KPC Kinesiology and Physiotherapy Comprehensive

P-ISSN: 2830-6317
E-ISSN: 2962-5491

The relationship between quadriceps muscle strength and patella position on knee function and patellofemoral pain syndrome

Luh Gede Risma Yanti[1,*], Ari Wibawa[2]

[1]Bachelor and Professional Program of Physiotherapy, Faculty of Medicine, Universitas Udayana, Bali, Indonesia
[2]Department of Physiotherapy, Faculty of Medicine, Universitas Udayana, Bali, Indonesia

ABSTRACT

Introduction: Patellofemoral pain syndrome (PFPS) is a common complaint experienced by athletes, characterized by anterior knee pain around the patella. PFPS is exacerbated by physical activity, weakness in one of the quadriceps muscles, and abnormalities in the position of the patella, which contribute to the onset of PFPS and decreased knee function. This study aimed to determine whether there was a relationship between quadriceps muscle strength and patella position on knee function and PFPS in level 1 athletes.

Methods: This research used the literature review method. The preparation of this study utilized secondary data from research journals that had been published and obtained from various scientific journal database sources on the internet. The search for literature articles was conducted online through searches on PubMed and Google Scholar using the keywords "Quadriceps muscle strength," "Patellofemoral Pain Syndrome," "Patella Tendon," "Knee Function," "Ultrasound," and "Patella Position."

Results: The results of the five literatures found that good quadriceps muscle strength can maintain knee stability and optimal patella position. The position of the patella shifts laterally, causing increased stress on the patellofemoral joint, which can interfere with knee function due to pain and increased symptoms of PFPS. The quadriceps muscle strength training program is intended to lower the incidence of PFPS.

Conclusion: The study demonstrated a significant relationship between quadriceps muscle strength and knee function. It also found a notable association between patella position and knee function, with these relationships being more pronounced in individuals with PFPS than those without it.

Keywords: knee function, knee position, patella tendon, patellofemoral pain syndrome, quadriceps muscle strength, ultrasound

Received: March 30, 2024. **Accepted**: July 13, 2024.
Type: Review Article; **Doi**: 10.62004/kpc.v3i2.49

***Corresponding Author:** Luh Gede Risma Yanti, Bachelor and Professional Program of Physiotherapy, Faculty of Medicine, Universitas Udayana;
Email: yuderismaaa123@gmail.com

Introduction

Patellofemoral pain syndrome (PFPS) is a clinical condition characterized by anterior knee pain and one of the most common musculoskeletal problems seen in high-activity individuals. PFPS is also known as a runner's knee.[1] PFPS is a pain that is difficult to allocate and is often located behind or around the patella. Symptoms in individuals with PFPS usually appear gradually and may occur bilaterally. Individuals have PFPS aggravated by loading on the flexed knee, running, climbing stairs, squatting, and feeling a locked knee.[2] The main factors contributing to PFPS are lower limb misalignment (Q-angle and genu valgum), lower limb imbalance, overexertion or overload, and trauma.[3]

PFPS is multifactorial and commonly related to biomechanical and tissue overload, leading to increased stress on the patellofemoral joint. The prevalence of PFPS is approximately 23% of adults and 29% of adolescents in the general population. The clinical incidence ranges from 20-40% of knee problems that occur more in women than men in a ratio of 2:1, with an incidence rate of 22/1000 people per year.[4] PFPS anterior or retropatellar knee pain without specific pathology is characterized by crepitation at the patellofemoral joint during or after activity.[5]

Knee function in individuals with PFPS is impaired, with limitations and pain that impact daily activities. Stiffness or pain, prolonged sitting with bent knees, and pain during activities that strain the knee, especially at the

KPC Kinesiology and Physiotherapy Comprehensive
P-ISSN: 2830-6317
E-ISSN: 2962-5491

patellofemoral joint. Individuals usually complain of knee weakness, which represents patellar instability, while pain is due to weak or decreased quadriceps muscle.[6] Knee swelling is a characteristic feature of PFPS, and it is a stiff sensation when the knee is flexed. The impact of the severity of symptoms arising with people having PFPS is a decrease in the quality of life associated with the knee, also causing impaired activity and limited functional movement of the knee.[7]

Athletes have a high level of physical activity, especially with continuous loading on the knees. Soccer, futsal, basketball, running, and volleyball athletes must have optimal physical condition, especially in the lower limbs. One of the lower limbs that plays a role is quadriceps muscle strength.[8] PFPS is common in runners and the most common injury, with a prevalence of 14.4% out of 196 runners. It suggests that there are 2.5 million cases of knee injuries annually, one of which is PFPS. A sudden increase in the frequency and intensity of physical activity without giving athletes enough time to adjust is also a contributing factor to the severity of PFPS.[4]

Quadriceps muscle strength plays a role in athletes maintaining optimal knee function and knee stability. This muscle consists of four muscles: rectus femoris, vastus medialis, vastus lateralis, and vastus intermedius. Quadriceps muscle strength helps keep the patella on track as the knee moves.[9] The imbalance or weakness in this muscle causes the patella to move abnormally and trigger PFPS. An essential role in controlling knee extension and flexion is reducing excess pressure on the patellofemoral with an evenly distributed load to avoid the risk of inflammation and reduce stress on other knee structures.[10] Quadriceps muscle strengthening exercises are needed to prevent the onset of PFPS conditions, especially in high activity, such as in level 1 athletes.[4]

Misalignment of the patella is also said to contribute to the development of PFPS. Typically, the sides of the patella and the trochlear groove wall in the bent knee should be almost parallel.[11] If the patella is misaligned, bending the knee will push the patella out laterally. Repeated lateral displacement of the patella will cause maltracking or abnormal movement, and excessive friction between the patella and the femoral condyle can cause pain around the patella. The change in patella position is caused by an imbalance between the medial and lateral patella due to dysfunction of the vastus medialis obliques (VMO) muscle.[12] Impaired patellar joint mobility plays a role in pain that develops in medial hypermobility or lateral retinaculum, which can increase joint load during knee flexion.[13] The presence of weak medial patellofemoral ligament strain, changes in knee shape, and physical activity involve heavy load on the knee joint, which can also trigger changes in patella position to predict impaired knee function and the cause of PFPS.[14] This literature review was conducted to explore the relationship between quadriceps muscle strength, patella position, knee function, and patellofemoral pain syndrome in level 1 athletes. The findings aim to enhance readers' and authors' understanding and knowledge.

Methods

This research used the literature review method. The preparation of this research utilized secondary data from research journals obtained from various sources of published scientific journal databases. Scientific journals on the internet related to the relationship between quadriceps muscle strength and patella position to knee function and patellofemoral pain syndrome in level 1 athletes were found online through searches on PubMed and Google Scholar using the keywords "Quadriceps muscle strength," "Patellofemoral Pain Syndrome," "Patella Tendon," "Knee Function," "Ultrasound," and "Patella Position."

The selected literature was chosen based on inclusion and exclusion criteria. The inclusion criteria used in this literature review were: 1) literature published by credible institutions, 2) literature related to PFPS, knee function, quadriceps muscle, and patella position, and 3) literature that measured quadriceps muscle and patella position concerning knee stability and PFPS. Exclusion criteria in this literature review were: 1) literature not related to PFPS, knee function, quadriceps muscle, or patella position, and 2) literature that did not measure the quadriceps muscle and patella position concerning knee stability and PFPS. The literature used in the literature review met the inclusion criteria set by the author.

Results

Based on the results of the literature search, five pieces of literature were obtained related to the research title written in Table 1. The research results by Handel Guney et al. mentioned that the correlation between eccentric and concentric strength of the quadriceps muscle was found in the legs involved in PFPS lower than the healthy legs.[15] The mean value of quadriceps eccentric strength was 76.8% at an angular velocity of 60° and 55.6% at an angular velocity of 180°, while the mean value of quadriceps concentric strength was 89.3% at an angular velocity of 60° and 80.5% at an angular velocity of 180°.[15] The study mentioned a negative correlation between quadriceps eccentric strength and knee joint position at an angular velocity of 60°/s (r = -0.30, p = 0.04) and an angular velocity of 180°/s (r = -0.29, p = 0.04) with 20° target joint position angle. Quadriceps eccentric strength at 60°/s angular velocity was negatively correlated with the 60° target joint position angle (r = -0.37, p = 0.01).12 Quadriceps concentric strength was negatively correlated only with 20° target joint position angle at 60°/s (r = -0.53, p < 0.001) and 180°/s (r = -0.31, p = 0.03). Quadriceps eccentric strength was significantly correlated with pain level during stair descent (r = -0.49, p = 0.01), squatting (r = -0.33, p = 0.02), and sitting (r = -0.38, p = 0.01) at 60°/s angular velocity only. Correlations between quadriceps concentric strength and pain during stair

P-ISSN: 2830-6317
E-ISSN: 2962-5491

climbing, squatting, and sitting were negatively correlated at 60 and 180°/*s* angular velocity (all $p < 0.05$). The correlation between functional outcome (kujala score) and pain level with concentric and eccentric quadriceps strength was significant in PFPS patients at 60°/s angular velocity with kujala score (r =-0.60, $p < 0.001$). [15]

KPC Kinesiology and Physiotherapy Comprehensive

P-ISSN: 2830-6317
E-ISSN: 2962-5491

Table 1. Summary of journals relevant to the research title

Author	Research Title	Methods	Results
Hande Guney, Inci Yuksel, Defne Kaya, Mahmut Nedlm Doral	The relationship between quadriceps strength and joint position sense, function outcome, and painful activities in patellofemoral pain syndrome	Study Design: Case-control prospective Sample size: 46 people Independent variables: Quadriceps muscle strength, patella position, pain. Dependent variable: PFPS Statistical test: Histogram test, Q plot, Kolmogorov-Smirnov test Measurement tools: Dynamometer, VAS, Kujala score 6.	1. Eccentric quadriceps muscle strength: 60° : p <0.001 180° : p <0.04 2. Concentric quadriceps muscle strength: c. 60°: p <0.001 d. 180°: p <0.001 3. Knee joint position: e. 20°: p <0.001 f. 60°: p <0.001 4. Average pain: g. Climbing stairs: 4.9 h. Descending stairs: 7.7 i. Squatting: 6.5 j. Prolonged sitting: 5.1 5. Average Kujala score: 50.6
Consuelo B Gonzalez-Suarez , Cherie-Lee A Apiag, Kris A. Agarao, Fe T. Chavez, Reil V. Espino, Saul A. Sibayan, Mark A. Serra, Ken E. Sosa and Ivan . Gomez	Sonographic evaluation of patellar tendon displacement and its correlation with patellofemoral pain syndrome	1. Study design: Cross-sectional 2. Sample size: 34 people 3. Independent variable: Patellofemoral pain syndrome (PFPS). 4. Dependent variable: Patellar tendon displacement 5. Statistical tests: SPSS, Independent t-test, Mann-Whitney U test, Pearson correlation, and post hoc analysis 6. Measurement tool: ultrasound	1. Displacement of the patellar tendon a. Supine (p=0.82). With PFPS: Mean rank 35.02, median -1. Without PFPS: Mean rank 34.04, median -1 b. Standing (p=0.02). With PFPS: Mean rank 39.20, median -2. Without PFPS: Mean rank 35.94, median -2

Kinesiology and Physiotherapy Comprehensive

P-ISSN: 2830-6317
E-ISSN: 2962-5491

Table 1. continued

Serkan Tas, Seval Yilmaz, Mehmet Ruhi Onur, Abdullah Ruhi soylu, Onur Altutas, Feza Korkusuz	Patellar tendon mechanical properties change with gender, body mass index, and quadriceps femoris muscle strength	1. Study design: Prospective study 2. Sample size: 67 people 3. Independent variable: Patellar tendon thickness and strength 4. Dependent variables: Gender, BMI, Quadriceps femoris muscle strength 5. Statistical test: SPSS, Kolmogorove Smirnov/Shapiroe Wilk test. 6. Measurement tools: Ultrasound, Dynamometer	1. Patellar tendon thickness (ICC: 0.947-0.956) a. QF muscle strength: Peak torque 60°/s: r=0.45 (p<0.001) 2. Patellar tendon stiffness (ICC: 0.947-0.966) a. QF muscle strength: Peak torque 60°/s: r=0.44 (p<0.001)
Ailsa Amany, Heri Priatna	Hubungan sudut Q-angle terhadap fungsional knee pada kasus patellofemoral pain syndrome	1. Study design: Non-experimental, correlation study 2. Sample size: 25 people 3. Independent variable: Q-angle 4. Dependent variable: Functional knee 5. Statistical tests: Spearman correlation test, Shapiro Wilk test. 6. KOOS, Goniometer	1. Q-angle: p=0.012 (p<0.5) 2. KOOS: p=0.011 (p<0.5) data is not normally distributed.
Joseph K.W. Chiu, MSc Yiu-ming Wong, PhD Patrick S.H.Yung, FRCS Gabriel Y.F. Ng, PhD	The effects of quadriceps strengthening on pain, function, and patellofemoral joint contact area in persons with patellofemoral pain	1. Study design: Prospective independent group 2. Sample size: 14 people 3. Independent variable: Quadriceps muscle strengthening 4. Dependent variable: Knee pain, knee function 5. Statistical test: SPSS, t-test 6. Measurement tool: Kujala score	1. Subjects with PFPS increased joint contact area after the exercise program (p<0.001) 2. Isokinetic & isometric knee strength increased after the exercise program (p=0.007 to p=0.05) 3. Pain and knee function improvement (p<0.001) 4. Kujala score (p<0.001) 4.

PFPS, patellofemoral pain syndrome: VAS, visual analog scale: ultrasound, ultrasonography: Kujala score, Kujala score: KOOS, knee injury, and osteoarthritis outcome score, PT: Patellar tendon: QF, Quadriceps femoris

P-ISSN: 2830-6317
E-ISSN: 2962-5491

A study conducted by Consuelo B Gonzalez-Suarez et al., with ultrasound evaluation, assessed patellar tendon displacement in supine and standing positions using ultrasound. A significant difference was found in tendon displacement during standing with greater displacement in subjects with PFPS (Mean rank=39.20 and Median= -2) compared to subjects without PFPS (Mean rank=30.32 and median= -2) *p*-value=0.02.16 Displacement in the supine position was not more significant for the PFPS group (Mean rank=35.02 and median= -1) *p*-value=0.82. There was no significant difference between the two groups for patellar tendon displacement from the prone position and patellar lateral displacement from the supine to standing position ($p = 0.44$).[16]

Research conducted by Sarkan Tas et al. used ultrasound as a measuring tool for the patellar tendon. The results showed a correlation (ICC=0.934-0.953) of patellar tendon thickness and (ICC=0.947-0.966) patellar tendon stiffness is very high, indicating consistent and reliable measurements. The average patellar tendon thickness was 0.8±1.3 m/s, patellar tendon stiffness was 0.39±0.07mm, and peak torque at 60°/*s* was 158.7±48.4 Nm. Patellar tendon strength at peak torque at 60°/s was higher in the obese group compared to the normal weight group ($p < 0.05$).[17] BMI had a moderate correlation with patellar tendon thickness $r = 0.54$ ($p < 0.001$) and a low correlation with peak torque at 60°/*s* $r = 0.45$ ($p < 0.001$). In patellar tendon stiffness, there was a moderate correlation with patellar tendon thickness $r = 0.44$ ($p < 0.001$).17 The study explained that quadriceps muscle strength was related to tendon thickness.[17]

The research was conducted by Ailsa Amany and Heri Priatna, who described the results of Q-angle measurements with a goniometer and functional knee with KOOS in PFPS cases.[14] The measurement of the Q-angle angle with a normality test that the *p*-value = 0.012 means ($p < 0.05$) that the data is not normally distributed. In the measurement of knee function, the value of $p = 0.011$ means ($p < 0.05$), or the data is not normally distributed. Q-angle and functional knee in PFPS cases, namely the value of $p = 0.454$ ($p > 0.05$), show no relationship between Q-angle and functional knee in PFPS cases.[14]

Research conducted by Joseph K.W. Chiu, MSc et al., in a study with an exercise program for eight weeks, including leg press and knee extension exercise for each exercise of 4 sets and 10x repetitions with a 1-minute break between sessions. The study showed results on increasing the contact area of the patellofemoral joint; namely, subjects with PFPS increased joint contact area after the exercise program with a value of $p < 0.001$.[11] Increased muscle strength both isometric or isokinetic increased after the exercise program in with and without PFPS ($p = 0.05$). On pain reduction and functional improvement of the knee, it was found that the pain scale decreased significantly ($p < 0.001$). At the same time, the patellofemoral Kujala score increased significantly after the exercise program ($p < 0.001$), indicating the program's effectiveness in reducing the symptoms of PFPS.[11]

Discussion

PFPS is a condition that causes anterior knee pain. PFPS is also known as a runner's knee.[4] Individuals affected by PFPS are often athletes who participate in sports, including jumping, spinning, and others. It is reported that the incidence of injuries encountered in medical clinics is almost 25% to 40% due to knee problems.[4] PFPS is also one of the injuries that result from overloading the knee, such as in soccer, futsal, basketball, and volleyball. There is usually a 2-10 times higher incidence of PFPS in females than in males. Athletes with PFPS symptoms cause restrictions on sports and other physical activities. Even 74% of patients cause discontinuation of sports.[4] Patients with PFPS have a pain time that can last for years with the possibility of causing long-term patellofemoral osteoarthritis and have a risk of ACL (Anterior Cruciate Ligament) injury.[18]

PFPS is a pain in the peripatellar or retropatellar region that can worsen in activities that overload the patellofemoral joint during weight bearing on the bent knee.[19] PFPS is usually caused by an imbalance in the forces that control patellar motion during knee flexion and extension, mainly when joint loading occurs. PFPS can also be associated with genu recurvatum, valgus knee, quadriceps weakness, and other dysfunctions. People suffering from PFPS often feel pain in the back or under or around the kneecap, and it is often difficult to localize. PFPS symptoms usually appear gradually and may occur bilaterally.[20,21]

For example, when squatting, climbing stairs, jogging or running, and jumping.[5] Overload knee injuries have extrinsic risk factors such as the type and volume of exercise, environmental conditions, and field surfaces. In addition, intrinsic factors related to individual characteristics are as follows: quadriceps muscle weakness, especially VMO, hip muscle dysfunction, hamstring muscle tension, core muscle endurance, quadriceps tightness, patellar hypermobility, and patellar misalignment.[4] The severity of symptoms arising from PFPS often has limitations in physical activity, potentially reducing quality of life (QoL).[10] Knee-related quality of life can be measured by KOOS (Knee Injury and Osteoarthritis Outcome Score).[22] Individuals with PFPS and a low KOOS score have a poorer quality of life regarding knee health or knee function than ordinary people.[6]

Quadriceps muscle strength in people with PFPS usually tends to weaken. According to a study by Handel Guney et al., concentric quadriceps strength was almost 30% lower in PFPS patients compared to a healthy group, while eccentric strength decreased by 40%.[15] Therefore, activities that require eccentric control trigger more pain in PFPS patients. Functional movements require proper regulation of joint and muscle position strength. Abnormal knee joint position also leads to musculoskeletal pathology by altering lower limb alignment, which leads to increased

P-ISSN: 2830-6317
E-ISSN: 2962-5491

patellofemoral pain during daily activities. The most important factor affecting the functional level of patients with PFPS is the loss of quadriceps muscle strength, influencing knee pain and function in PFPS patients.[15]

Patellar misalignment is also one of the leading causes of PFPS, as well as the patella's position and muscle strength. Quoted from the article of Consuelo B et al., the position of the patella focusing on the patellar tendon is measured using ultrasonography to determine the presence of patellar tendon shift.[16] Decreased quadriceps muscle strength, especially the VMO muscle, contributes to loss of knee stability, resulting in suboptimal patellar position, namely lateral shift and PFPS. Individuals with PFPS are also associated with patellar maltracking, which contributes to the occurrence of pain. Maltracking patella is also characterized by lateral translation of the patella during full extension. Factors contributing to excessive patella lateral tracking include a large quadriceps angle and patellofemoral ligament laxity.[16] Conditions where the position of the patella is abnormal, such as patellar tilt, have a significant effect on the onset of patellofemoral pain. This is a risk for functional knee deterioration due to the pain caused.[16] Research conducted by Serkan Tas et al. also mentioned that increasing quadriceps muscle strength is associated with patellar tendon thickness and cross-sectional area due to increased mechanical load on the tendon.[17] In terms of research conducted by Joseph K.W. Chiu, MSc et al. showed that a quadriceps muscle strength training program can reduce mechanical stress on the joint, changes in the angle of inclination of the patella, and a decrease in the level of pain felt in subjects with PFPS. It can be concluded that exercise programs are also effective as rehabilitation to reduce symptoms of PFPS.[17]

This study has several limitations inherent in its methodology and scope. Firstly, the research relied exclusively on the literature review method, which may limit the depth of analysis compared to primary data collection. Secondly, the research was confined to online scientific journals, specifically those indexed in PubMed and Google Scholar. This may have omitted relevant studies published in other databases or non-digitized formats, creating a potential selection bias. Furthermore, the study focused on literature related to the relationship between quadriceps muscle strength and patella position concerning knee function and patellofemoral pain syndrome in level 1 athletes. This narrow focus may limit the generalizability of the findings to other populations, such as non-athletes or athletes of different levels.

Conclusion

Based on some of the literature that has been found, the researcher can conclude that there is a possible relationship between quadriceps muscle strength and patella position on knee function and patellofemoral pain syndrome because, with adequate quadriceps muscle strength, especially the VMO muscle can maintain knee stability and optimal patella position to reduce stress on the patellofemoral joint and reduce the risk of injury. A quadriceps muscle strength training program to maintain good patella position can improve knee function and prevent PFPS in level 1 athletes.

Ethical consideration

The review study utilized publicly available articles, so informed consent and ethical considerations were unnecessary.

Funding

This study found no sources of grant funding.

Conflict of interest

The author declares that no potential conflicts of interest are related to this paper's research, writing, or publication.

Author contributions

GRY developed the study design, oversaw data collection, and drafted the manuscript, while IPGSA and AW collected and reviewed the data.

References

1. Thomeé R, Augustsson J, Karlsson J. Patellofemoral pain syndrome. A review of current issues. Sports Med. 1999; 28: 45-53.
2. Lankhorst NE, Bierma-Zeinstra SMA, Van Middelkoop M. Risk factors for patellofemoral pain syndrome: A systematic review. J Orthop Sports Phys Ther. 2012; 42(2): 81-94.
3. Halabchi F, Mazaheri R, Seif-Barghi T. Patellofemoral pain syndrome and modifiable intrinsic risk factors; how to assess and address? Asian J Sports Med. 2013; 4(2): 85-100.
4. Halabchi F, Abolhasani M, Mirshahi M, Alizadeh Z. Patellofemoral pain in athletes: clinical perspectives. Open Access J Sports Med. 2017; 8: 189-203.
5. Walli O, McCay M, Tiu T. Patellofemoral Syndrome: a Review of Diagnosis and Treatment. Curr Phys Med Rehabil Rep. 2023; 11: 52-60.
6. Reijnders L, Van de Groes SAW. The quality of life of patients with patellofemoral pain - a systematic review. Acta Orthop Belg. 2020; 86: 45-52.
7. Nair T, Kumar GP. Correlation Between Severity of Symptoms and Quality of Life in Patellofemoral Pain Syndromes: A Cross-Sectional Study. Cureus. 2023; 15(4): 1-7.
8. Faisal Chevidikunnan M, Al Saif AM, Allah Gaowgzeh R, Mamdouh K. Effectiveness of core muscle strengthening for improving pain and dynamic balance among female patients with patellofemoral pain syndrome. J Bodyw Mov Ther. 2022; 29: 49-55.
9. Waryasz GR, McDermott AY. Patellofemoral pain syndrome (PFPS): A systematic anatomy review and potential risk factors. Dyn Med. 2008; 7(9): 1-14.
10. Coburn SL, Barton CJ, Filbay SR, Hart HF, Rathleff MS, Crossley KM. Quality of life in individuals with patellofemoral pain: A systematic review including meta-analysis. Phys Ther Sport. 2018; 33: 36-47.
11. Chiu JKW, Wong YM, Yung PSH, Ng GYF. The effects of quadriceps strengthening on pain, function, and patellofemoral joint contact area in persons with patellofemoral pain. Am J Phys Med Rehabil. 2012; 91(2): 98-106.
12. Putra PWK, Antana IWA, Laksmi IAA. Selektif vastus medial obliquus exercise menurunkan derajat nyeri dan pencapaian range of motion pasien dengan patellofemoral pain syndrome. J Ilmu Teknol Kesehat. 2019; 6(2): 102-108.
13. Jayaseelan DJ, Holshouser C, McMurray MW. Functional joint mobilizations for patellofemoral pain syndrome: A clinical suggestion. Int J Sports Phys Ther. 2020; 15(4): 563-568.

P-ISSN: 2830-6317
E-ISSN: 2962-5491

14. Amany A, Priatna H, Fisioterapi F, Unggul E. Hubungan sudut q-angle terhadap fungsional knee pada kasus patellofemoral pain syndrome. Jurnal Fisioterapi. 2019; 19(2): 23-30.
15. Guney H, Yuksel I, Kaya D, Doral MN. The relationship between quadriceps strength and joint position sense, functional outcome, and painful activities in patellofemoral pain syndrome. Knee Surg Sports Traumatol Arthrosc. 2016; 24(9): 2966-2972.
16. Gonzalez-Suarez CB, Apiag CLA, Agarao KA, Chavez FT, Espino RV, Sibayan SA, et al. Sonographic evaluation of patellar tendon displacement and its correlation with patellofemoral pain syndrome. J Orthop Trauma Rehabil. 2021; 28: 1-8.
17. Taş S, Yilmaz S, Onur MR, Soylu AR, Altuntaş O, Korkusuz F. Patellar tendon mechanical properties change with gender, body mass index, and quadriceps femoris muscle strength. Acta Orthop Traumatol Turc. 2017; 51(1): 54-9.
18. Boling MC, Padua DA, Marshall SW, Guskiewicz K, Pyne S, Beutler A. A prospective investigation of biomechanical risk factors for patellofemoral pain syndrome: The Joint Undertaking to Monitor and Prevent ACL Injury (JUMP-ACL) Cohort. Am J Sports Med. 2009; 37(11): 2101-9.
19. Akhtar MW, Karimi H, Gilani SA. Effectiveness of core stabilization exercises and routine exercise therapy in chronic non-specific low back pain management: A randomized controlled clinical trial. Pak J Med Sci. 2017; 33(4): 1002-6.
20. Winaya IMN, Nugraha MHS, Adhitya IPGS, Kinandana GP. Efektivitas penambahan mobilization with movement dalam menurunkan nyeri dan meningkatkan kemampuan fungsional lutut pada patellofemoral pain syndrome. FISIO MU: Physiotherapy Evidences. 2023; 4(2): 181-8.
21. Wiguna GLNAA, Setiawan CR. Patellofemoral Pain Syndrome: Literature Review. Int J Sci Res Publ. 2022; 12(5): 21-29.
22. Ihsan M, Wibawa A, Muliartha IM, Tianing NM. Indonesian Version of the Anterior Cruciate Ligament-Return to Sport After Injury Questionnaire Through Cross-Cultural Adaptation, Validity, and Reliability Testing. Phys Ther J Indones. 2022; 3(1): 11-8.