A systematic review of randomized controlled trials concerning degenerative meniscus tears

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Abstract

Background: The diagnosis of a degenerative meniscus tear is related to the patient's age, symptoms, knee joint line tenderness, and imaging. Physical activity in patients struggling with knee problems or simply in the general population is important. Knee arthroscopy is one of the most popular surgical procedures for the treatment of degenerative meniscus tears. The answer for the question how to treat a middle-aged patient with degenerative knee changes is still needed.

Aims: To provide an overview of high-quality randomized controlled trials (RCTs) on the treatment of degenerative meniscus tears.

Material and methods: A literature search was conducted in September 2022 on the PubMed, PEDro, and Cochrane Central Register of Controlled Trials to identify RCTs comparing different treatment methods and rehabilitation of degenerative meniscus tears.

Results: A total of 12 RCTs involving 1422 patients were collected. They included treatments like arthroscopic partial meniscectomy (APM), exercise interventions, hyaluronic acid injection (HAI), platelet rich plasma (PRP) intrameniscal injections, and human mesenchymal stem cell injections.

Conclusions: Exercise therapy should be the first line of treatment for degenerative meniscus tears in middle-aged and older people without traumatic injuries. A sample exercise therapy plan based on the included research is presented in this work. A surgical (or sham) approach may be considered if conservative treatment fails.

Key words

degenerative meniscus tears, arthroscopic partial meniscectomy, exercise therapy.

Introduction

Researchers are constantly looking for an appropriate exercise plan for patients, however, to date there has been no study bringing together adequate publications on the issue and outlining such an exercise plan for patients with degenerative meniscus tears.

Menisci are located between the femur and the tibia bone in both legs. Normally there are medial and lateral menisci in both legs. The menisci have a fibrous structure and a crescent shape. The meniscus in cross-section resembles a wedge. Their tasks include stabilizing the knee, absorbing shocks, transferring loads through the joint, and deepening the tibia plateau [1].

The diagnosis of a degenerative meniscus tear is related to the patient's age, symptoms, knee joint line tenderness, and imaging [2]. The patient is unable to link the onset of pain to a specific event or injury, the build-up of pain is insidious [2], which can delay decisions to see a doctor.

Based on Snoeker's study [3], risk factors for meniscus damage include as strong evidence: age above 60, male gender, kneeling and squatting related to work, and climbing stairs (more than 30 degrees). As moderate evidence those researchers included: BMI greater than 25, walking more than 2 miles per day, standing more than 2h per day, lifting or carrying objects heavier than 10, 25, 50kg more than 10 times per week. There was little to no evidence that alcohol consumption, driving more than 4 hours per day, and smoking are risk factors for degenerative meniscus tears. Surprisingly, there was strong evidence that sitting more than 2 hours a day reduces the chances of degenerative meniscus tears [3]. Those risk factors are merely correlation based on few studies and we need much more evidence to find causality. We should keep in mind that this review [3] is based on a small number of studies, and as new information becomes available, the above information may prove to be outdated or incorrect.

Physical activity in patients struggling with knee problems or simply in the general population is important. In this umbrella review [4] researchers have observed strong evidence of the beneficial effects of physical activity on the pain decreasing effect and improving functional capabilities in patients with hip and knee osteoarthritis. Based on this [4] study we can't draw definitive conclusions on mechanisms through which those exercise interventions work, but we can see the positive outcome of engaging people in physical activity and meeting physical activity guidelines [5].

Knee arthroscopy procedures are counted in thousands in the USA [6]. In England between 1996-1997 and 2016-2017 over 1 million meniscectomies were performed [7]. The good news is the amount of those procedures performed is declining with the publication of new findings [7]. The motive for performing some of these surgeries is the radiological changes observed in these patients, but we see these changes in pain and injury-free population too [8]. They are more prevalent with aging. 97% of knees in this study showed abnormalities on magnetic resonance imaging (MRI) [8]. Meniscus tears occurred in 30% of knees, and meniscus degeneration in 18% of cases [8].

With the publication of more and more studies, we are slowly approaching the answer to the question of how to treat a middle-aged patient with degenerative knee changes.

Aims

Aim of the study was to review the existing high-quality evidence by summarizing current randomized controlled trials (RCTs) concerning degenerative meniscus tears.

Materials and methods

Literature search

A literature search was conducted in September 2022 on the PubMed, PEDro, and Cochrane Central Register of Controlled Trials to identify RCTs comparing different treatment methods and rehabilitation of degenerative meniscus tears.

A search was conducted using the following terms to achieve maximum search results: 'meniscus' 'meniscal', 'degenerative', 'tear', 'lesion', 'meniscus damage', 'meniscopathy', and 'meniscal degeneration'. 157 records have been found in 3 databases. Inclusion and exclusion criteria are specified below (**Table 1**).

Risk of bias

The risk of bias was assessed with the PEDro risk of bias scale which is a decent and reliable tool to assess research design [9,10]. Research has been evaluated by one reviewer if it was not evaluated and confirmed by the PEDro database at the time. Only studies rated 6 and above on a 10-point scale were included in this paper to avoid a high risk of bias. The points most often not complied with were respectively: lack of therapist blinding, lack of subject blinding, no intention to treat analysis, and no concealed allocation which is consistent with other findings [9].

Data extraction

The data were obtained and interpreted by explicitly one researcher. The data were extracted from each study and a summary of the most important findings can be found below (**Table 2**).

Results

After a literature search, all duplicates were removed without the help of an automated program. Then 114 records were screened based on title and abstract. Further 66 records have been removed. An attempt was made to acquire the full text of 48 papers. Failed to achieve full text of 10 papers. The 38 full-text papers were screened according to inclusion and exclusion criteria. 18 papers were accepted, of which 7 were earlier versions of another study allowing 11 papers to be included in this systematic review. Furthermore, citation lists from these papers were screened for additional RCTs that could meet eligibility criteria. 5 papers were found, retrieved, and assessed for eligibility (one of them had 5/10 points on a PEDro scale, and the second one wasn't RCT). Three papers were accepted, two of which were duplicates of other studies, and only one was included in this review giving a final total of 12 papers. The whole process was summarized in **Fig. 1** in the section Results.

Names of authors, years of publication, descriptions of subjects, interventions, outcome measures, results, and PEDro scales are characterized in the chart (**Table 2**).

Table 1. Inclusion and exclusion criteria.

Inclusion criteria:	Exclusion criteria:
Randomized Controlled Trial; Peer reviewed; Study written in English; At least 6/10 points on a PEDro scale;	Study based not on humans; No access to full text; Meniscus degenerative tear not being the main interest of study; Duplication of other publication already included

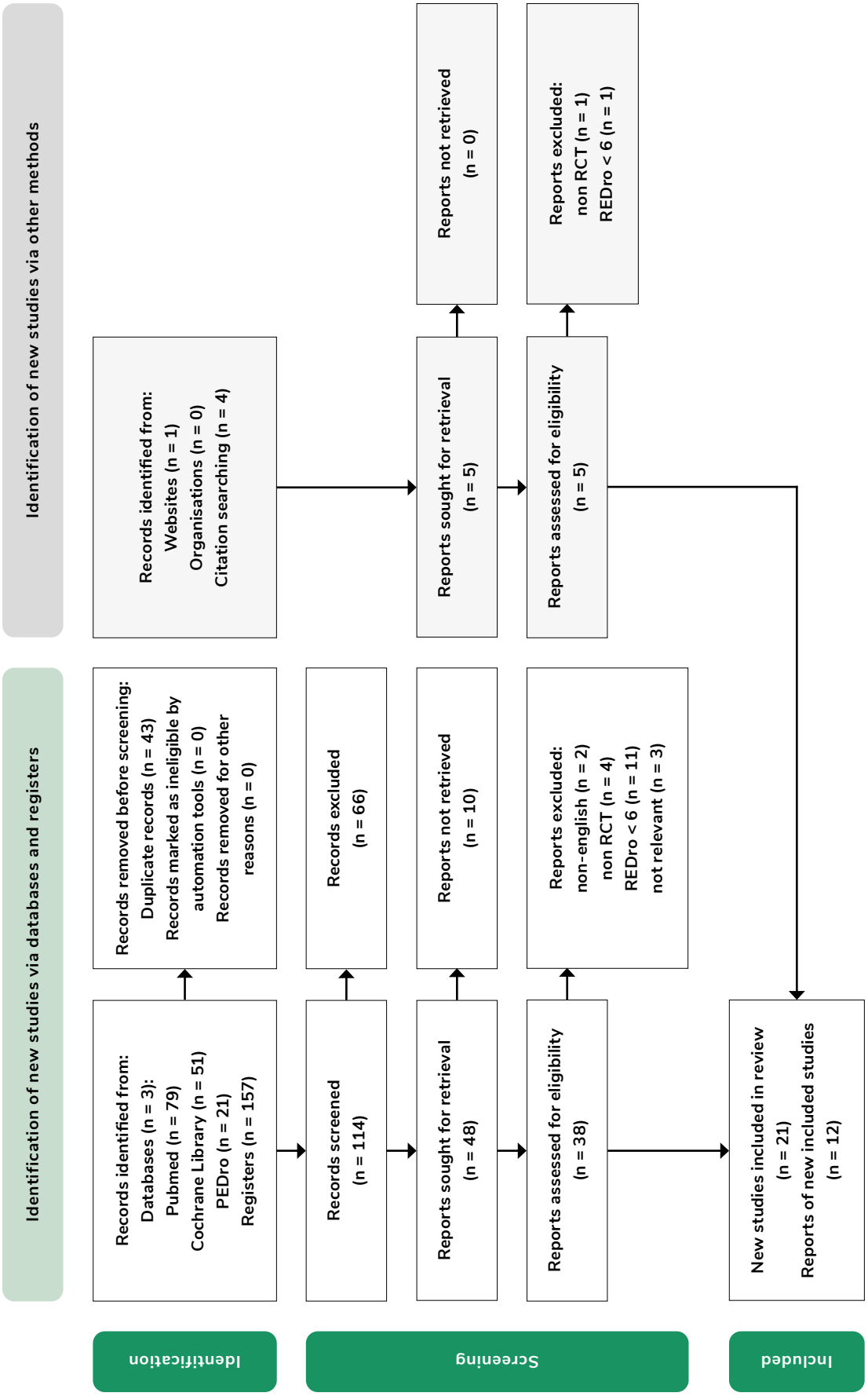

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of identified results and included studies.

Table 2. Summary of randomized controlled trials on meniscus degenerative tears:

Author (year)	Subjects	Intervention	Outcome measure	Results	PEDro
Basar et. Al. (2021) [11]	men and women, age 40–60, n=192	Group 1: APM Group 2: APM+HAI Group 3: PT Group 4: PT+HAI PT consisted of 8 weeks of exercises therapy (progressive neuromuscular and strength exercises), TENS, low-intensity ultrasound APM with preserving stable meniscus tissue, patients were discharged a day after surgery and were allowed for full bearing mobilization. HAI with APM after week 4, in the PT group before physical therapy, started	WOMAC, VAS, ROM at baseline, 2 months, 6 months	There was no difference in WOMAC and VAS between all groups, ROM was statistically higher in PT groups (3 and 4) at 2 and 6 months. The results of ROM were worse in ATM groups (1 and 2). HAI didn't have any effect on those results. Patients with late-grade osteoarthritis (KellgrenLawrence grade 3) achieved worse results during all therapies ($p<0.05$).	6/10
Ericsson (2008) [12]	29 men and 16 women who had meniscectomy 1 to 6 years ago aged 35-45 n=45	Exercise therapy n=22 Control group n=23 Exercise therapy: 3 supervised exercise sessions per week for 16 weeks, elements of training: stretching, balance exercises, functional strength, functional stability	one-leg hop, one-leg rising, square hop, isokinetic thigh muscle strength, measured at baseline and after 16 weeks	Only 30 subjects completed follow-up tests. In comparison to the control group, the exercise group achieved significant differences regarding one-hop test ($p=0.04$), hamstring strength ($p=0.033$), and quadriceps endurance ($p=0.001$). The improvement was dose-dependent - participants performed better with more therapy sessions. No result changed in the control group.	6/10
Gauffin (2017) [13]	41 men and 31 women, aged 18-68, n=72	Group 1: percutaneous meniscal trephination with placebo augmentation (6–8 mL of sterile 0.9% saline) n=30 Group 2: percutaneous meniscal trephination with PRP augmentation (6–8 mL of PRP solution) n=42 After that all patients were referred to the outpatient physiotherapy unit and encouraged to follow rehabilitation protocol.	Assessment of meniscus healing on MRI arthrography. The median follow-up lasted for 92 weeks (54–157 weeks) Secondary outcome measures were: VAS, KOOS, WOMAC, and IKDC at 3, 6, 12, and 24 months.	The healing rate was not significantly different but was slightly better in the PRP group (11 healed, 4 partially, 13 failed) than the control group (7 healed, 4 partially, 15 failed). KOOS-pain score and VAS didn't differ between the control and PRP group. Fewer patients undertook arthroscopy in the PRP group.	10/10

Kamiński (2019) [14]	41 men and 31 women, aged 18-68, n=72	Group 1: percutaneous meniscal trephination with placebo augmentation (6–8 mL of sterile 0.9% saline) n=30 Group 2: percutaneous meniscal trephination with PRP augmentation (6–8 mL of PRP solution) n=42 After that all patients were referred to the outpatient physiotherapy unit and encouraged to follow rehabilitation protocol.	Assessment of meniscus healing on MRI arthrography. The median follow-up lasted for 92 weeks (54–157 weeks) Secondary outcome measures were: VAS, KOOS, WOMAC, and IKDC at 3, 6, 12, and 24 months.	The healing rate was not significantly different but was slightly better in the PRP group (11 healed, 4 partially, 13 failed) than the control group (7 healed, 4 partially, 15 failed). KOOS-pain score and VAS didn't differ between the control and PRP group. Fewer patients undertook arthroscopy in the PRP group.	10/10
Kise (2016) [15]	86 men and 54 women, average age 49,5 years (35,7-59,9) n=140	Group 1: exercise therapy group (progressive neuromuscular and strength exercises 2-3 times per week for 12 weeks) Group 2: arthroscopic partial meniscectomy group (all unstable meniscus tissue was removed)	Isokinetic thigh muscle strength, KOOS, SF-36, lower extremity performance test at baseline, 3, 12 and 24 months.	No difference in KOOS in the two years follow-up. Thigh muscle improved at 3 months after exercise therapy, but it was diminishing at 12 months with exercise cease.	8/10
Noorduyn (2022) [16]	161 women, 160 men, 45-70 years old, n=321	Group 1: Exercise therapy (n=162) Group 2: Meniscal surgery (n=159) The exercise group received 16 sessions, over the next eight weeks, lasting 30 minutes each. The meniscal group received arthroscopic partial meniscectomy; surgeons removed parts of the meniscus until a stable part remained.	IKDC, KL scale, OARSI atlas sum score at baseline, 3, 6, 12 months, 2, and 5 years	Despite meniscectomy achieving slightly better outcomes there were no significant differences between both treatments during 5 years old. There were comparable rates of OA progression in both groups.	6/10
Osteras (2014) [17]	26 men, 16 women, aged 35-60 postoperative n=42	Group 1: Intervention (APM+exercise) (n=22) Group 2: Control (only APM) (n=20) Exercise therapy was supervised and lasted 12 weeks with a frequency of 3 times per week, with a goal of doing 30 repetitions, 3 sets of individually chosen exercises (combination of aerobic exercises and resistance exercises).	VAS, KOOS, HADS, muscle and functional tests (one leg broad jump, 5RM leg extension, isokinetic thigh muscle tests) tested at 1-, 3-, and 12-months post operation	Adjusted difference between groups was statistically significant (p<0,01) in the intervention group in comparison to the control group from baseline to 3 months and from 3 months to 12 months.	6/10

Osteras (2012) [18]	23 women, 47 men, 35-60 years old, n=70	Group 1: Intervention (APM+exercise) (n=36) Group 2: Control group (only APM) (n=34) Exercise therapy was supervised and lasted 12 weeks with a frequency of 3 times per week, with a goal of doing 30 repetitions, 3 sets of individually chosen exercises (combination of aerobic exercises and resistance exercises).	VAS, KOOS, and 5RM leg extension were tested at 1- and 3-months post-surgery.	At 3 months post-surgery both groups improved in VAS and KOOS compared to 1 month ($p<0.05$). The intervention group achieved better results in VAS and KOOS at 1 and 3 months compared to the control group ($p<0.05$).	7/10
Sihvonen (2020) [19]	57 women, 89 men, aged 35-65 years old (mean age 52) n=146	Intervention group: APM (n=70) Placebo group: Sham APM (n=76) The APM was designed to remove loose parts of the meniscus until the remaining part was solid. Sham APM mimicked sounds and sensations of surgery, sham operation took as long as the real one. The post-operative care was the same for both groups and included the same home exercise program and instructions.	KL grade, OARSI, WOMAC, LKSS, and NRS measured at baseline, 6 months, 1, 2, 3, 4, and 5 years	Knee symptoms and function improved in both groups and maintained over 60 months. There was no difference in knee pain post-exercise, WOMAC, or LKSS between groups. There was a slightly higher chance of progression of OA. All secondary outcomes were alike.	9/10
Stensrud (2015) [20]	29 women, 53 men, aged 35-60 years (mean age 49) n=82	Group 1: Exercise therapy (n=40) Group 2: APM (n=42) Exercise therapy contained supervised (one session per week, 1-2 not supervised) neuromuscular and strength exercises with progression over 12 weeks (2-3 sessions per week. During APM unstable parts of meniscuses were removed. Patients were advised to perform home exercises 2-4 times per day.	Isokinetic knee extension peak torque, maximum a number of knee-bends in 30 sec, one-leg hop for distance, 6m timed hop, at baseline and after 3 months, patient opinion about treatment effect on a GRC at 3 months	Exercise therapy group achieved better results than APM in regards to isokinetic knee extension peak torque. Most of the outcomes improved in both groups with slightly better results in exercise therapy.	8/10

Vangsness (2014) [21]	mean age 46 years old. n=60	Group 1: APM+50×10⁶ human mesenchymal stem cells (n=20) Group 2: APM+150×10⁶ human mesenchymal stem cells (n=20) Group 3: Vehicle control APM+HAI (n=20) Patients received stem cells or hyaluronic acid at 7-10 days post-surgery.	MRI was used to assess meniscus volume, cartilage degeneration, thickening, sclerosis of subchondral bone, osteophyte formation, and femoral or tibial edema. VAS and LKSS were measured at baseline, 6 months, 1 year, and 2 years.	There was no evidence of ectopic tissue on the MRI. Meniscal volume increased above the 15% threshold in 24% (n=4) patients in group 1 and 6% (n=1) in group 2 at 1-year follow-up, at 2 years follow-up meniscus volume decreased in both groups to 3 patients in group 1 and 0 patients in group B. VAS scores decreased significantly in all groups compared with baseline with the highest improvement in group 1 which had the highest baseline pain score. LKSS improved in all groups with the highest improvement in the control group.	8/10
Yim (2013) [22]	81 women, 21 men, aged 43-62 (mean age 53,8 years old) n=102	Group 1: Meniscectomy (n=50) Group 2: Strengthening exercises (n=52) Meniscectomy group received resection with limited removal of the lesion on the articular surface. After surgery, they were advised to do home exercises for the next 8 weeks. Group 2: NSAIDs and muscle relaxants for 2 weeks and supervised physical therapy sessions for 60 minutes 3 times per week for 3 weeks, then they received home exercises for the next 8 weeks. The exercise programs at home were identical.	VAS, LKSS, TAS at baseline, 3 and 6 months, 1 and 2 years, radiological evaluation with KL classification at baseline and 2 years follow-up, patient's subjective satisfaction at 2 years follow-up.	VAS and LKSS scores improved similarly in both groups at 2 years follow-up, subjective satisfaction was alike. TAS scores returned to baseline at 2 years follow-up. By the KL scale, 3 patients in the strengthening exercise group and 2 patients in the meniscectomy group progressed to second-grade KL classification.	7/10

Abbreviations: APM, Arthroscopic partial meniscectomy; PT, physical therapy; HAI, hyaluronic acid injection; VAS, visual analog scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; ROM, range of motion; KOOS, Knee Injury and Osteoarthritis Outcome Score; EQ-5D, EuroQol 5 dimensions; PRP, Platelet Rich Plasma; MRI, magnetic resonance imaging, IKDC, International Knee Documentation Committee; SF-36, short form health survey; KL, Kellgren-Lawrence; OARSI, Osteoarthritis Research Society International; OA, osteoarthritis; HADS, Hospital Anxiety and Depression Scale; RM, repetition maximum; LKSS, Lysholm Knee Scoring Scale; NRS, Numerical Rating Scale; GRC, 7-point Global Rating Scale of Change; CPK, serum creatine phosphokinase; TAS, Tegner Activity Scale; NSAIDs, Nonsteroidal anti-inflammatory drugs.

Discussion

The main conclusion of this systematic review is that there is no significant advantage of APM over the conservative approach. Currently, exercise therapy should be the first therapy offered to patients with degenerative meniscus damage.

Exercise or physical therapy was included as part of the intervention in 9 out of 12 papers in this systematic review [11-13,15-18, 20, 22]. In most cases, it lasted for 8-12 weeks supervised, and then patients were advised to do a home exercise program. The intensity of the exercises in many cases was not controlled and depended on the subjective feeling of the patient, symptoms, pain, the opinion of the supervisor, or on a pre-imposed training program in order to standardize the program for the entire study group. Progression and intensity in Stensrud's study [20] were controlled with the "plus-two principle" which indicated that the last set should always be performed with as many repetitions as possible, if a patient were able to perform more than two or three reps then he had planned to do in the training program the weight was increased in next session.

Despite the varying intensity, exercise selection, volume, duration, and other factors exercise therapy groups improved compared to the baseline. Exercise therapy appeared to be as good as APM with respect to pain at long-term follow-up and better with respect to patients' physical capabilities (isokinetic and fitness tests); however, it can be assumed that these results would level off at sufficiently long follow-up due to the lack of continued exercise. Therefore, our goal should not only be to treat the patient, but also to change his lifestyle to a more active one. Many works confirm that a small number of adults meet physical activity guidelines [23,24].

Based on the above studies, we can offer patients the following exercise plan (Table 3) to improve strength, range of motion and function. This exercise therapy plan is designed for 12 weeks, but patients should be advised to continue training and being active after completing this program to maintain adaptations achieved during this program. During these 12 weeks, patients will meet and surpass World Health Organization (WHO) physical activity guidelines [25].

The 12 weeks exercise therapy program contains cardiovascular exercises (with steady state and intervals), stretching, strength exercises, plyometrics and balance exercises. Some of those are optional and the decision to include them should be based on patient needs and capabilities. For example, there is no need to implement stretching in a patient with a satisfactory range of motion. Progression should be individual based, in this program RPE scale is used and advised as it's likely suitable for selecting the optimal load intensity during strength training to ensure maximum rehabilitation benefits [26]. Implementing the "plus-two principle" [20] may be useful to properly dose training intensity. The goal of physical therapy may differ between patients. A 40 year-old former amateur athlete may want to come back to different activities than a 70 year-old sedentary type person, therefore our approach and exercise selection should also vary. Rest times between sets should be between 1-3 minutes. In strength training including at least one variation of quadriceps, hamstring, hip and ankle dominant exercises is advised and should be selected adequately to the patient's capabilities and progressed with weight, number of sets, reps, intensity (RPE), range of motion and variation. For example, increasing range of motion during squats by removing the box may increase difficulty of this particular exercise. On the contrary, we can perform a box squat with the help of our hands to reduce the load and improve stability.

APM was part of 11 out of 12 studies in this review [11-13, 15-22]. In most cases, the operation was performed by an experienced surgeon, preserving as much of the stable tissue as possible. There was no significant statistical difference at the end of the observation period in these studies compared to other groups.

Sihvonen's study [19] compared APM to placebo surgery and found no difference between groups in regard to knee symptoms or function. The APM group had a slightly higher risk of developing osteoarthritis based on radiographic findings. More trials like this one are needed to draw compelling conclusions but the effect of APMs is getting lower with improving studies control (blinding patients, therapists, assessors, adding a control group or even a sham surgery group like in this paper).

A study from Basar [11] included HAI in the exercise group and APM group in comparison to the APM group and exercise group without HAI. The results of this study do not indicate a beneficial effect of HAI in patients with a degenerative meniscus injury, further studies with a placebo-controlled group should be conducted to find whether HAI has any meaningful use there.

Only one study addressed the use of stem cells [21] and conclusions are inconclusive, it's hard to draw far-reaching conclusions based on just this paper and its design. Further studies on this topic with a larger group of patients from other researchers and other stem cell values are needed to know the effect of this therapy.

As with stem cells – only one study [14] included in this review compared the effects of trephination with PRP against trephination with a placebo. Despite the highest score on the PEDro scale (10/10), we can't draw a firm conclusion based on just one study. The effects of this therapy compared to the control group are slightly better in regards to the healing rate.

Science is designed to contradict certain methods, beliefs, and therapies and with all this research we are getting closer to changing our attitude regarding APMs and our approach to meniscus degenerative tears treatment.

Medical knowledge is constantly changing therefore with the passage of time and the emergence of new evidence, especially of the highest quality, we may come to different conclusions and thus this work may not be an adequate source of information, with that we should be always open to change our mind on our current beliefs and biases.

Limitations of the study

A systematic review can only be as good as the studies it includes. Limitations of this study include a single investigator, a narrowed number of studies (only 12 studies and 1422), a significant number of studies that had PEDro scores of 7 and 8, and no placebo or sham groups in most studies. The current state of knowledge is insufficient to definitively define an exercise plan and approach, there is a need to publish more well-designed RCTs to define important aspects of an exercise plan. RCTs comparing two or three well designed exercise therapy programs may answer the questions about importance of specific exercise selection and variables. In most studies intensity wasn't controlled and training wasn't supervised. In this systematic review most of the patients were middle-aged, so the results of this study should be translated and applied to this population. The proposed 12-week physical therapy plan has not yet been evaluated in any RCT or study and is only a proposal based on the research presented and the current foundation of knowledge regarding rehabilitation, training, and return to physical activity. It should always be tailored to the patient's capabilities (health, economic, environmental, family), preferences and goals.

Conclusions

Exercise therapy should be the first line of treatment for degenerative meniscus tears in middle-aged and older people without traumatic injuries. A sample exercise therapy plan based on the included research is presented in this work (**Table 3**). Clinicians are advised to base their exercise therapy on this and modify variables to suit the patient in front of them. A surgical (or sham) approach may be considered if conservative treatment fails.

Table 3. Proposed 12 weeks exercise therapy plan.

Exercise	Week	Intensity, time, repetitions, sets	Variations	Progressions
Cardio:		preferred resistance and cadence		increasing resistance,
• Steady state	• wks 0-4, 1x/wk • wks 5-12, 1-2x/wk	• RPE 5-6, 10-20 min per training session • RPE 5-7, 20-30 min per training session	• Brisk walking, elliptical trainer easy cycling, easy rowing, jogging, running	• cadence, time of exercise, effort (based on RPE), picking harder variation
• Interval (optional)	• wks 5-12, 1x/wk	• 20s sprint RPE 9-10, 100s rests, repeat 5-10 times	• cycling, running, rowing, elliptical trainer	• same as above
• Stretching (optional)	• wks 0-12, 1-7x/wk • wks 0-12, 1-7x/wk	• 2-4 sets, 5-20 min, intensity should be tolerable to the patient. • same as above	• knee extensions ROM • knee flexion ROM	• AQC, heel prop, banded TKE • stationary bike (lowering seat will increase knee flexion), heel slides, TKRB
• Strength training	• wks 0-4, 2x/wk • wks 5-12, 2-3x/wk	• 2-3 sets, 12-30 reps, with load of 50-70% 1RM, RPE 5-10 • 2-5 sets, 6-30 reps with load of 50-85% 1RM RPE 6-10	• quadriceps dominant exercise • hamstrings dominant exercise • Hip strength exercise • Ankle strength	• seated KE, resisted KE, leg press, squats, lunges, step ups • Standing KF, machine KF, sliders KF, SDL, RDL • Side plank, glute bridge, hip thrusts, deadlift seated CR, standing CR
Plyometrics (optional)	• wks 5-12, 1-2x/wk	• 2-4 sets, 3-6 reps, RPE 8-10	• Vertical jump • Lateral jump • Horizontal jump	• box jump, weighted jump, single leg jump • bilateral, banded jump, single leg jump • bilateral jump, banded jump, weighted jump, single leg jump
Balance training (optional)	• wks 0-12, 1-2x/wk	• 2-4 sets, 10-60s	• one leg balance • Y-balance • single leg RDL	• adding ball, weight, task, perturbation, unstable surface, closing eyes,

Abbreviations: cardio, cardiovascular training; wks, weeks; wk, week; RPE, rating of perceived exertion; s, seconds; min, minutes; ROM, range of motion; AQC, active quadriceps contractions; TKE, terminal knee extensions; TKRB, tall kneeling rock backs; 1RM, one-repetition maximum; KE, knee extension; KF, knee flexion; RD, Romanian deadlift; SLD, Stiff leg deadlift, CR, calf raise.

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