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# Squat and patellofemoral pain syndrome: protocol for a systematic review

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**Abstract**

Background: Patellofemoral Pain Syndrome (PFPS) represents anterior knees' diseases. The PFPS is a multifactorial disease, with high prevalence. It presents a direct relationship of deterioration through the act of squatting, descending and climbing stairs, interfering both in working and daily activities. The main purpose of the study will be to find evidence of the direct relationship between the variations of squatting during muscular daily physical exercises and the patellofemoral disease. Methodology: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) Statement was used to elaborate the adequate research guidelines to address the research objective. Seven databases will be accessed (Academic Search Complete, Scopus, Science Direct, Web of Science, PubMed, Informaworld by Taylor & Francis, and Medline via PMC) and, at least, 10 keywords will be combined. Study appraisal and synthesis methods: One author will independently screen titles and abstracts against the eligibility criteria at first, and full-texts of potentially eligible records at a second phase, followed by extraction of data from qualifying studies. Two review authors will also assess the risk of bias and the quality of evidence, using the Cochrane Collaboration's Tool, Rob 2.0. This protocol is registered in PROSPERO under the code CRD42019128711.

## 1. INTRODUCTION

### Background

According to the Consensus on Patellofemoral Pain, the Patellofemoral Pain Syndrome (PFPS), represents anterior knees' diseases such as chondromalacia patellae, anterior knee pain syndrome and the runner's knee and patellofemoral tendon disease, being, or not, associated with other pathologies such as Knee Osteoarthritis (Collins et al., 2018; Crossley et al., 2016; Powers, Witvrouw, Davis, & Crossley, 2017). In 2017 and 2018 the updates in the topic during the International Consensus on Patellofemoral Pain (Collins et al., 2018; Powers et al., 2017) schematically determined the leading causes of the disease, demonstrating that PFPS could be caused by cartilage and bone stress during functional tasks of the patellofemoral joint, having two main predisposing factors:

1) Decrease in the contact space of the patellofemoral joint caused by patellar misalignment or its maladjusted movement, which may occur due to an alteration in bone structure or imbalance of the hip and femur musculature;

2) Increase of force reactions on the patellofemoral joint occurring due to:
   - Decreased forces of the posterior and anterior muscles of the thigh (Collins et al., 2018)

- Alterations in the kinetics of movement of the tibia-femoral joint caused by changes in the force imposed on the joint in relation to the muscular imbalance of the trunk and hip, or alteration in the movement of the feet and ankles (Besier et al., 2015; Ho, Hu, Colletti, & Powers, 2014; Powers, Bolgla, Callaghan, Collins, & Sheehan, 2012; Powers, Ho, Chen, Souza, & Farrokhi, 2014; Powers et al., 2017; Wirtz, Willson, Kernozek, & Hong, 2012)

Through research developed by Powers et al. (2017) it was demonstrated that the causes of patellofemoral pain could be determined due to stress forces in the bone or the cartilage of the patellofemoral joint. In that case, pain is always intense and has the same characteristics of the pain in the anterior region of the knee or even retropatellar pain, which worsens with certain movements such as crouching down, climbing or descending stairs, and squat. It is described as pain without irradiation, characteristically a stabbing pain (Liporaci, Saad, Felício, Baffa, & Grossi, 2013).

Patellofemoral pain is common throughout active individuals' lives and is a frequent cause for seeking medical care in Physiotherapy, General Medicine, Orthopedics, Sports Medicine and possibly in other related specialties (Powers et al., 2017).

Contextualizing this matter into the working environment, it can be observed that within tasks involving loads movement with squat, a direct relationship between the act of squatting and the occurrence of those pathologies is evidenced (Dali, Justine, Ahmad, & Othman, 2013; Lee et al., 2016; Sadler, Graham, & Stevenson, 2013). They affect more females than males in a proportion of two women for each man, with a prevalence of approximately 11-14% on physically inactive population and of 25-40% on those performing any physical activity (Van Middelkoop, Van Linschoten, Berger, Koes, & Bierma-Zeinstra, 2008; Wood, Muller, & Peat, 2011). Furthermore, it can reach up to 23% in adults, 29% in adolescents, 13.5% in the military and 36% in cycling professionals (Collins et al., 2018; Smith et al., 2018).

### Objective

In the perspective of the Patellofemoral Pain Syndrome, this condition could worsen due to many factors, including the act of squatting (Crossley et al., 2016; Powers et al., 2017). Following the referred Consensus on Patellofemoral pain, the systematic review intends to find evidence on results related to the exercise therapies suggested as necessary to be developed (Collins et al., 2018).

The main objective of this work is to define a protocol for a systematic review seeking to find evidence of the direct relationship between the variations of squatting during muscular daily physical exercises and the patellofemoral disease.

## 2. METHODOLOGY

To develop this protocol, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P) guidelines were used (Moher et al., 2009; Shamseer et al., 2015). This protocol is registered in PROSPERO under the code CRD42019128711.

### Eligibility criteria

### 2.1. Report characteristics

The information search will be completed in two or three steps, depending on the results found. As so, in the first step, literature available from 2014 will be searched, considering only published articles and article in press, in English, and published in journals with peer-review.

In the succeeding steps, articles, and other works published before 2014 will be considered, and snowballing procedures (Wohlin & Claes, 2014) will be followed. For the cases in which the peer-review process fails (potentially weakening quality and exemption), authors will assume the role of reviewers.

### 2.2. Study characteristics

*Participants*

The research will focus on investigations developed on human subjects with no gender or age restrictions, healthy or with knee injuries. Studies developed on humans with prosthesis and orthoses, and studies with animal targets or corpses will be excluded.

*Type of interventions*

Interventions are accepted and evaluated if they approach:

- The evaluation of the muscles of the thigh, leg, and gluteus through electromyography (EMG) and/or video analysis and/or motion kinetics.
- The assessment of the knee or hip joints during squat movements, by video and/or kinetic analysis.

The patellofemoral pain syndrome and its relationship with different squatting movements will also be evaluated if they fulfill the above mentioned criteria. Studies focused on other muscles or joints will be excluded.

*Study design*

Inclusion criteria consider case studies, cohort studies, and cross-sectional studies that evaluate muscles responsible for the movements related to the studied joints, within any type of exercise that involves squatting. Restrictions on the studies durations will not be applied.

### 2.3. Information sources

The following electronic databases will be searched: Academic Search Complete, Scopus, Science Direct, Web of Science, PubMed, Informaworld by Taylor & Francis, and Medline (via PMC). For all keyword combinations, databases filters will be used: publication year (≥2014), document type (articles and articles in press), source type (journals and trade publications) and language (English) The research will be conducted from February to April 2019.

### 2.4. Search strategy

The search strategy includes the combination of the following keywords: squat, “squat technique”, “musculoskeletal disorder”, “musculoskeletal disease”, knee, “knee pain”, syndrome, “patellofemoral pain”, “functional task”, worker.
As a result, 14 combinations are going to be used:

1. squat AND "musculoskeletal disorder" AND worker
2. squat AND "musculoskeletal diseases" AND worker
3. “squat technique”
4. squat AND syndrome AND worker
5. squat AND worker AND Knee AND NOT osteoarthritis
6. "squat technique" AND knee AND patellofemoral
7. squat AND knee AND syndrome AND NOT osteoarthritis AND NOT "low back"
8. “knee pain” AND worker
9. "musculoskeletal disorder" AND “patellofemoral pain" AND NOT Osteoarthritis AND NOT "low back" AND NOT ankle
10. "musculoskeletal disease" AND “patellofemoral pain”
11. squat AND "functional task"
12. "functional task" AND "patellofemoral pain" AND NOT Osteoarthritis AND NOT ankle AND NOT "low back"
13. "patellofemoral pain" AND worker AND NOT Osteoarthritis AND NOT ankle AND NOT "low back"
14. “Knee pain” AND worker

New keywords can be integrated later if they are found in this primary step. When possible, the search will be performed in the title, abstract and keywords of the records. In the data sources in which this is not possible, fields used for selection of the records will be registered and reported.

### 2.5. Study records

#### 2.5.1 Data management

Data management will vary according to the information source:

- *Records directly identified through the databases and with peer reviews.* Studies selected from these sources will be directly saved with the help of a reference manager software (Mendeley).
- *Records from other various sources, such as conference articles, opinion articles, reports, thesis, and dissertations.* Before being saved in the above-mentioned software,

these records will be analyzed by the review team in order to validate the provided information.

Information management through Mendeley will improve the review process. After identification of the records to be analyzed, data extraction will be performed record by record, to a customized Excel table. In this table, every row will correspond to a different record, and each column to one of the parameters to be extracted from each article.

### 2.5.2 Selection process

During a first screening phase, records obtained with every combination will be selected automatically according to the publication year (≥2014), document type (articles and articles in press), source type (peer-reviewed journals) and language (written in English). Given the automatic features of this process, it will be performed by only one member of the review team.

Within the remaining records, a verification of their alignment with the research question and the objectives of the review will be performed. This procedure will be done by one of the elements of the team who will be in charge of rejecting all the articles found to be unequivocally out of topic and analysis.

This phase will be completed based on screening the title and abstract only. Articles in which doubts emerge will be analyzed and discussed by a second team member after a full-text reading. For the articles in which a consensus cannot be reached between the two team members, a third element will make the final decision after an own analysis of the study. All articles found in this last group will be reported in the review article, despite its acceptance or rejection in this last screening phase.

Once the screening phase is completed, eligibility procedures will take place. These procedures include the verification of several aspects for which a full-text reading of each record is necessary. Consequently, studies will only be accepted if they fulfill all these minimum criterions:

- Inclusion of healthy humans or with knee injuries, but without any prosthesis or orthoses.
- Medical evaluation or by a qualified professional.
- Description of the relationship between squat and PFPS and/or strain on the knee joint.
- Approach thigh, leg and gluteus musculature, evaluated through EMG and/or video analysis and motion kinetics.
- Evaluation of the knee or hip joints during movement, using video analysis and motion kinetics.
- Study of the patellofemoral disease and its relationship with any type of physical exercise.

### 2.5.3 Data collection process

From each of the selected studies, the full-text will be analyzed with the objective of collecting information according to the proposed objectives. The extracted information will include:

- General information: authors, publication year, country.
- Population: athletes/workers, type of developed activities.
- Sample: size, gender distribution, mean age, BMI.
- Study characteristics: goals, assessed parameters, procedures/methods, equipment, and software, conclusions.
- Parameters: type of exercise, muscles, and joints involved, tensions on muscles tendons, applied interventions, results, studies characteristics.
- Studies limitations.
- Quality assessment: possible risks of bias (risk of selection bias, precision, risk of information bias, risk of investigator bias), reporting (assessment of the overall study quality), external validity (assessment of whether the study results are generalizable), internal validity (assessment of bias due to study sample selection and/or confounding), power (assessment of whether study results could be obtained by chance).

During the data collection process, each article will be thoroughly evaluated considering both its qualitative and quantitative data.

### 2.6. Outcomes and prioritization

The primary outcomes proposed for this work are the following:

- Identification of the techniques that can potentially increase the risk of patellofemoral injury, within all the possible movements that can be performed within squat (such as single Leg, Double Leg, Leg Press, Back Squat, Walking lunge and Split Squat).
- Verification of the existence of evidence to confirm the possibility of using squats as rehabilitation tools in muscle strengthening, with no risk of knee joint injury and, if so, how and under what conditions it should be done

Correspondingly, as secondary outcomes are the following:

- Identification of contraindications between the different types of exercises performed in strengthening and rehabilitation. Taking into account the risk of aggravation of patellofemoral disease described in the available literature, during the execution of squats.
- Identification of alternative exercises to squatting, in particular in weight training, considering the PFPS risk.

### 2.7. Risk of bias in individual studies

The risk of bias will be assessed independently by two reviewers. Quality of selected articles will be assessed using the Cochrane Collaboration's Tool for assessing the risk of bias, RoB 2.0 (Higgins et al., 2011).

Selected components for evaluation will include: participants selection process, intervention procedures, used tools and equipment, and analysis of results. Quality of each component will be ranked as "high", "low" or "unclear". If disagreements emerge, they will be solved by a discussion between reviewers and a third one will be designated to solve any additional divergences.

### 2.8. Data synthesis

A narrative and qualitative synthesis will be conducted, with basis on the risk of bias and quality of selected articles. Results from each study will be evaluated according to their aimed objectives and will be classified in the following groups: motion biomechanics, participants' anatomic variations and the relationship between the motion kinetics and the different muscular contraction forces of the lower limbs muscles.

Furthermore, all studies will be narratively described and compared, relating extracted information to the study's objective. Through this narrative, it will be possible to obtain a clear comparison of the interventions effects, and the identified results.

### 2.9. General information

#### 2.9.1 Authors' contributions

Study design: PMP
Study Coordination: PMP
Title-/ abstract screening: PMP
Full-text screening: PMP
Data extraction: PMP
Critical appraisal: PMP
Data analysis and interpretation: PMP, JD, JF, JTC, FC
Draft of the manuscript: PMP, JD

#### 2.9.2 Support

The University of Porto provided access to all the necessary information through its library resources.

All authors read and approved the final version.

## REFERENCES


Besier, T. F., Pal, S., Draper, C. E., Fredericson, M., Gold, G. E., Delp, S. L., & Beaupré, G. S. (2015). The Role of Cartilage Stress in Patellofemoral Pain. *Medicine and Science in Sports and Exercise*, *47*(11), 2416–2422. https://doi.org/10.1249/MSS.0000000000000685

Collins, N. J., Barton, C. J., Van Middelkoop, M., Callaghan, M. J., Rathleff, M. S., Vicenzino, B. T., … Crossley, K. M. (2018, June 20). 2018 Consensus statement on exercise therapy and physical interventions (orthoses, taping and manual therapy) to treat patellofemoral pain: Recommendations from the 5th International Patellofemoral Pain Research Retreat, Gold Coast, Australia, 2017. *British Journal of Sports Medicine*, p. bjsports-2018-099397. https://doi.org/10.1136/bjsports-2018-099397

Crossley, K. M., Stefanik, J. J., Selfe, J., Collins, N. J., Davis, I. S., Powers, C. M., … Callaghan, M. J. (2016). 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome m. *Br J Sports Med*, *50*(14), 839–843. https://doi.org/10.1136/BJSPORTS-2016-096384

Dali, S., Justine, M., Ahmad, H., & Othman, Z. (2013). Comparison of ground reaction force during different angle of squatting. *Journal of Human Sport and Exercise*, *8*(3). https://doi.org/10.4100/jhse.2013.83.02

Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., … Sterne, J. A. C. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ (Online)*, *343*(7829), 1–9. https://doi.org/10.1136/bmj.d5928

Ho, K.-Y., Hu, H. H., Colletti, P. M., & Powers, C. M. (2014). Recreational runners with patellofemoral pain exhibit elevated patella water content. *Magnetic Resonance Imaging*, *32*(7), 965–968. https://doi.org/10.1016/J.MRI.2014.04.018

Lee, S.-J., Jin, D.-Y., No, H.-J., Kwon, S.-J., Yoon, M.-H., Jung, Y.-J., … Lee, D.-Y. (2016). The effects of squat exercises on the space between the knees of persons with genu-varum. *Indian Journal of Science and Technology*, *9*(25). https://doi.org/10.17485/ijst/2016/v9i25/97206

Liporaci, R. F., Saad, M. C., Felício, L. R., Baffa, A. do P., & Grossi, D. B. (2013). *Contribuição da avaliação dos sinais clínicos em pacientes com síndrome da dor patelofemural*. *Acta Ortopédica Brasileira* (Vol. 21). https://doi.org/10.1590/s1413-78522013000400003

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., Altman, D., Antes, G., … Tugwell, P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine*, *6*(7). https://doi.org/10.1371/journal.pmed.1000097

Powers, C. M., Bolgla, L. A., Callaghan, M. J., Collins, N., & Sheehan, F. T. (2012). Patellofemoral Pain: Proximal, Distal, and Local Factors—2nd International Research Retreat, August 31–September 2, 2011, Ghent, Belgium. *Journal of Orthopaedic & Sports Physical Therapy*, *42*(6), A1–A54. https://doi.org/10.2519/jospt.2012.0301

Powers, C. M., Ho, K.-Y., Chen, Y.-J., Souza, R. B., & Farrokhi, S. (2014). Patellofemoral Joint Stress During Weight-Bearing and Non—Weight-Bearing Quadriceps Exercises. *Journal of Orthopaedic & Sports Physical Therapy*, *44*(5), 320–327. https://doi.org/10.2519/jospt.2014.4936

Powers, C. M., Witvrouw, E., Davis, I. S., & Crossley, K. M. (2017). Evidence-based framework for a pathomechanical model of patellofemoral pain: 2017 patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester, UK: part 3. *British Journal of Sports Medicine*, *51*(24), 1713–1723. https://doi.org/10.1136/bjsports-2017-098717

Sadler, E. M., Graham, R. B., & Stevenson, J. M. (2013). Gender difference and lifting technique under light load conditions: a principal component analysis. *Theoretical Issues in Ergonomics Science*, *14*(2), 159–174. https://doi.org/10.1080/1463922X.2011.611264

Shamseer, L., Moher, D., Clarke, M., Ghersi, D., Liberati, A., Petticrew, M., … Whitlock, E. (2015). Preferred reporting items for systematic review and meta-analysis protocols (prisma-p) 2015: Elaboration and explanation. *BMJ (Online)*, *349*(January), 1–25. https://doi.org/10.1136/bmj.g7647

Smith, B. E., Selfe, J., Thacker, D., Hendrick, P., Bateman, M., Moffatt, F., … Logan, P. (2018). Incidence and prevalence of patellofemoral pain: A systematic review and meta-analysis. *PLOS ONE*, *13*(1), e0190892. https://doi.org/10.1371/journal.pone.0190892

Van Middelkoop, M., Van Linschoten, R., Berger, M. Y., Koes, B. W., & Bierma-Zeinstra, S. M. (2008). Knee complaints seen in general practice: active sport participants versus non-sport participants. *BMC Musculoskeletal Disorders*, *9*(1), 36. https://doi.org/10.1186/1471-2474-9-36

Wirtz, A. D., Willson, J. D., Kernozek, T. W., & Hong, D.-A. (2012). Patellofemoral joint stress during running in females with and without patellofemoral pain. *The Knee*, *19*(5), 703–708. https://doi.org/10.1016/J.KNEE.2011.09.006

Wohlin, C., & Claes. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering - EASE '14* (pp. 1–10). New York, New York, USA: ACM Press. https://doi.org/10.1145/2601248.2601268

Wood, L., Muller, S., & Peat, G. (2011). The epidemiology of patellofemoral disorders in adulthood: a review of routine general practice morbidity recording. *Primary Health Care Research & Development*, *12*(02), 157–164. https://doi.org/10.1017/S1463423610000460