The Effects of Physical Exercise on Pain Management in Patients with Knee Osteoarthritis: A Systematic Review with Metanalysis

Os efeitos do exercício físico sobre o manejo da dor em pacientes com osteoartrose de joelho: Uma revisão sistemática com meta-análise

Thiago Casali Rocha1 Plínio dos Santos Ramos1 Alessandra Germano Dias2 Elaine Angélica Martins2

1 Faculdade de Ciências Médicas e da Saúde de Juiz de Fora, Hospital e Maternidade Therezinha de Jesus, Juiz de Fora, MG, Brazil
2 Latu Sensu Graduation Program in Traumatic and Orthopedics Physical Therapy, Faculdade de Ciências Médicas e da Saúde de Juiz de Fora, Juiz de Fora, MG, Brazil

Address for correspondence Thiago Casali Rocha, Master, Faculdade de Ciências Médicas e da Saúde de Juiz de Fora, Hospital e Maternidade Therezinha de Jesus, Alameda Salvaterra, 200, Salvaterra, Juiz de Fora, MG, 36033-003, Brazil (e-mail: thiagocasali@physio10.com.br).

Rev Bras Ortop 2020;55(5):509–517.

Abstract

Objective The present study verified, through a systematic review with meta-analysis, the effects of a rehabilitation, physical training program for the treatment of pain and muscle strength in knee osteoarthritis (OA).

Methods We analyzed studies published between 2008 and 2018 referenced at the Medline (National Library of Medicine) database, selecting 7 randomized controlled clinical trials about exercise programs to improve pain and muscle strength in patients with knee OA with Physiotherapy Evidence Database (PeDro) score higher than 8. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) systematization was used to prepare this review, and a meta-analysis was carried out to obtain mathematical evidence the outcomes of physical exercise on pain.

Results The studies included in the analysis contained a total of 934 participants aged 40 to 73 years-old, with 34.90% males. Most of the exercise sets offered in OA treatment had a significantly positive outcome result in both criteria, but mainly for pain relief (statistically significant difference, \( p < 0.003 \)).

Conclusion We infer that there was an improvement of pain in all articles that performed muscle strengthening, but there is still an obstacle to the protocols used.

Keywords ► pain ► muscle strength ► osteoarthritis of knee ► exercise and movement techniques

Resumo

Objetivo O presente estudo verificou por meio de uma revisão sistemática com metanálise os efeitos de um programa de reabilitação, através de um programa de

Work developed at Faculdade de Ciências Médicas e da Saúde de Juiz de Fora, Hospital e Maternidade Therezinha de Jesus, Juiz de Fora, MG, Brazil.

Received November 4, 2018
Accepted March 12, 2019

DOI https://doi.org/10.1055/s-0039-1696681.
ISSN 0102-3616.

Copyright © 2020 by Sociedade Brasileira de Ortopedia e Traumatologia. Published by Thieme Revinter Publicações Ltda, Rio de Janeiro, Brazil

License terms
The Effects of Physical Exercise on Pain in Patients with Knee Osteoarthritis

Rocha et al.

Introduction

Population aging has grown all over the world, increasing the health challenges, especially with regard to the large number of conditions affecting the elderly. Among them, osteoarthritis (OA) stands out. According to Framingham, OA is the second cause of work absenteeism and the main cause of disability in the elderly.

Osteoarthritis is as a degenerative and progressive non-inflammatory joint disease consisting of articular cartilage degradation and subchondral bone alterations. This condition affects the normal synchronous movement of the joint, resulting in pain, stiffness, muscular strength deficit, and joint instability, which can reduce the individual's functional mobility and lead to functional loss. However, it is believed that OA does not result from the aging process, but from biochemical changes and biomechanical stresses affecting joint cartilage.

As such, it is known that knee OA mostly affects females, since, anatomically, in females, the cartilage of this region is thinner, with smaller area and volume, resulting in an increased shear force at the site.

In a randomized controlled trial, Nguyen et al. have shown that exercise therapy is successful in improving the physical performance of patients with knee OA and severe comorbidities. In line with this information, the updated 2014 guidelines from the Osteoarthritis Research Society International (OARSI) considered rehabilitation as the main treatment for OA. Through a meta-analysis, OARSI concluded that exercise therapy associated with strength training and aerobic exercise reduced pain and improved the individual’s physical function.

In a systematic review, Lange et al. evaluated the efficacy of resistance training in the management of knee OA. They observed a general improvement in the symptoms and physical performance of the patients; in addition, these authors verified that more than half of the included studies reported success in the application of resistance training as physical function and muscular strength, which improved significantly when compared to the groups receiving standard care.

Tanakar et al., in a systematic review with meta-analysis of randomized clinical trials, pointed out that aerobic exercises associated with non-weight-bearing strengthening exercises were more effective in relieving pain in short-term activities. However, the literature reports that balance exercises, endurance training and aerobic exercises are associated with pain reduction, stiffness relief, and physical function improvement in patients with knee OA.

As such, we need to understand the efficacy of physical training over knee OA impact factors. There are several evidences on the benefits of some knee OA rehabilitation methods, but the ideal treatment regimen for each condition is still in question. These rehabilitation methods include physical training using methods or programs to promote, maintain or restore the physical and physiological well-being of an individual.

Thus, this study aims to verify controlled and randomized studies through a systematic review of the effects of a rehabilitation, physical training program for pain management and muscle strength in knee OA.

Methods

The most relevant studies originally published in English at the MEDLINE (National Library of Medicine), Scientific Electronic Library Online (SciELO), and Latin American and Caribbean Literature in Health Science database (LILACS) databases between January 2008 and December 2018 were included in our analysis. To select studies with the highest...
scientific evidence, only randomized controlled clinical trials (RCTs) were used for the bibliographic review. The search for scientific papers contained the following combinations of keywords: movement techniques exercise, knee osteoarthritis AND pain AND muscle strength AND proprioception training, as well as their variations at Medical Subject Headings (MeSH).

Inclusion and exclusion criteria are shown in Box 1.

The studies were selected by two independent reviewers; those not related to the review subject or presenting some kind of bias were excluded. To verify the validity of eligible randomized trials, pairs of reviewers working independently and reliably determined the adequacy of randomization regarding exercise protocols performed by the control and intervention groups.

Next, the abstracts of the selected papers were analyzed to identify those meeting the inclusion and exclusion criteria. Papers that did not have any of the study outcomes, did not address knee OA, did not have a specific group, or did not perform any type of exercise, in addition to those that were study protocols, were excluded.

The relevant papers were submitted to a final evaluation according to their score in the Physiotherapy Evidence Database (PEDro) scale to help researchers quickly identify which ones have internal validity and enough statistical information for results interpretation. To be eligible for this systematic review, a minimum PEDro score of eight was required. In addition, the scale proposed by Jadad et al. was employed. This scale consists of 5 criteria, ranging from 0 to 5 points, and a score lower than 3 indicates that the study has low methodological quality and that its results will hardly be extrapolated for other scenarios.

Statistical Analysis
For data on exercise programs and knee pain symptom, a meta-analysis was performed using the Medcalc software, version 15.8 (BVBA, Ostend, Belgium). The Hedges’ $g$ statistical method was used to formulate a standardized mean difference under a fixed effects model. Next, the heterogeneity statistical analysis is incorporated to calculate the summarized standardized mean difference under a random effects model using the random and fixed-effect statistical analysis, considering the heterogeneity of the studies. The 95% confidence interval (95% CI) was calculated for each study individually and then for the combination of selected studies. The mean and standard deviation values of each study were identified, and only $p$-values $<0.05$ were considered significant.

Results
Based on the previously described keywords, 986 papers were selected from the MedLine, Lilacs, and ScieLo databases. After applying all inclusion and exclusion criteria, 35 papers were read and evaluated using the PEDro and the Jadad scales. Seven papers were considered relevant for our systematic review, as shown in Figure 1.

Tables 1 and 2 show the PEDro and Jadad scores of the 7 studies included in this systematic review, with a minimum score of 8 points in 11 papers and 3 points in 5 papers, respectively.

The studies included in the analysis contained a total of 934 participants aged 40 to 73 years-old, with 34.90% of the subjects being male. The studies evaluated the effectiveness of an exercise set for knee OA management, and some compared the exercises with other treatment techniques, which took place over a mean period of 12 weeks. The analyzed variables were pain and muscle strength, and most exercises sets for OA treatment led to significantly positive outcomes for both variables, but mainly pain, as shown in Table 3.

Metanalysis
Only five of the seven studies included in this review provided sufficient data to analyze knee pain after the exercise program. The metanalysis was performed based on those five papers, totaling a sample with 520 volunteers. Among the reported outcomes, five of the seven papers used the Western Ontario and McMaster Universities Arthritis Index (WOMAC) questionnaire as a pain assessment method, whereas two papers demonstrated that exercises are effective when compared to other knee OA treatment techniques, as shown in Figure 2 and Table 4. The forest plot chart evidences the analysis of the exercise program effect on knee pain. The results at the left side indicate favorable-influencing values of the exercise program in pain relief when compared to the control group, whereas the combined effect is represented by the rhombus. There is evidence of a statistical difference ($p = 0.0031$).

Discussion
The present study aimed to analyze the efficacy of an exercise program in the treatment of knee OA, with pain and muscle strength being the main outcomes addressed. Our results demonstrate that a rehabilitation program that includes strengthening of a particular muscle group has positive effects on pain.
The quadriceps femoris, ischium cruralis, psoas major, gluteus maximus and medius, gastrocnemius, fascia lata tensor, long adductor, short adductor, gracilis, adductor magnus, and sartorius are the most evidenced muscles in this systematic review.

Among the muscles cited in rehabilitation programs, the main focus is on the femoral quadriceps. Its strengthening is commonly indicated in the treatment and progression of OA because it has a static and dynamic chondroprotective effect on the knee joint, and its weakness can generate joint

Table 1 Physiotherapy Evidence Database scale

| PEDro Scale | Study | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | Score |
|-------------|-------|----|----|----|----|----|----|----|----|----|-----|-----|-------|
| Study       |       |    |    |    |    |    |    |    |    |    |     |     |       |
| Boon-Whatt Lim et al., 2008 | 33     | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 1   | 1   | 8/10  |
| K.L. Bennell et al., 2010 | 25     | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 1   | 1   | 8/10  |
| G. Kelley Fitzgerald et al., 2011 | 20    | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1   | 1   | 8/10  |
| Saccomanno MF et al., 2016 | 21     | 1  | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1   | 1   | 8/10  |
| Palmer S et al., 2014 | 22     | 1  | 1  | 1  | 1  | 1  | 0  | 1  | 0  | 1  | 1   | 1   | 8/10  |
| Holsgaard-Larsen A et al., 2017 | 23    | 1  | 1  | 1  | 1  | 0  | 0  | 1  | 1  | 1  | 1   | 1   | 8/10  |
| Jorge RT et al., 2015 | 24     | 1  | 1  | 1  | 1  | 0  | 1  | 1  | 1  | 1  | 1   | 1   | 8/10  |

Abbreviation: PEDro, Physiotherapy Evidence Database.
overload, resulting in pain and instability.\textsuperscript{26} According to O’Reilly et al.,\textsuperscript{27} there is an inverse relationship between quadriceps muscle strength in OA patients and pain reports, that is, the higher the muscle strength, the lower the pain.\textsuperscript{27,28} However, the muscle at its greatest power may increase the shear force, or the compressive force, within the joint, which may increase the pain in the knee affected by OA; as such, when the joint is in a more flexed position, the muscle becomes more relaxed and these forces decrease over the joint, increasing the patient’s comfort and reducing muscle activation.\textsuperscript{29,30} The literature still discusses the relationship between the femoral quadriceps muscle and knee OA, and it is controversial whether muscle weakness contributes to the pathology or the pathology causes muscle weakness.\textsuperscript{31,32}

The joint kinematic imbalance resulted from mechanical factors may also influence the cause and progression of knee OA because alignment plays an important role in determining articular loads distribution, minimizing the impact effect; so, it is postulated that increased muscle strength is a major cause of impact, pain reduction and disability. As such, one needs to understand the influence of poor joint alignment in the treatment of OA. Lim et al.\textsuperscript{33} showed that quadriceps strengthening in a group of patients with severe knee misalignment caused worsening of pain compared to the control group, but not in the group presenting better joint alignment. In addition, these authors noted that quadriceps strengthening did not improve knee alignment, showing that a 3% increase in quadriceps strength worsened knee misalignment by 1 degree. This finding is not necessarily in line with our results, but it highlights the importance of observing the joint alignment before starting a strengthening program to obtain positive outcomes, especially regarding pain.\textsuperscript{34}

Range of motion is also an important issue in joint treatment success, since patients with chronic knee OA may be subjected to immobilization or inactivity due to pain, resulting in joint capsule contractures and adaptive shortening.\textsuperscript{35} Assuming that more elongated muscles have greater torque, the benefits of stretching programs exceed alignment and muscle balance. Hence, stretching therapy as an adjunctive treatment would be a favorable technique to be included in an exercise program for OA management. Both proprioceptive neuromuscular facilitation (PNF) and static stretching show excellent results, but PNF stretching was more effective than static stretching exercises.\textsuperscript{35,36} Only three of the papers included in the present review had stretching exercises in their programs.\textsuperscript{21,23,33}

Most studies included in this review address, in addition to strengthening, balance and proprioceptive techniques. However, only Fitzgerald et al.\textsuperscript{20} evaluated these techniques separately, and found no significant evidence that these exercises improve pain and muscle strength in OA patients. This finding does not corroborate the study by Diracoglu et al.,\textsuperscript{37} who compared kinesthesia and balance exercises or only strengthening exercises in women with knee OA, obtaining positive outcomes on muscle strength, quality of life, and the physical function scale, according to the WOMAC questionnaire.

To measure each of these outcomes, all authors opted for evaluation tools such as the WOMAC questionnaire and the visual analogue scale (VAS). The WOMAC questionnaire is an easy-to-apply, low-cost and specific instrument for knee OA composed of three domains, namely, pain, stiffness, and functionality.\textsuperscript{38} Meanwhile, the VAS is a numerical instrument, with scores ranging from 0 to 10, with 10 cm in length, to validate pain sensation; greater VAS scores reflect increased pain levels.\textsuperscript{30}

Confronting each evaluation instrument, we can observe that when the evaluation of a specific question is required, as in OA, the VAS scale and the WOMAC questionnaire become

| Table 2 Jadad scale |
|-------------------|
| Items | Boon-Whatt 2008 | K.L. Bennell 2010 | G. Kelley 2011 | Sacco 2011 | Palmer 2014 | Holsgaard-Larsen 2017 | Jorge RT 2015 |
| Was the study described as randomized? | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Was there a description of randomization? | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Were there comparisons and results? | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Was there a description of comparisons and results? | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Was there a description of withdrawals and dropouts? | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| TOTAL | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
Table 3 Summary of studies and their main results on muscle strength and knee pain

| Study | SAMPLE | AGE | GROUPS | GI | GC | Duration | Analyzed variables |
|-------|--------|-----|--------|----|----|----------|--------------------|
| Lim et al., 2008 | 107 | 48 | 53–73 years old | GI: 54 | GC: 53 | 12 weeks | Significant pain improvement in the group with better knee alignment |
| K.L. Bennell et al., 2010 | 102 | 51 | 62–73 years old | GI: 51 | GC: 51 | 12 weeks | Pain improvement in GI compared to GC |
| G. Kelley Fitzgerald et al., 2011 | 183 | 61 | 63–73 years old | GI: 92 | GC: 91 | 4 years and 2 months | Both groups presented modest improvements, but with no significant differences between them |
| Saccomanno MF et al., 2016 | 165 | 44 | 40–70 years-old | GI-1: 53 | GI-2: 53 | 6 months | At the 1st month, GI-2 scores were significantly better compared to GI-1. GC and GI-2 presented a significant reduction at the 1st and the 6th month |
| Palmer S et al., 2014 | 224 | 83 | 60–72 years old | GI: 73 | GC: 74 | 6 weeks | Each score from each group significantly improved over time |
| Holsgaard Larsen A et al., 2017 | 93 | 39 | 40–70 years old | GI: 47 | GC: 46 | 8 weeks | There were no significant differences between groups |
| Jorge RT et al., 2015 | 60 | NA | 40–70 years old | GI: 29 | GC: 31 | 13 weeks | Pain in the GI group was significantly lower in 45 and 90 days |

Abbreviations: GC, control group; GI, intervention group; NA, not analyzed; TENS, transcutaneous electrical neural stimulation; T0, initial time.
very subjective; however, since WOMAC specifies momentary pain only in knee OA, it is most satisfactory for this type of evaluation.\textsuperscript{30,38}

Based on common evidence aspects, we conclude that for a rehabilitation program to be beneficial in the treatment of OA, it should satisfactorily evaluate knee joint misalignment and subsequently develop a treatment plan tailored to the needs of each patient. This evaluation will guide the therapist in the formulation of a physical training program focusing on the appropriate muscular group.

Our results indicate that an ideal program would include isometric and quadriceps femoris and crural ischial muscles isotonic strengthening exercises, especially quadriceps isotonic strengthening, crural and gastrocnemius ischial muscles dynamic stretching and proprioception and balance exercises.

The studies analyzed present some limitations, including the lack of a detailed description of the interventions, the load used, and the evolution of the exercises, mainly in relation to muscular stretches, thus hampering the final elaboration of an adequate physical training program. The duration of the intervention was very variable, not allowing us to reach a consensus about the ideal time to treat OA. The long-term benefits of therapy exercises and possible OA prevention are not yet known due to the lack of studies on these effects.

Another limitation observed is the absence of a gold standard instrument for muscle strength evaluation, such as the use of a dynamometer, compromising the quantitative analysis of this variable. We believed that the lack of such gold standard may be caused by reduced availability and high cost of evaluation devices.

**Table 4** Metanalysis data

| Study                | N1  | N2  | TOTAL | SMD  | 95% IC       |
|----------------------|-----|-----|-------|------|--------------|
| Lim et al., 2008     | 54  | 53  | 107   | -0.165 | -0.549 to 0.219 |
| Bennell et al., 2010 | 51  | 51  | 102   | -0.481 | -0.880 to -0.0824 |
| Jorge et al., 2015   | 29  | 31  | 60    | -0.122 | -1.788 to -0.655 |
| Saccomanno et al., 2016 | 51 | 53  | 104   | -0.126 | -0.516 to 0.263 |
| Palmer et al., 2014  | 73  | 74  | 147   | 0.000  | -0.326 to 0.326 |
| Total (fixed effect) | 258 | 262 | 520   | -0.275 | -0.450 to -0.101 |
| Total (randomized effect) | 258 | 262 | 520   | -0.357 | -0.712 to -0.00181 |

Significance level: $P = 0.0031$

Abbreviations: IC, confidence interval; N1, sample from the intervention group; N2, sample from the control group; SMD, difference between average values.

![Fig. 2 Forest plot graph of the studies included in the fixed and random effect analysis; the standardized mean difference was set at a 95% confidence interval.](image-url)
Conclusion

This analysis shows that all papers examining the role of muscle strengthening in the treatment of OA reported pain improvement; however, the protocols used were not properly described, making it difficult to establish a specific physical exercise program for the treatment of knee OA. In addition, only two papers evaluated muscular strength, maybe due to the difficulty in measuring/using an appropriate instrument.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

1. van der Pas S, Castell MV, Cooper C, et al. European project on osteoarthritis: design of a six-cohort study on the personal and societal burden of osteoarthritis in an older European population. BMC Musculoskelet Disord 2013;14:138

2. Felson DT. The epidemiology of knee osteoarthritis: results from the Framingham Osteoarthritis Study. Semin Arthritis Rheum 1990;20(03, Suppl 1):42–50

3. Lane NE, Brandt K, Hawker G, et al. OARSI-FDA initiative: defining the disease state of osteoarthritis. Osteoarthritis Cartilage 2011;19(05):478–482

4. Conn VS, Haldahl AR, Minor MA, Nielsen PJ. Physical activity interventions among adults with arthritis: meta-analysis of outcomes. Semin Arthritis Rheum 2008;37(05):307–316

5. Kerkhof HJ, Bierma-Zeinstra SM, Arden NK, et al. Prediction model for knee osteoarthritis incidence, including clinical, genetic and biochemical risk factors. Ann Rheum Dis 2014;73(12):2116–2121

6. Sharma L, Song J, Dunlop D, et al. Varus and valgus alignment and incident and progressive knee osteoarthritis. Ann Rheum Dis 2010;69(11):1940–1945

7. Otterness IG, Eckstein F. Women have thinner cartilage and smaller joint surfaces than men after adjustment for body height and weight. Osteoarthritis Cartilage 2007;15(06):666–672

8. Nguyen C, Lefèvre-Colau MM, Poiraudeau S, Rannou F. Rehabilitation (exercise and strength training) and osteoarthritis: A critical narrative review. Ann Phys Rehabil Med 2016;59(03):190–195

9. McAlindon TE, Bannuru RR, Sullivan MC, et al. OARSI guidelines for the non-surgical management of knee osteoarthritis. Osteoarthritis Cartilage 2012;20(03):363–388

10. Lange AK, Vanwanseele B, Fiatarone Singh MA. Strength training for treatment of osteoarthritis of the knee: a systematic review. Arthritis Rheum 2008;59(10):1488–1494

11. Tanaka K, Ozawa J, Kito N, Moriymasa H. Efficacy of strengthening or aerobic exercise on pain relief in people with knee osteoarthritis: a systematic review and meta-analysis of randomized controlled trials. Clin Rehabil 2013;27(12):1059–1071

12. Levering P, Dunn J, Bifera N, Butson M, Elias G, Hill KD. High-speed resistance training and balance training for people with knee osteoarthritis to reduce falls risk: study protocol for a pilot randomized controlled trial. Trials 2017;18(01):384

13. Mat S, Tan MP, Kamaruzzaman SB, Ng CT. Physical therapies for improving balance and reducing falls risk in osteoarthritis of the knee: a systematic review. Age Ageing 2015;44(01):16–24

14. Hatfield GL, Morrison A, Wenman M, Hammond CA, Hunt MA. Clinical Tests of Standing Balance in the Knee Osteoarthritis Population: Systematic Review and Meta-analysis. Phys Ther 2016;96(03):324–337

15. Li Y, Su Y, Chen S, et al. The effects of resistance exercise in patients with knee osteoarthritis: a systematic review and meta-analysis. Clin Rehabil 2016;30(10):947–959

16. Iwamoto J, Sato Y, Takeda T, Matsumoto H. Effectiveness of exercise for osteoarthritis of the knee: A review of the literature. World J Orthop 2011;2(05):37–42

17. Jan MH, Lin CH, Lin YF, Lin JJ, Lin DH. Effects of weight-bearing versus nonweight-bearing exercise on function, walking speed, and position sense in participants with knee osteoarthritis: a randomized controlled trial. Arch Phys Med Rehabil 2009;90(06):897–904

18. Bartholdy C, Juhl C, Christensen R, Lund H, Zhang W, Henriksen M. The role of muscle strengthening in exercise therapy for knee osteoarthritis: A systematic review and meta-regression analysis of randomized trials. Semin Arthritis Rheum 2017;47(01):9–21

19. Jadad AR, Moore RA, Carroll D, et al. Assessing the quality of reports of randomized clinical trials: is blinding necessary? Control Clin Trials 1996;17(01):1–12

20. Fitzgerald GK, Piva SR, Gil AB, Wisniewski SR, Oddis CV, Irrgang JJ. Agility and perturbation training techniques in exercise therapy for reducing pain and improving function in people with knee osteoarthritis: a randomized clinical trial. Phys Ther 2011;91(04):452–469

21. Saccomanno MF, Donati F, Careri S, Bartoli M, Severini G, Milano G. Efficacy of intra-articular hyaluronic acid injections and exercise-based rehabilitation programme, administered as isolated or integrated therapeutic regimens for the treatment of knee osteoarthritis. Knee Surg Sports Traumatol Arthrosc 2016;24(05):1686–1694

22. Palmer S, Domaillie M, Cramp F, et al. Transcutaneous electrical nerve stimulation as an adjunct to education and exercise for knee osteoarthritis: a randomized controlled trial. Arthritis Care Res (Hoboken) 2014;66(03):387–394

23. Holsgaard-Larsen A, Clausen B, Søndergaard J, Christensen R, Andriacchi TP, Roos EM. The effect of instruction in analgesic use compared with neuromuscular exercise on knee-joint load in patients with knee osteoarthritis: a randomized, single-blind, controlled trial. Osteoarthritis Cartilage 2017;25(04):470–480

24. Jorge RT, Souza MC, Chiari A, et al. Progressive resistance exercise in women with osteoarthritis of the knee: a randomized controlled trial. Clin Rehabil 2015;29(03):234–243

25. Bennell KL, Hunt MA, Wrigley TV, et al. Hip strengthening reduces symptoms but not knee load in people with medial knee osteoarthritis and varus malalignment: a randomised controlled trial. Osteoarthritis Cartilage 2010;18(05):621–628

26. Creamer P, Lethbridge-Cejku M, Hochberg MC. Factors associated with functional impairment in symptomatic knee osteoarthritis. Rheumatology (Oxford) 2000;39(05):490–496

27. O’Reilly SC, Jones A, Muir KR, Doherty M. Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. Ann Rheum Dis 1998;57(10):588–594

28. Avelar Di Sabatino Santos ML, Fabiano Gomes W, Zille de Queiroz B, Brito Rosa NMd, Sirneu Pereira D, Domingues Dias JM, et al. Desempenho muscular, dor, rigidez e funcionalidade de idosas com osteoartrite de joelho. Acta Ortop Bras 2011;19(04):

29. Schipplein OD, Andriacchi TP. Interaction between active and passive knee stabilizers during level walking. J Orthop Res 1991;9(01):113–119

30. Bolognese JA, Schnitzer TJ, Ehrich EW. Response relationship of VAS and Likert scales in osteoarthritis efficacy measurement. Osteoarthritis Cartilage 2003;11(07):499–507

31. Alnahdi AH, Zenn JA, Snyder-Mackler L. Muscle impairments in patients with knee osteoarthritis. Sports Health 2012;4(04):284–292

32. Segal NA, Glass NA, Felson DT, et al. Effect of quadriiceps strength and proprioception on risk for knee osteoarthritis. Med Sci Sports Exerc 2010;42(11):2081–2088

33. Lim BW, Hinman RS, Wrigley TV, Sharma L, Bennell KL. Does knee malalignment mediate the effects of quadriiceps strengthening on knee adduction moment, pain, and function in medial knee
osteoarthritis? A randomized controlled trial. Arthritis Rheum 2008;59(07):943–951
34 Foroughi N, Smith RM, Lange AK, Singh MA, Vanwanseele B. Progressive resistance training and dynamic alignment in osteoarthritis: A single-blind randomised controlled trial. Clin Biomech (Bristol, Avon) 2011;26(01):71–77
35 Weng MC, Lee CL, Chen CH, et al. Effects of different stretching techniques on the outcomes of isokinetic exercise in patients with knee osteoarthritis. Kaohsiung J Med Sci 2009;25(06):306–315
36 Ferreira de Meneses SR, Hunter DJ, Young Docko E, Pasqual Marques A. Effect of low-level laser therapy (904 nm) and static stretching in patients with knee osteoarthritis: a protocol of randomised controlled trial. BMC Musculoskelet Disord 2015;16:252
37 Diracoglu D, Aydin R, Baskent A, Celik A. Effects of kinesthesia and balance exercises in knee osteoarthritis. J Clin Rheumatol 2005;11(06):303–310
38 Marx FC, Oliveira LM, Bellini CG, Ribeiro MCC. Tradução e validação cultural do questionário algofuncional de Lequesne para osteoartrite de joelhos e quadris para a língua portuguesa. Rev Bras Reumatol 2006;46(04):253–260