM (n=25) based on inclusion criteria. Both the techniques were given for 3 days in a week for 4 weeks. Outcome measures NPRS and Kujala anterior knee pain were done at the baseline, 1st week and at 4th weeks after intervention. Outcome measures were compared and used to established an effectiveness of treatment.

**Result:** The baseline characteristics age, gender, duration of pain, NPRS and KAKS score were calculated for both the groups. The pre-test and post-test difference for NPRS score is 2.12 and 1.56 for Group A (LPM) and Group B (TFM) respectively and for KAKS score is 7.88 and 7.32 for Group A (LPM) and Group B (TFM) respectively. These results show there is no statistically significant difference between both the groups. Hence, both the technique found to be equally effective and no technique is superior to the other.

**Conclusion:** There is no significant difference between Lumbopelvic manipulation Versus Tibiofemoral mobilization on pain and quality of life in Patellofemoral pain syndrome.

***Keywords:*** *Patellofemoral pain syndrome, Lumbopelvic manipulation, Tibiofemoral mobilization.*

## Introduction

Patellofemoral pain syndrome is defined by retro patellar or peripatellar pain associated with activities involving excessive loading in the lower limb (e.g., walking, running, jumping stair climbing, prolonged sitting and kneeling). It is a condition affecting both malalignment and muscular dysfunction. It is the most frequent overuse injury of the lower limb and is especially present in those who are physically active. Diffuse pain in one or both the knees is the most

common symptom of PFPS. [1]

The factors that commit to PFPS is unclear. [1,2] Factors such as fear avoidance (kinesiophobia) and catastrophizing may be contributing factor. Central neurological mechanisms such as sensitization or neuropathic pain can also be the mechanisms affecting the pain experienced in some people with patellofemoral pain syndrome.

Furthermore, there are various physical characteristics related to the development of PFPS, such as femoral anteversion, internal rotation of the femur, patellar malalignment, or patellar hypermobility. Patellofemoral pain syndrome can also be related to genu recurvatum, valgus knee, lateral tibial torsion, quadriceps weakness and other dysfunction. [3]

Manual therapy is most favourable technique to treat a variety of musculoskeletal conditions. The modulatory effects of manual therapy on joint pain mechanisms have been demonstrated experimentally in animal model studies and in chronic pain populations[4]. While the effects of manual therapy are likely multimodal, the modulation of facilitated spinal reflexes i.e., the nociceptive reflex and facilitation of conditioned pain modulation have been demonstrated following application of oscillatory joint mobilization on the affected joint, indicating that the analgesic effects of manual therapy are, at least in part are centrally mediated. Given that patellofemoral pain syndrome is a painful condition related with joint and soft tissue impairments, manual therapy interventions would appear suitable for this population.

Spinal manual therapy includes hands-on mobilisations and/or manipulations of the thoracolumbar region and/or Sacroiliac Joint. Although their immediate positive effects have been repeatedly demonstrated, lumbar manipulations have been considered inappropriate as stand-alone intervention in patients with PFPS in the short term. The effectiveness of manual therapy focused mainly over spinal region, in the treatment of Patellofemoral pain syndrome is based on the concept of regional interdependence of musculoskeletal problems. [5]

Joint manipulation and mobilization have been used to diminish pain and strengthen muscle activation in people with PFPS. Joint mobilization and manipulation stimulate sensory receptors within and around the joint and it has shown to influence muscle activation both near and distant from the site of intervention. [6]

Joint manipulation can stimulate mechanoreceptor and nociceptor, which are primary receptor involved in muscle inhibition, within and around the joint and can thus affect spinal afferent signals. In addition, because of the common nerve root level of sacroiliac joint (L2-S3), quadriceps (L2-L4) and knee (L2-S3), afferent information from each structure might alter motor signals of the other structure with similar nerve root innervations. [7]

Lumbopelvic manipulation led to a significant decrease in quadriceps inhibition and reported that quadriceps muscle strength increased significantly following sacroiliac joint manipulation in patients with PFPS. [8]

Although alternative interference like therapeutic exercise, braces, taping and orthotics have all shown some level of benefit in the treatment of PFPS., as a result joint manipulation may be less used as a treatment protocol in routine physical therapy care in those with PFPS, as there is little evidence to support its effectiveness in managing pain and function in this population. [9]

The tibiofemoral joint mobilization in PFPS has shown the effect in normalization of biomechanics

and movement pattern. Biomechanically, an anterior-posterior mobilization of the tibiofemoral joint can be presumed to have an effect on the motion of the patella as kinematics of the lower extremity have been thought to influence the patellofemoral joint resulting in decreased anterior knee irritation and it has been concluded that tibiofemoral joint mobilization as a successful management of patellofemoral pain syndrome. [10]

The main objective of the present study was thus to compare the effect of lumbopelvic manipulation versus tibiofemoral mobilization on pain and quality of life in patellofemoral pain syndrome. A secondary objective was to determine the effect of each technique within the group at a duration of 4 weeks.

## Method

Research design

Non randomized controlled trial, with two parallel group of allocation ratio 1:1.

**Participants**

**Inclusion Criteria: 50** subjects with patellofemoral pain syndrome aged from 18-50 years both male and female participants with anterior knee pain for more than 3 months, with a pain intensity on NPRS ranging from 3-8 score and no other neurological involvement.

Lumbopelvic manipulation:

· Decrease in quadriceps muscle strength and function.

Tibiofemoral mobilization:

· Decrease in the motion of tibiofemoral joint.

**Exclusion Criteria**: participants were excluded with knee or spine surgery in last 3 years, Severe lumbosacral nerve compression signs, Ligamentous instability or suspected meniscal injury, Pregnancy and osteoarthritis.

**Sampling:** Purposive sampling method

**Allocation**: Subjects were allocated to one of the two groups according to the selection criteria.

**Study duration:** 3 months

**Study setting:** Physiotherapy clinic in and around Bangalore

**Sample size:** 50

Experimental procedure

Ethical clearance was obtained from the concerned ethical committee. Informed consent was taken from 50 participants who fulfilled the inclusion criteria. Baseline assessment was done at the commencement of the protocol. Then the participants were allocated to one of the two groups according to the inclusion criteria, either Group A (Lumbopelvic manipulation) or Group B (Tibiofemoral mobilization) Both the techniques were given three days in a week for alternative days for a duration of four weeks.

All the participants had undergone measurements for three times with an interval period of pre-test, 1st week and 4th week.

**Procedure for Group A (LUMBOPELVIC MANIPULATION):**

**No. of sessions:** 3 times per week for 4 weeks.

**Patient position:** supine lying position.

**Technique:**

· Lumbopelvic manipulation consists of applying rotational gliding force to the ipsilateral lumbopelvic region of the involved knee.

· The lumbopelvic joint manipulation (Grade

V) was performed on ipsilateral side of the test limb.

- The participant lay supine and the therapist stood contralateral to the side which has to be manipulated.
- The participant was side-bent passively towards and rotated away from the selected side.
- Then a quick thrust in posterior, inferior and lateral direction was applied to the anterior superior iliac spine on the side of involved knee.
- If cavitation was experienced either by examiner or by the participant, during the thrust portion of the manipulation, it will be considered to be complete.
- If no cavitation will be felt, one more thrust was given. Each participant received maximum of two manipulations on symptomatic side.
- If both knees were symptomatic, the participant was asked to choose most symptomatic side to be treated.

Procedure for Group B (TIBIOFEMORAL MOBILIZATION):

- **No. of sessions:** 3 times per week for 4 weeks.
- **Patient position:** crook lying position.

**TIBIOFEMORAL ANTERIOR GLIDE:**

PATIENT POSITION – Prone, beginning with knee in resting position; progress to the end of available range. Placing a small pad under the distal femur to prevent patellar compression.

HAND PLACEMENT – Grasp the distal tibia with the hand that is closer to it and place the palm of the proximal aspect of the proximal tibia.

MOBILIZING FORCE – apply force with the hand on the proximal tibia in an anterior direction.

**TIBIOFEMORAL POSTERIOR GLIDE:**

PATIENT POSITION – Supine with the foot resting on the table.

HAND PLACEMENT – Sit on the table with the therapist thigh fixating the participant foot. With both hands, grasp around the tibia, fingers pointing posteriorly and thumb anteriorly.

MOBILIZING FORCE – with extended elbows, push the tibia posteriorly with thumbs.

**Outcome Measures:**

i) PAIN - Numeric pain rating scale (NPRS)

ii) QUALITY OF LIFE - kujala anterior knee pain scale (KAKS).

**Statistical Analysis:**

The study was conducted on 50 subjects with PFPS to compare the effect of Lumbopelvic Manipulation versus Tibiofemoral Mobilization on pain and quality of life in PFPS. Baseline demographic and clinical characteristics were analysed using median and interquartile range. The data was carefully collected and calculated. In this study Kruskal Wallis test, Mann Whitney U test were used a statistically tool for detecting the significant difference within and between the group A (LPM) and group B (TFM). Descriptive statistics (mean and standard deviation) were also calculated for all the measurements consideration for the study. The sub-group difference was calculated using Kruskal-wallis test and effect size was calculated cohen's d table.

**Table: 1 BASELINE CHARACTERISTICS OF PARTICIPANTS**

| Baseline characteristics | Group A (LPM)* N (25) | Group B (TFM)* N (25) |
|---|---|---|
| Gender, (in mean) | 13 | 10 |
| Male | | |
| Female | 10 | 15 |
| Age (M±S.D) | 28.32±4.87 | 28.44±44 |
| Side of knee pain | 14 | 11 |
| Right side | | |
| Left side | 16 | 9 |
| Duration of pain (months) (MEDIAN±IR) | 5±2 | 5±3 |
| NPRS* SCORE (0 – 10) (MEDIAN±IR) | 7±1 | 5±2 |
| KAKS* SCORE (0 – 100) (MEDIAN±IR) | 72±11 | 72±8 |

*Abbreviations used: LPM: Lumbopelvic manipulation, IR – Interquartile range TFM: Tibiofemoral mobilization, NPRS – Numeric pain rating scale, KAKS – Kujala anterior knee pain scale.

Table: 1 shows the baseline characteristics of main variables for both Group A (LPM) and group B (TFM). Which represents the age in years of the subject in both the group with range of 19-36 years. Ordinal data are in Median ± Interquartile Range (Median±IR).

**Table: 2 Comparative effectiveness of Group A (Lumbopelvic Manipulation) versus Group B (Tibiofemoral Mobilization) on pain using NPRS scale.**

| Outcome measure (NPRS) | Pre-test (MEAN±S.D) | Post-test (MEAN±S.D) | Difference B/W Post-Pre (MEAN±S.D) | p – value* |
|---|---|---|---|---|
| Group A (LPM) | 6.56±1.35 | 4.48±1.06 | 2.12±0.99 | .5486** |
| Group B (TFM) | 5.76±1.10 | 4.26±0.89 | 1.56±1.13 | |

****Not significant**

The above Table 2 shows the pre-test and post-test difference value of NPRS scale from baseline to post-test (4th week) for both the Group A (LPM) and Group B (TFM). Mann-Whitney U test was done to calculate the statistical significance and found to be .5486, which is not significant $p < .05$.

**Table: 3 Comparative effectiveness of Group A (Lumbopelvic Manipulation) versus Group B (Tibiofemoral Mobilization) on Quality-of-life using KAKS SCALE.**

| Outcome measure (KAKS) | Pre-test (MEAN±S.D) | Post-test (MEAN±S.D) | Difference B/W Post-Pre (MEAN±S.D) | p – value* |
|---|---|---|---|---|
| Group A (LPM) | 72.24±5.2 | 80.12±2.25 | 7.88±4.86 | .7039** |
| Group B (TFM) | 72.52±5.72 | 80.96±3.28 | 7.32±4.36 | |

**Not significant

The above Table 3 shows the pre-test and post-test difference value of KAKS scale from baseline to post-test (4th week) for both the Group A (LPM) and Group B (TFM). Mann-Whitney U test was done to calculate the statistical significance and found to be .7039, which is not significant $p < .05$.

**Table: 4 NPRS scores at baseline, 1st week and 4th week within group mean changes scores of Group A (LPM) and Group B (TFM).**

| OUTCOME MEASURES | Group A (LPM) mean ± Standard Deviation | Group B (TFM) mean ± Standard Deviation |
|---|---|---|
| Knee pain intensity (NPRS 0-10) Baseline | 6.56±1.35 | 5.76±1.10 |
| 1st week changes | 5.04±0.82 | 4.92±1.01 |
| Short-term changes: Within-group changes baseline to 1st week | 1.52 | 0.84 |
| 4th week changes | 4.48±1.06 | 4.26±0.89 |
| Long term changes: Within-group changes baseline to 4th week | 2.08 | 1.5 |
| p – value* | .00001* | .0007* |

*p < .05 significant

Table 4 includes the difference between the baseline, 1st week and 4th week scores of NPRS for each group and difference between the groups. Kruskal-Wallis test shows that within group changes are statistically significant within group A (.00001) and group B (.0007). Where both the result is significant statistically $p < .05$.

**Table: 5 KAKS scores at baseline, 1st week and 4th week within group mean changes scores of Group A (LPM) and Group B (TFM).**

| OUTCOME MEASURES | LPM Mean ± Standard deviation | TFM Mean ± Standard deviation |
|---|---|---|
| Kujala anterior knee pain scale (0-100) Baseline | 72.24±5.2 | 72.52±5.72 |
| 1st week changes | 76.64±2.85 | 77.4±4.44 |
| Short-term changes: Within-group changes baseline to 1st week | 4.4 | 4.88 |
| 4th week changes | 80.12±2.25 | 80.96±3.28 |
| Long-term changes: Within-group changes baseline to 4th week | 7.88 | 8.44 |
| p – value* | .00001 | .00001 |

*$p < .05$ significant

Table 5 includes the difference between the baseline, 1st week and 4th week scores of KAKS scores for each group and difference between the groups. Kruskal-Wallis test shows that within group changes are statistically significant within group A (.00001) and group B (.00001). Where both the result is significant statistically $p < .05$.

**EFFECT SIZE: (i)** when comparing the effect size using mean and standard deviation of Group A (LPM) and Group B (TFM) on NPRS score using the difference in pre-test and post-test values with confidence interval 95%. The Effect-size r was found to be **0.14,** when comparing the relationship between 'r' and 'd' value, the magnitude of treatment effect is **SMALL,** according to Cohen's standard.

**(ii)** when comparing the effect size using mean and standard deviation of Group A (LPM) and Group B (TFM) on KAKS score using the difference in pre-test and post-test values, with confidence interval 95%. The Effect-size r was found to be **0.147,** when comparing the relationship between 'r' and 'd' value, the magnitude of treatment effect is **SMALL** according to Cohen's standard.

## Results

50 subjects were included in this study. The statistics was done by using Kruskal-Wallis test and

Mann Whitney U test to see the effectiveness of both the intervention Lumbopelvic manipulation and Tibiofemoral mobilization among patellofemoral pain syndrome. There is evidence of significant difference within the group A (LPM) was noted on NPRS score p-value is .00001 and KAKS score p-value is .00001 and Group B (TFM) was noted on NPRS score p-value is .00007 and KAKS score p-value is .00001. There was no significant difference when compared between pre-test and post-test difference in Group A (LPM) and Group B (TFM) on NPRS score was 2.12 and 1.56 respectively, at the duration of 4 weeks. The results suggests that there is no difference in NPRS score when compared between the groups, and it is also found statistically not significant p-value .5486 ($p < .05$) and when compared pre-test and post-test difference in Group A (LPM) and Group B (TFM) for KAKS score was 7.88 and 7.32 respectively, at the duration of 4 weeks. The results suggests that there is no significant difference between KAKS score when compared between the group, and it is also found statistically not significant p-value .7039 ($p < .05$). Hence, this study proves that there is no statistical difference when compared between the group and no technique is superior to the other. Both the technique used in this study found to be equivalent.

## Discussion

In this present study, the main objective of this clinical trial was to find out the effectiveness of Lumbopelvic manipulation versus Tibiofemoral mobilization on pain and quality of life in patellofemoral pain syndrome. The study results were interpreted on basis on outcome measure were used in this study. According to the results, the average changes obtained on the self-reported outcome obtained by the subjects in both the groups, (NPRS & KUJALA scale) Group A (LPM) versus Group B (TFM) there was no significant improvement on pain and quality of life in patellofemoral pain syndrome receiving the interventions. But when compared within the groups there is significant improvement in pain and quality of life in patellofemoral pain syndrome. This makes a conclusion that both the technique is proportionately improved.

**Changes in pain intensity between Group A (Lumbopelvic manipulation) versus Group B (Tibiofemoral mobilization):**

The result of this present study showed that comparatively no significant improvement in pain intensity between the Group A (LPM) versus Group B (TFM). The pre- and post-test mean difference was found to be 2.06 and 1.46 from baseline to 4$^{th}$ week for Group A and Group B respectively. These results suggest that there is no difference in pain intensity when compared between the groups, and it is also found to be statistically not significant $p = .1141$ ($p > .05$).

**Iverson PT et al.,** developed a clinical prediction rule (CPR) to identify patients with PFPS who may respond favourably immediately following lumbopelvic manipulation. Although the mechanism that accounts for symptom relief is not known, the authors theorized that neurophysiologic changes or regional interdependence may have been responsible for the observed changes[29]. Previously, **Suter and colleagues** demonstrated that a lumbopelvic manipulation led to a significant decrease in quadriceps inhibition[30], and **Hillermann et al**. reported that quadriceps muscle strength increased significantly following sacroiliac joint manipulation in patients with PFPS[32]. However, none of these studies was able to show any benefit beyond the immediate effects of the treatment. All the previous studies as to the best of our knowledge shows only immediate effect of Lumbopelvic manipulation, and our results also suggest that lumbopelvic manipulation is a successful

management for patellofemoral pain syndrome when applied for a duration of 4 weeks. Lumbopelvic manipulation can also be combined with other mode of treatment protocol like Vastus medialis oblique strengthening, ischemic compression and tapping for long term management as shown effective in previous studies.

**Courtney et al., (2016)** has concluded that 3 min of anterior-to-posterior glides of flexed knee reduced pain sensitivity and facilitated improvements in descending pain inhibitory system[33]. Also, in a study by **Moss et al, (2007)** concluded that 9 mins of accessory mobilization to the knee immediately minimized pain and improved functional performance in patients with mild-to-moderate Osteoarthritis[34]. There is also lack of studies which shows effect of Tibiofemoral mobilization on patellofemoral pain syndrome. Only one study has done and it shows positive effect on pain intensity and Quality of Life.

**Justin M Lantz et al., 2016** has shown improvement in both biomechanical and neurophysiological outcome measures after 8 sessions of Tibiofemoral mobilization on PFPS. Mobilization was in accordance with Concave-convex rule of the tibiofemoral joint in a manner accepted to promote knee flexion[35]. Several studies have ben advocated the use of tibiofemoral joint mobilizations in reducing pain, increasing motor unit recruitment, and improving function in patients with Osteoarthritis of the knee. Tibiofemoral mobilization was found to be effective in reducing anterior knee pain and increase patient's functional status which enhanced Quality of Life in our study.

The conclusion of this study was stated that both the Lumbopelvic manipulation and Tibiofemoral mobilization was found to be effective in reducing knee pain equivalently and indeed no technique is superior to the other one. Hence, according to the statistical analysis this study rejected the alternate hypothesis.

**Changes in Quality-of-Life scale between Group A (Lumbopelvic manipulation) versus Group B (Tibiofemoral mobilization):**

The result of this present study showed statistically no significant improvement in Quality of life between the Group A (LPM) and Group B (TFM). The pre-test and post-test mean difference in Group A (LPM) and Group B (TFM) for Quality of life was 7.2 and 8.01 respectively, at the duration of 4 weeks. These results suggest that there is no difference in Quality of life when compared between the groups, and it is also found to be statistically not significant $p = 1$ ($p > .05$).

**Sally. L Coburn et al., 2018** concluded that individuals with PFPS aged under 50 years, have impaired knee- and health-related QoL compared to the general population and pain-free individuals. Findings from previous intervention studies indicate that knee- and health-related QoL improved following interventions for PFP including bracing, taping, manual therapy and exercise therapy. [36]

**Neal R. Glaviano 2017** conducted a study on physical levels in individual with and without PFPS. He had concluded that individuals with PFPS are less physically active than their healthy counterparts in both steps per day and minutes spent conducting physical activity. A relationship between subjective function and physical activity exists in individuals with PFPS. [37]
**Sirous Azizi et al., 2020** concluded that using manual therapy caused significant improvements in PFPS patients compared to the sole therapeutic exercise. Accordingly, incorporating this method can improve the functions of PFPS patients. Hence, according to the statistical analysis this study rejected the alternate hypothesis[38]. Both the groups had equal improvement and indeed no group is superior to the other.

**Changes in pain intensity within Group A (Lumbopelvic manipulation):**

The secondary objective of this study was to find out the difference in pain intensity within each group at the duration of 1st week and 4th week. The results show that the mean difference in NPRS score at the duration of 1st week and 4th week as 1.54 and 2.07 respectively, which shows that changes are statistically significant with value of .002 ($p < .05$).

Previous research on the reliability and responsiveness of NPRS score in individual with Patellofemoral pain syndrome identified as minimal clinically importance difference from 1.5 to 2.0cm. In the present study, Group A (LPM) had a mean difference in NPRS score of 2.08 from baseline to 4th week. There is a change in NPRS score of 2cm within the group A (LPM) post-test which concludes it is clinically significant according to Minimally clinically important difference. (MCID)

**Changes in pain intensity within Group B (Tibiofemoral mobilization):**

The secondary objective of this study was to find out the difference in pain intensity within each group at the duration of 1st week and 4th week. The results show that the mean difference in NPRS score at the duration of 1st week and 4th week for Group B as 1.4 and 1.47 respectively which shows that changes are statistically significant with value of .00561 ($p < .05$).

Previous research on the reliability and responsiveness of NPRS score in individual with Patellofemoral pain syndrome identified as minimal clinically importance difference from 1.5 to 2.0cm. In the present study, Group B (TFM) had a mean difference in NPRS score of 1.5 from baseline to 4th week. There is a change in NPRS score of 1.5cm within the group B (TFM) post-test which concludes it is clinically significant according to Minimally clinically important difference. (MCID).

## Conclusion

This study concludes that, both Lumbopelvic Manipulation and Tibiofemoral mobilization technique found to be effective in reducing knee pain and quality of life among patellofemoral pain syndrome and indeed no technique is superior to the other. Thus, this study hereby accepts the Null hypothesis that there is a no significant difference between Lumbopelvic manipulation versus Tibiofemoral mobilization on pain and quality of life among patellofemoral pain syndrome.

**Limitations**

Firstly, the Duration of the study was 4 weeks (can be done for long duration) and it also did not include long term follow up. Secondly, biomechanical and structural factors such as Q angle and hip internal rotation were not assessed and the subjects were assessed in different time duration, which may influence the quality of tests. There was lack of prior research studies. Thirdly there was no control group in this study. The exercise programme given in this study did not progress in load or repetition during the treatment period. Lastly participants in this study were young, the results may not be generalized to all age groups.

**Conflict of Interest:** Nil

## Refernces

1. Heintjes EM. Non-traumatic knee complaints in adolescents and young adults in general pratice-(Doctoral dissertation, Erasmus MC: University Medical Center Rotterdam). 2006
2. Petersen W, Ellermann A, Gösele-Koppenburg A, Best R, Rembitzki IV, Brüggemann GP, Liebau C. Patellofemoral pain syndrome. Knee surgery, sports traumatology, arthroscopy. 2014

Oct;22(10):2264-74.

3. Schiavone-Panni A, Perisano C, Del Regno C, Corona K, D'Amelio A, Vasso M. Anterior Knee Pain. InArthroscopy and Sport Injuries 2016 (pp. 373-379). Springer, Cham.
4. Waryasz GR, McDermott AY. Patellofemoral pain syndrome (PFPS): a systematic review of anatomy and potential risk factors. Dynamic medicine. 2008 Dec;7(1):1-4.
5. Dye SF. The pathophysiology of patellofemoral pain: a tissue homeostasis perspective. Clinical Orthopaedics and Related Research®. 2005 Jul 1;436:100-10.
6. Rothermich MA, Glaviano NR, Li J, Hart JM. Patellofemoral pain: epidemiology, pathophysiology, and treatment options. Clinics in sports medicine. 2015 Apr 1;34(2):313-27.
7. Collado H, Fredericson M. Patellofemoral pain syndrome. Clinics in sports medicine. 2010 Jul 1;29(3):379-98.
8. Boling M, Padua D, Marshall S, Guskiewicz K, Pyne S, Beutler A. Gender differences in the incidence and prevalence of patellofemoral pain syndrome. Scandinavian journal of medicine & science in sports. 2010 Oct;20(5):725-30.
9. Smith BE, Selfe J, Thacker D, Hendrick P, Bateman M, Moffatt F, Rathleff MS, Smith TO, Logan P. Incidence and prevalence of patellofemoral pain: a systematic review and meta-analysis. PloS one. 2018 Jan 11;13(1):e0190892.
10. Fredericson M, Yoon K. Physical examination and patellofemoral pain syndrome. American journal of physical medicine & rehabilitation. 2006 Mar 1;85(3):234-43.