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Capstone Project

Evidence Table

Articles	**Question:** In individuals with knee osteoarthritis, which exercises are best to treat the pathology?	**Search Sources:** PubMed, PEDro	**Abbreviations:** Electromyographic (EMG) Osteoarthritis (OA) Sit-to-stand (STS) Vastus Lateralus (VL) Maximal voluntary isometric contractions (MVIC) Knee Injury and Osteoarthritis Outcome Scores (KOOS) 6-minute walk test (6MWT) Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) Gluteus maximus (GMax) Gluteus Medius (GMed)
Author/ Year: Al Amer HS, 2018[1]	**Purpose:** To assess quadriceps muscle EMG activity, particularly the VL, while performing STS from varying heights and with different feet positions in patients with knee OA. **Design:** Cross-sectional study **Subjects:** n = 8 (5 male, 3 female) Participants had severe unilateral knee OA and volunteered to participate 1-2 weeks prior to a scheduled TKA. *Inclusion Criteria:* no additional musculoskeletal or neurological pathologies, no hip, knee, spine, or neck surgeries in the past year **Interventions & Procedures:** 2 surface electrodes were placed longitudinally, in a bipolar configuration, over the muscle belly of the VL of the affected knee, within 2cm of one another. The ground electrode was placed over the fibular head. STS tasks were done in a particular order: (1) from normal height (knee-height seat) with feet side by side, shoulder width apart., (2) from normal height with feet askew (semi-tandem with the arthritic extremity posterior), (3) from low height (25% lower than knee height) with feet together, (4) from low height with feet askew Participants started by sitting in a chair with no back or arms and keeping feet flat on the ground with the thighs apart at hip width. Individuals were instructed to hold their arms across their chest and stand by weighting each foot equally. In the askew feet positions, individuals could choose how to load their feet. Each STS position was performed twice. To normalize EMG data, participants also did 2 MVICs, in 90° of hip flexion, and 15° of knee flexion. using an electromechanical dynamometer and the EMG was recorded. 2 trials lasting 10 seconds were performed with a rest period in between. Using the data, peak EMG signal amplitudes were determined during STS and MVIC trials. Peak EMG signals from the STS tasks were normalized to the maximum EMG signal from either the VIC or the STS trials (whichever had greater activity levels). The average of the normalized peak EMG activity of the VL was taken for both trials of a STS task, and used as the outcome score for the task.		

	Outcomes/ Results: The VL produces the greatest amount of EMG activity of the 4 quadriceps muscles during a STS. Normalized EMG activity production: low height feet askew > low height feet together > normal height feet askew > normal height feet together. VL EMG activity was significantly greater when performing a STS from a low height with feet askew, than a STS from normal height with either position of feet. Foot position and chair height influenced the amount of muscle activity during STS tasks. In feet together STS, participants could compensate by reducing load on the arthritic extremity due to quadricep weakness, and/or pain and placing more load through the uninvolved side. In the askew position, since the involved limb was posterior to the uninvolved limb, compensation was not possible. Greater load demand was produced through the arthritic limb due to a higher ground reaction force associated with its position. Higher EMG activity was yielded with higher demand on knee extensors. Lower seat height increases the knee flexion angle and moment, yielding greater quadriceps demand for knee extension. **Limitations/ Comments:** Small sample size affects the generalizability of results in this population, although all of the participants likely had end-stage knee OA. EMG testing and quadricep strength testing was not performed for the uninvolved limb. Low height feet askew STS would be a good exercise for individuals with knee OA to help strengthen the quadriceps. If the patient is unable to perform this level of exercise, it can be modified to begin with normal height and feet shoulder-width apart, then progress to normal height feet askew, low height feet shoulder-width apart, and finally low height feet askew. Seat height is a valuable variable which can influence greater quadriceps muscle activation. STS exercises are functional and can help patients perform ADLs and transfers (getting on and off the toilet).
Author/ Year: Yuenyongviwat V, 2020[2]	**Purpose:** To determine the effect of hip abductor strengthening exercises in patients with medial compartment (medial tibiofemoral) knee OA. **Design:** Randomized controlled trial **Subjects:** n = 86 (7 male, 79 female) *Inclusion Criteria:* Individuals with medial compartment knee OA, ≥ 50 years old, able to ambulate without an assistive device, knee flexion > 90°, knee varus < 10°, had plain standing radiographs showing grade 2 or 3 medial compartment knee OA (KL classification). *Exclusion Criteria*: Individuals with inflammatory arthritis, hip OA, a prior knee or hip surgery, intraarticular injection < 6 months ago, individual with neurological and muscle issues. **Interventions & Procedures:** The participants were randomized into 2 groups. The first group had individuals perform exercises for strengthening of the hip abductors in combination with quadriceps strengthening. Exercises were taught by a physical therapist. The quadriceps exercise was performing seated knee extension (long arc quad) with a 10 second hold, beginning with the knee in 90° of flexion. The hip abductor exercise was performed in side-lying, with the patient abducting the hip to 45° with a 10 second hold. Both exercises were done with a sandbag of appropriate weight (according to the protocol) wrapped around the ankle. The exercises were completed in a combination of 4 sets of 10 repetitions, twice a day,

	3 days per week. In the control group, participants only performed the quadriceps strengthening exercise, but followed the same protocol as the other group. The exercise protocol defined the weight of the sandbag per week based on the percentage of 10 repetition maximum. The protocol was as follows: week 1-2 (50%), week 2-4 (60%), week 4-6 (70%), week 6-8 (80%), week 8-10 (90%). All participants were prescribed naproxen for moderate-severe pain or pain-related function limitations, which could be used no more than 2x/day upon request. Both groups received the same patient education regarding self-care, activity modification, sport, and weight management. The KOOS outcome measure consists of 5 subscales, and was utilized to assess pain, symptoms, function with activities of daily living, function in sport and recreation, and knee-related quality of life. This assessment was done at follow-ups, which were conducted at weeks 2, 4, 6, 8, and 10. Additionally, participants had to report the amount of analgesic used. Patient demographics were collected at baseline including age, height, weight, Body Mass Index, and tibiofemoral angle. Information such as gender, side of OA, history of diabetes, KL classification, and usage of rescue medicine was compared with Fisher's exact test. A t-test was used to analyze each subscale of the KOOS. A longitudinal association between exercise type and every KOOS subscale was assessed using the generalized estimating equation (GEE). The minimum clinically important difference of the KOOS was determined to be 8 points. **Outcomes/ Results:** No differences were found in baseline demographic data. No significant difference was found between the 2 groups at any of the follow-ups. The GEE analysis also found no difference in each subscale at the end of the 10-week treatment period. Both participant groups displayed significant improvement (> 8 points) on the KOOS pain, sports and recreation, and quality of life subscales at 10 weeks. All other subscale scores improved from baseline as well. The group that performed hip abductor and quadricep exercises saw improvements in pain earlier than the control group. The combined exercise group also saw significant improvements in pain, symptoms, activities of daily living, and quality of life by week 2, which were seen in the control group during week 4, except for improvement in symptoms, which was seen in week 6. The control group improved more quickly in sport and recreation (at 8 weeks) than the combined exercise group (10 weeks). All patients used naproxen as necessary, with no difference in rate of usage between the groups. **Limitations/ Comments:** Performing hip abductor strengthening exercises in combination with quadricep strengthening exercises produced similar results in pain and function to quadricep strengthening exercises alone. However, since both pain and function improved at a faster rate with the addition of hip strengthening exercises, this is a good intervention to incorporate in the clinic for patients with knee OA, to help speed up their plan of care. Limitations of the study include that the participants were not blinded to the protocol and may have had biases with thinking that the protocol would influence function and symptoms. Only patients with mild and moderate severity knee OA were included in the study, so these results may not carry over into someone with severe knee OA. Also, individuals were not excluded for having prior physical therapy or exercise participation, and there was a drastically higher number of females in the study than males, which may have impacted results.

Author/ Year:	
Singh S, 2016[3]	**Purpose:** To determine the effect of hip abductor muscle strengthening on pain and function related to medial compartment knee OA, by reducing knee load. **Design:** prospective, randomized controlled trial **Subjects:** n= 30 (14 male, 16 female); hip abductor strengthening group (n=15) & conventional group (n=15) *Inclusion Criteria*: >50 years of age, symptomatic knee OA (defined according to the American College of Rheumatology's criteria), chronic knee pain for 4-6 months, a majority of pain/tenderness over the medial knee, grade 2 or 3 on X-ray (KL classification), able to ambulate without an assistive device, and the more affected side was chosen as the test legs for individuals with bilateral medial compartment knee OA. *Exclusion Criteria:* lateral tibiofemoral joint space width less than medial, Knee surgery of intra-articular corticosteroid injection within 6 months prior to the study, hip OA and/or prior trauma to 1 or both hips, systemic arthritis, other muscular, joint, or neurological condition affecting lower extremity function. **Interventions & Procedures:** Individuals were randomized into either the experimental (hip abductor strengthening) group or the control group. Both groups performed an intervention 5x/week for 6 weeks. Baseline and post-intervention measurements were taken for the 6MWT, WOMAC, hip abductor strength, and hip abductor endurance. Strength was measured using a modified sphygmomanometer, with the patient in side-lying with the test leg on top, and the bottom leg in 90° of hip and knee flexion. A belt was fastened around the distal thigh to offer hip abduction resistance, and a folded sphygmomanometer cuff was velcroed to the distal thigh. The cuff was inflated to 20 mmHg prior to each trial. During the test, patients were instructed to exert maximal hip abduction effort against the cuff, and they were offered verbal encouragement. The patient performed 3 maximal isometric contractions, with a 1-minute rest-period between each trial. The final measurement for hip abductor strength was taken by averaging the 3 trials together. Hip abductor endurance was measured with 50% of the individual's 1 repetition maximum (RM). Individuals cycled for 5 minutes on a stationary bike to warm up prior to testing. Patients assumed the same testing position as was used to measure strength and were instructed to abduct the test leg with weight attached to the ankle matching 50% of the 1 RM. Patients were told to repeatedly abduct their leg without rest until the patient could no longer lift due to fatigue (when the individual could no longer complete a 3-second hold even with verbal encouragement. Assessors stated that no compensatory movements were made during hip abduction. The number of repetitions prior to fatigue was recorded as a measure for endurance. The WOMAC outcome measure was used to evaluate pain, stiffness, and physical function related to knee OA. The 6MWT was used to assess walking performance, and participants were given a practice walk prior to taking the actual measurement. The control group performed only conventional exercises which consisted of isometric quadriceps strengthening (quad sets) with 6 second holds and 10 second breaks between repetitions, straight leg raises with 5-10 second holds and ankle weight as appropriate, and short arc knee extension with 5-10 second holds and ankle weight added as appropriate. The intervention for the experimental group consisted of the conventional exercises with hip abductor strengthening exercise, which consisted of side-lying hip abduction with 5-10 second holds and ankle weight added as appropriate. Both groups underwent passive stretching of the rectus femoris, hamstring, iliotibial band, calf, and posterior capsule of the knee joint.

	Stretching was performed slowly to the point of discomfort and then held for 30 seconds, with a progressive increase in range. It was repeated 3 times with 15-second breaks in between. Both groups followed the same progression protocol for strengthening exercises: Week 1 (50% of 1RM; 1 set of 10 reps), Week 2 (50% of 1RM; 2 sets of 10 reps), Week 3 (55% of 1RM; 2 sets of 10 reps), Week 4 (60% of 1RM; 2 sets of 10 reps), Week 5 (65% of 1RM; 2 sets of 10 reps), Week 6 (65% of 1RM; 3 sets of 10 reps). Participants held contractions for 5-10 seconds, with a 10 second rest period between reps, and a 1-minute rest between sets. For weeks 1-2 participants performed 2 sets of 10 reps of isometric quadriceps with a 6-second muscle contraction and a 10-second rest between reps. For the remaining weeks, the exercise progressed to 3 sets of 10 reps. Also, a hot pack was provided to patients for 15 minutes post-exercise to decrease soreness. Data was analyzed using the Statistical Package for Social Sciences 16.0 version. Dependent variables were assessed using a 2x2 ANOVA. **Outcomes/ Results:** The ANOVA showed no difference in baseline measurements between groups. All groups demonstrated improvement in hip abductor strength and endurance, WOMAC scores, and 6MWT post-intervention, but the experimental group showed significantly greater improvement across all measures. The experimental group improved from 97.30 ± 9.42 at baseline to 124.70 ± 9.45 post-treatment in hip strength, and from 11.93 ± 2.34 at baseline to 19.80 ± 2.48 post-treatment in hip endurance. The control group improved by about 1.09 mmHg in hip strength and by 0.34 repetitions in hip endurance. **Limitations/ Comments:** The experimental group which also performed hip abductor strengthening exercises saw a greater improvement in all 4 measures, hip abductor strength and endurance, the WOMAC, and the 6MWT, than the control group which only performed knee extension exercises and passive stretching.
Author/ Year: Brosseau L, 2017[4]	**Purpose:** To determine which strengthening exercise programs are effective for patients with knee OA, and to provide clinicians and patients with current, high-quality suggestions for treatment of knee OA with land-based exercises. **Design:** Systematic Review **Subjects:** n=26 studies (randomized controlled trials) *Inclusion Criteria:* RCT included in Brosseau et al. (2015)[5]: PEDro score of ≥ 6, studies with a strengthening exercise program and at least 1 positive recommendation *Exclusion Criteria:* low quality RCT (PEDro score < 6), no non-exercise group, secondary analysis, not written in English, inappropriate control group, inappropriate outcomes, unable to analyze, wrong comparator, earlier analysis, not quasi-randomized, cluster-randomized trial. **Interventions & Procedures:** Data regarding pain, physical function, and quality of life outcomes were used to designate an intervention grade based on difference between baseline and treatment assessments, to help examine outcomes. Statistical and clinical importance was assessed to determine the effectiveness of each strengthening program for knee OA

management. The intervention grades, mean, relative differences, and absolute benefit for each study were also calculated. Grading consisted of a hierarchical system (A, B, C+, C, D, D+, D-) based on statistical significance ($p < 0.5$) and clinical importance ($\geq$ 15% improvement)

Outcomes/Results: The following are exercise programs that are recommended by the Ottawa Panel for

- home-based progressive strengthening program with isotonic & resistance exercises of hips and knees with ankle weights (3x/week for 4 months). Improvements in pain and physical function (WOMAC subscales), and quality of life (SF-36).
- Home-based progressive hip strengthening program with isotonic resistance, with ankle weights/resistance bands (5x/week for 12 weeks + 7 physical therapy sessions within 2 months. Improvements in pain and physical function (WOMAC subscales)
- 4-week group education program followed with an 8-week unsupervised home-based program (AROM exercises, muscle strengthening, and muscle stretching - 45 minutes, 1 day/week)

A majority of the studies involved isotonic exercises in their program, which were effective (grade A, B, or C+) for pain relief, function, or quality of life. 5 RCTs did not find isotonic exercises effective. ⅘ studies which included isokinetic concentric-eccentric strengthening exercises found them to be effective, while 1 study did not. 8/11 studies determined that isometric strengthening is effective for knee OA, while 3 studies did not find it effective. 12/26 RCTs only looked at non-weight bearing exercises, while 1 study utilized only weight-bearing exercises. 3/13 studies which looked at strengthening exercises in addition to exercises for coordination, balance, and/or function were not effective, while the other 10 RCTs determined that they were.
A variety of strengthening exercise programs may be effective in improving knee OA within 6-months.
Programs with only strengthening exercises saw significant improvements in:

- Pain: Grade A (4); Grade B (10), Grade C+ (2)
- Physical function: Grade A (4), Grade B (8)
- Quality of life: Grade B (3)

Strengthening + other types of exercise (coordination, balance, functional) displayed significant improvements in:

- Pain: Grade A (3), Grade B (2), Grade C+ (8)
- Physical function: Grade A (2), Grade B (4), Grade C+ (3)
- Quality of life: Grade A (1), Grade C+ (1)

Exercise programs included in the RCTs were commonly 6 weeks, 8 weeks, or 12 weeks in length. Equipment used included resistance bands, weights, and isokinetic resistance machined or gym resistance machines (for individuals who had access). The programs were either home-based or supervised and clinic-based, with both yielding positive recommendations by the Ottawa Panel.

Limitations/ Comments:
Limitations of the systematic review include that most of the studies analyzed only compared a single exercise program to a control, which was typically no exercise. Since different types of exercise were not compared against one another, judgement on superior exercises to manage knee OA cannot be made. Some of the exercises included have limited ability to be performed in the clinical setting, such as ones that require isokinetic resistance devices. Additionally, exercise is

	normally prescribed in conjunction with other interventions. However, the influence of the combinations can be difficult to measure. This literature review determined that there can be benefits in terms of knee OA management with various types of exercise including isometric exercises, isokinetic exercises, isotonic strengthening, weight bearing and non-weight bearing exercises, stretching, ROM exercises, and coordination, balance, and functional exercises. Basically, any exercise in general is beneficial for helping manage knee OA.
Author/ Year: Reiman MP, 2012[6]	**Purpose:** To review existing literature about the activation of GMax and GMed during various exercises, and help clinicians create gluteal strengthening programs. **Design:** Systematic Review **Subjects:** n= 10 studies (6 GMax, 4 GMed) *Inclusion Criteria:* studies about EMG activity for GMax or GMed *Exclusion Criteria:* studies that did not look at EMG activity for the GMax & GMed, studied that measured EMG activity w/ added weight or resistance, studies that used machines or equipment, studies that only measured EMG during the eccentric phase, studies that did not normalized EMG activity to a MVIC, studies that looked at gender differences, studies lacking information regarding inclusion/exclusion criteria **Interventions & Procedures:** A literature search was done using the databases Medline, CINAHL, and Sports Discus, to find articles (randomized controlled trials, systematic reviews, narrative reviews, & meta-analyses). Reference lists were also scanned for relevant articles. To effectively compare EMG activity between studies, activation was categorized into: low-level muscle activation at 0-20% MVIC, moderate-level activation at 21-40% MVIC, high-level activation at 41-60% MVIC, & very high-level activation at > 60% MVIC. **Outcomes/ Results:** Exercises for GMax and GMed muscle activation are listed below. *GMax:* - *Low-level activation:* prone bridge/plan (9% ± 7% MVIC); lunge with posterior trunk lean (19% ± 12% MVIC), Bridging on Swiss ball (20% ± 14% MVIC) - *Moderate-level activation:* Side-lying hip abduction (21% ± 16% MVIC); lunge with forward trunk lean (22% ± 12% MVIC), Bridging on stable surface (25% ± 14% MVIC); side-lying hip ER with 30° hip flexion (34% ± 27% MVIC); lunge in neutral trunk position (36% MVIC), side-lying hip ER with 60° hip flexion (39% ± 24% MVIC); unilateral bridge (40% ± 20% MVIC) - *High-level activation*: lateral lunge (41% ± 20% MVIC); lateral step-up (41% MVIC); Backward lunge (49% ± 20% MVIC); quadruped with contralateral arm/leg lift (56% ± 22% MVIC); Unilateral mini-squat (57% ± 44% MVIC); Retro step-up (59% ± 35% MVIC); wall squat (59% MVIC); single-limb squat (59% ± 27% MVIC); single-limb deadlift (59% ± 28% MVIC) - *Very high-level activation*: Forward step-up (74% ± 43% MVIC) *GMed:*

	- *Low-level activation*: n/a - *Moderate-level activation:* prone plank (27% ± 11% MVIC); Bridging on stable surface (28% ± 17% MVIC); lunge neutral trunk position (34% MVIC); Unilateral mini-squat (36% ± 17% MVIC); retro step-up (37% ± 18% MVIC); side-lying hip ER with 60° hip flexion (38% ± 29% MVIC); lateral lunge (39% ± 19% MVIC); side-lying hip ER with 30° hip flexion (40% ± 38% MVIC) - *High-level activation:* lateral step-up (41% MVIC); quadruped with contralateral arm & leg lift (42% ± 17% MVIC); forward step-up (44% ± 17% MVIC); unilateral bridge (47% ± 24% MVIC); backward lunge (47% ± 24% MVIC); wall squat (52% ± 22% MVIC); side-lying hip abduction (56 MVIC); Pelvic drop (57% ± 32% MVIC); single-limb deadlift (58% ± 30% MVIC) - *Very high-level activation*: single-limb squat (64% ± 24% MVIC); side-bridge to neutral spine position (74% ± 30% MVIC) **Limitations/ Comments:** Clinicians can use information from this study to help choose interventions (as appropriate) for patients with ITBS or another LE pathology with presentation of GMax and/or GMed weakness. Improvements in strength are expected in active muscles with EMG activity >40% MVIC, so high-level activation and very-high level activation exercises listed above could be beneficial to use in an exercise program or treatment plan. Both variations of side-lying hip ER exercises created comparable activation levels between the GMax and GMed, targeting both muscles relatively equally. High-level activation of the GMax was done with mostly standing exercises. The results provide logical progressions of exercises. Individuals who are unable to perform GMed exercise in weight bearing could benefit similarly with side-lying exercises. High- to very-high level exercises should be added later in the plan of care, as the patient progresses. A limitation of this systematic review is that most of the participant selection criteria in the studies excluded individuals with a prior history of LE injury or surgery. Therefore, we do not know if these exercises would elicit the same results in someone with such a history (common for patients seen in the clinic).

<table>
<tr><td>Articles</td><td>Question: In individuals with iliotibial band syndrome (ITBS), which exercises are best to treat the pathology?</td><td>Search Sources: PubMed, PEDro</td><td>Abbreviations: iliotibial band (ITB)
iliotibial band syndrome (ITBS)
Tensor fascia latae (TFL)
Gluteal-to-TFL muscle activation (GTA index)
Gluteus maximus (GMax)
Gluteus medius (GMed)
Lower Extremity (LE)
Electromyographic (EMG)
maximal voluntary isometric contraction (MVIC)
External Rotation (ER)
Functional motor control (FMC)
Range of motion (ROM)
Quadratus Lumborum (QL)
Upper Extremity (UE)</td></tr>
<tr><td>Author/ Year:

Bishop BN, 2018[7]</td><td colspan="3">Purpose: To assess gluteal-to-TFL muscle activation (GTA index), compare EMG for GMax, GMed and TFL activation during 13 common exercises used to target the GMax and GMed. Excessive hip internal rotation, gluteal weakness, and decreased IT band extensibility can cause ITBS.

Design: Repeated measures cohort study

Subjects: n = 11 (5 male, 6 female)
Inclusion Criteria: healthy, physically active, no low back pain, no LE injuries
Exclusion Criteria: No hip, back, or LE injuries, and no surgeries in the past year.

Interventions & Procedures: Using exercises which limit TFL activation but focus on glute max and glute med activation. EMG activation was measured for the GMax, GMed, and TFL on the dominant leg while the individual performed 5 reps of 13 exercises. 3 of the exercises were done using resistance bands.
Surface electrode placement (all placed parallel to the direction of muscle fibers):
● GMax: half-way between the greater trochanter and the S3 vertebra, level with the trochanter
● GMed: anterior to GMax, proximal ⅓ distance between the iliac crest and greater trochanter
● TFL: 2 cm inferior to the ASIS, with leg extended
Reference electrode placement: over the right AC joint
Participants warmed-up by cycling on a stationary bike for 5 minutes without resistance. The maximal voluntary isometric contraction (MVIC) testing was done for each muscle group in the appropriate MMT position. MVIC was measured over 3 repetitions, with 5 second holds. The highest value was recorded to represent the MVIC of each muscle.
5 repetitions of the following exercises were performed: side-lying hip ER w/o resistance, side-lying hip ER w/ resistance, side-lying hip abduction w/o resistance, prone hip extension w/o resistance, quadruped hip extension w/ resistance, bridge w/o resistance, bridge w/ resistance, standing hip abduction w/ resistance on stance leg, standing hip abduction w/</td></tr>
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	resistance on moving leg, standing hip extension w/ resistance on stance leg; standing hip extension w/ resistance on moving leg, running man exercise on stability trainer. Green (heavy resistance, 4.6 lbs.)[8] therabands used by males, and red (medium resistance, 3.7 lbs.)[8] therabands used by females. Percent activation (GMax, GMed, TFL) = peak activation ÷ corresponding MVIC GTA Index = {[(GMed/TFL) x GMed] + [(GMax/TFL) x GMax]}/2 A high GTA score represents a high normalized EMG amplitude for the glute max and glute med, with both being higher than TFL activity. **Outcomes/ Results:** The exercise ranking based on GTA scoring were (highest to lowest): (1) side-lying hip ER w/ resistance, (2) side-lying hip ER w/o resistance, (3) running man on stability trainer w/o resistance), (4) bridge with resistance, (5) prone hip extension w/o resistance), (6) side-lying hip abduction w/o resistance), (7) Bridge w/o resistance, (8) Quadruped hip extension w/ resistance, (9) Standing hip abduction w/ resistance on moving leg, (10) Standing hip abduction w/ resistance on stance leg, (11) Quadruped hip extension w/o resistance, (12) Standing hip extension w/ resistance on stance leg, (13) Standing hip extension w/ resistance on moving leg *Exercises which produced greatest GMax activation*: Running man on stability trainer w/o resistance (50.94±21.38) > side-lying hip ER with resistance (42.03±19.31) > bridge w/ resistance (38.34±31.43), side-lying hip ER w/o resistance (36.32±14.62) > side-lying hip abduction w/o resistance (34.44±14.37) *Exercises which produced greatest GMed activation*: Running man on stability trainer w/o resistance (55.36±22.19) > Standing hip abduction w/ resistance on stance leg (45.06±9.84) > side-lying hip abduction w/o resistance (42.23±18.08) > standing hip abduction w/ resistance on moving leg (37.68±8.30) > side-lying hip ER w/ resistance (30.48±16.66) *Exercises which produced greatest TFL activation:* Standing hip abduction w/ resistance on stance leg (41.62±13.97) > running man on stability trainer w/o resistance (40.11±22.87) > standing hip abduction w/ resistance on moving leg (37.98±20.04) > side-lying hip abduction w/o resistance (33.18±14.77) **Limitations/ Comments:** There was a small sample size composed of only healthy individuals, so the results may not translate to someone experiencing pain EMG technology could have been influenced by muscles not being targeted, resulting in "cross-talk." Activation of the 3 muscles were not significantly influenced by the addition of resistance in 3 exercises. side-lying hip ER exercise is appropriate for patients with hip musculature weakness who want to strengthen their gluteal muscles and limit TFL activation
Author/ Year: Reiman MP, 2012[6]	Same as above, on page 7-8 (Knee OA evidence table)
Author/ Year	**Purpose:** To compare the effects of FMC versus therapeutic exercise on pain, ROM, strength, and function in national-level Greco Roman wrestlers with ITBS.

Jahanshahi M, 2022[9]	**Design:** Randomized Controlled Trial **Subjects:** n = 60 *Inclusion Criteria:* Age 18-35 years, national-level Greco Roman wrestler, pain along the IT band at Gerdy's tubercle or the lateral femoral epicondyle during wrestling exercises, (+) stiffness with Ober's test, and (+) pain during Noble's compression test. *Exclusion Criteria*: history of LE surgery, knee ligamentous of meniscal injury, and unwilling to participate in the exercise program. **Interventions & Procedures:** Participants were randomly assigned into one of 3 groups: FMC, therapeutic exercise, control group. 20 individuals were assigned to each group. The intervention lasted 8 weeks, with measurements of pain (VAS), hip ROM (goniometer), strength (handheld dynamometer), and function (triple hop test for distance, single-leg vertical jump test, agility *T* test) taken at baseline and at 8 weeks (post-intervention). Individuals in the control group did not receive a training program and were told to continue performing their routing wrestling exercise. Both intervention groups participated in their exercise programs 3x/week for 60-90 minutes, with the therapeutic exercise group's sessions averaging 60 minutes. Each group had 24 sessions. The goal of the FMC exercises was to improve cognitive and automatic control of the knee's kinematics. *FMC Exercise Program:* - Week 1: double-leg squat (25 reps), isometric standing hip abduction (10 reps), single-leg stance w/ UE activities (1-2 reps) - Week 2: double-leg squat (25 reps), standing hip abduction w/ resistance (2-3x 10 reps), single-leg stance (25 reps) - Week 3: double-leg squat (25 reps), single-leg stance w/ UE activities & on unstable surface (2-3 reps), single-leg squat w/ UE support (25 reps) - Week 4: double-leg squat (25 reps), single-leg stance on unstable surface while holding theraband and producing relative hip ER (1-2 reps), single-leg squat w/o UE support (25 reps) - Week 5: jump squats w/ landing position held for 5 sec (1-2x 5 reps), Resisted lunges (1-2x 10 reps), Single-leg squat w/ contralateral lower leg facing wall (25 reps) - Week 6: Jump squats (3x 5 reps), resisted lunges (1-2x 10 reps), single-leg squat w/ opposite food facing wall (25 reps) - Week 7: Jump squats w/ rotation (1-2x 5 reps), Lunges (3x 12 reps), Single-leg squat w/ UE support (25 reps) - Week 8: Jump squats w/ rotation (3x 5 reps), lunges (3x 12 reps), single-leg squat w/o support (25 reps) The single-leg squat was performed weeks 3-8, in reparations of 25, with the following progression of movements each week: (1) opposite foot on a low step w/ UE support, (2) opposite foot on a low step w/o UE support, (3) opposite lower leg facing the wall, (4) opposite foot facing the wall, (5) only UE support, (6) no UE support *Therapeutic Exercise Program:* all exercises for the week were taught & demonstrated by 2 physical therapists during the first session each week. - Weeks 1 & 2: self-myofascial release via foam rolling (TFL, ITB, Hip adductor, QL), stretch (TFL, ITB, Hip adductor, QL)

	- Week 3: self-myofascial release (TFL, ITB, Hip adductor, QL), active stretching (TFL, ITB, Hip adductor, QL) - Week 4: self-myofascial release (TFL, ITB, Hip adductor, QL), dynamic stretching (TFL, ITB, Hip adductor, QL) - Week 5: GMax & GMed strengthening (increasing intensity or isometric/ eccentric) - Week 6: hip abduction & hip extension resistance (increasing intensity or isometric/ eccentric) - Week 7: integrated dynamic movement for lateral subsystem in frontal plane (single-leg balance reach, lunge to balance, step-up to balance, ice skater, power step-up) - Week 8: integrated dynamic movement for lateral subsystem in transverse plane (single-leg balance reach, lunge to balance, step-up to balance, ice skater, power step-up **Outcomes/ Results:** 5 participants did not complete the study due to personal reasons. Both intervention groups had a significant improvement in pain and all functional measures post-intervention as compared to the control group, with the FMC group demonstrating a better outcome. The FMC group also demonstrated greatest improvement in LE muscle strength post-intervention, while the therapeutic exercise group was superior in post-intervention hip ROM (abduction, adduction, internal & external rotation). **Limitations/ Comments:** In the national-level Greco Roman wrestlers with ITBS, FMC and therapeutic exercises are both effective in improving outcomes. However, FMC is significantly better at improving pain, function, and LE strength. Limitations include that no long-term post-intervention follow-ups were done. Therefore, we do not know if the intervention programs sustained their benefits long-term. Handheld dynamometry was used to measure strength, but isokinetic testing would have been more accurate. Additionally, inclusion criteria required positive Ober's and Nobles tests, both of which have poor psychometric properties for ITBS diagnosis.

<table>
<tr>
<td>Articles</td>
<td>Question: In individuals with patellar tendinopathy, which exercises are best to treat the pathology?</td>
<td>Search Sources: PubMed, PEDro</td>
<td>Abbreviations: Patellar Tendinopathy (PT)
Lower Extremity (LE)
Eccentric exercise (EE)
Single leg decline squat (SLDS)
Transcranial magnetic stimulation (TMS)
Victorian Institute of Sport Assessment-patellar tendon (VISA-P)
Maximal voluntary isometric contraction (MVIC)
Short interval intracortical inhibition (SICI)
Active motor threshold (AMT)
Maximum Voluntary Contraction (MVC)
Minimal clinically important difference (MCID)</td>
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<tr>
<td>Author/ Year:

Morgan S, 2016[10]</td>
<td colspan="3">Purpose: To study available evidence and determine which factors (intrinsic & extrinsic) cause PT, and how to treat the deficits in rehabilitation.

Design: Systematic Review

Subjects: n = 20 studies: RCT, prospective cohort studies, cross-sectional studies, systematic review, meta-analysis, online survey, experimental study, controlled clinical trial, case report/series, pilot study
Inclusion Criteria: Publication between January 2010 & October 2015, research design: systematic reviews, RCTs, non-RCTs, quantitative research studies, qualitative research studies, participants aged 18-60, focus on causes of PT, and/or PT rehabilitation.
Exclusion Criteria: participants having other knee pathologies, prior knee surgery or injection therapy, study focus on PT, articles published in language other than English, articles with only the abstract available

Interventions & Procedures: An electronic search of 10+ databases was done. An independent researcher chose the articles based on inclusion criteria and methodology.
Data was gathered regarding characteristics of causative factors and rehabilitation of PT.

Outcomes/ Results:
Intrinsic factors:
- Impaired muscle flexibility: iliotibial band, quadriceps, and hamstrings
- Strength: reduced quadriceps strength, greater vastus medialis strength
- Alignment: inferior patellar pole alignment
- High body mass index
- Range of motion: decreased dorsiflexion
- Higher BMI can induce greater load through the PT
Extrinsic factors:
- Type of sport (involving jumping), player position
- Training surface (hard surface increases tendon load)</td>
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	- Potential impact from patellar strap or tape - Higher levels of sport participation Extrinsic & intrinsic factors load the PT differently. *Rehabilitation:* - Recommended period of 6-12 weeks - LE EE (helps reduce neovascularity, helps improve neuromuscular activation, increases muscle strength & endurance) - EE with SLDS on decline board w/ angle of 25° at a slow speed has superior results to a squat on a flat step; 3 sets of 15 repetitions, 1-2x/day, 5-7 day/week. - Static stretching of muscles around hip & knee to improve flexibility helps reverse PT - Eccentric-concentric loading program - Hip & core strengthening: glute max - Jumping with appropriate kinematics to achieve a soft landing (decreases load on PT) - Deep transverse friction massage decreases adhesions and promotes collagen fiber realignment. - Reduce tendon load to improve symptoms Main risk factors found were muscle flexibility, strength, acquisition of skill, and level of skills (all others were inconclusive. Recommendation: start w/ non-weight bearing strengthening exercises, progress to advanced exercises to help improve LE biomechanics during landing. **Limitations/ Comments:** There may be direct publication bias due to a high incidence of the same authors included in the systematic review. Also, only a limited number of articles were selected for the systematic review. There was no recommendation provided of how long to implement the EE program. Reducing tendon load can be done by decreasing frequency, intensity, or duration of activity. Progression of loading needs to be gradual. Although this study did not look at EMG activity for muscles, it did point out the causes of PT and how to address/manage the symptoms. Interventions should include exercises.
Author/ Year: Rio E, 2015[11]	**Purpose:** To study the immediate effects of isotonic and isometric exercise on pain related to PT. There has been a lack of adherence to eccentric exercise programs in athletes with PT due to pain and inconsistent outcomes. This study examined whether there is another viable intervention that is effective in pain reduction and will promote compliance. The secondary purpose is to determine cortical motor function changes. **Design:** Single-blinded, randomized cross-over study **Subjects:** n=6 (male, volleyball athletes). Age range 18-40 years; 3 had unilateral symptoms, 3 has bilateral symptoms *Inclusion Criteria:* Taking no medication, had unilateral or bilateral patellar tendon pain, diagnosed for PT by one specific sports physiotherapist based on clinical presentation – localized pain at the inferior pole of the patella during jumping, landing, and while testing single-leg decline squat (SLDS). Diagnosis confirmed by ultrasound imaging. Additionally, all the subjects followed the same schedule of playing 1x/wk and training 2x/wk

	Interventions & Procedures: TMS was used to assess changes in cortical motor function. The study blinded the TMS tester from the intervention status and the data analysis was completed without knowledge of intervention status. Tests were performed 1 week apart to ensure that the playing schedules were consistent. The order of interventions was determined based on concealed randomization. *Baseline* measurements of quadricep strength, pain, and TMS were taken at week 1, with no intervention. Participants completed the VISA-P, and the SLDS was used to obtain measures of strength and tendon pain. Pain was reported on the 11-point numerical rating scale ('0-no pain', '10- worst possible pain'). Individuals with bilateral PT used their more painful side for the SLDS quadriceps strength measurement. The MVIC quadriceps torque was measured with isokinetic devices (Biodex system 4 Pro, Biodex medical 2 Systems) to determine baseline. 3 trials were conducted in an identical manner and at 60° of knee flexion. The maximum peak torque of the 3 trials was recorded. Corticospinal excitability and SICI were measured using single-pulse and paired-pulse TMS. Single-pulse measures were taken, in the form of stimulus-response curves, with low-level isometric quadriceps contractions by performing a 10% MVIC with the knee joint flexed at 60° (non-painful). 20 stimuli were delivered in a ramp-up manner, in increments of 20%, beginning at 90% of the individual's AMT and up to 170% of their AMT. SICI was determined using paired-pulse stimuli and recorded in a percent ratio. A low SICI ratio indicates high levels of inhibition. EMG testing was performed over the rectus femoris, using a Bistim unit and a 110 concave double coil cone. AMT was the intensity that ≥ 5/10 stimuli produced amplitudes of corticospinal excitability (>200 μV) from the rectus femoris. Testing was performed on the same day and at the same time each week (week 2 and week 3). Isometric exercises were performed with the Biodex Pro, with 5 repetitions of 45 seconds, at 60 degrees of knee flexion, and with a load of 70% of maximal voluntary contraction. Isotonic exercises were performed on the leg extension machine, with the following parameters: 4 sets of 8 repetitions, with a 4 second eccentric phase, a 3 second concentric phase, at 100% 8 repetition maximum. There was a recovery time of 2 minutes for each of these interventions. Data was analyzed using a split-plot in time-repeated measures analysis of variance (ANOVA). **Outcomes/ Results:** There was no major difference in pain with SLDS prior to the isometric or isotonic intervention, with baseline isometric exercise pain being 7/10±2.04 and baseline isotonic exercise pain rating 6.33/10±2.80 ($p>0.99$). Isometric intervention instantly decreased pain with SLDS to 0.17/10±0.41($p=0.004$), which remained at 45 minutes-post intervention. The pain decreased by about 6.8/10 with isometric exercise. The isotonic intervention also demonstrated instant pain relief with the SLDS, but the results did not last 45 minutes-post intervention. The immediate reduction in pain with isotonic exercise was 2.6/10. Additionally, it was found that cortical inhibition was released with isometric contractions, from 27.53%±8.30 to 54.95%±5.47 (increase in SICI ratio indicates decrease in inhibition). Isotonic contractions did not significantly change inhibition. **Limitations/ Comments:** From the findings of the study, isometric exercises seem like a viable intervention for athletes in-season, as they produce immediate and short-term PT pain relief. Although isotonic exercises also provide immediate pain relief, isometric

	exercises have superior results. A limitation of the study was that the sample size was extremely small, with only 6 participants. Additionally, all of the participants were male volleyball players. Therefore, it is difficult to make claims about how these findings might translate into females with PT or a population consisting of athletes other than volleyball players. Also, the study only looked at immediate and short-term time frames. Therefore, we do not know if isometric interventions are effective for long-term pain-relief.
Author/ Year: Breda S, 2020[12]	**Purpose:** To determine the effectiveness of progressive tendon-loading exercises in comparison to eccentric exercises in individuals with patellar tendinopathy **Design:** Randomized controlled trial **Subjects:** n=76 *Inclusion Criteria*: age 18-35 years, history of knee pain around patellar tendon with training and competition, participation in sports ≥ 3x/ week, tender to palpation over inferior pole of patella, structural tendon changes on grey scale ultrasound & power Doppler, and score of < 80/100 on the VISA-P. (+) clinical examination defined by reproduction of tenderness over the inferior pole of the patella or patellar tendon with palpation and with a single-leg squat *Exclusion Criteria*: Existing acute knee or patellar tendon injuries, inflammatory joint disease or familial hypercholesterolemia, daily drug use with possible effect on the patellar tendon (fluoroquinolones), corticosteroid injections administration within the prior 12 months, prior patellar tendon rupture, daily exercise therapy ≥ 4 weeks within the last 12 months, unable to perform an exercise program, actively participating in other treatment program, coexisting knee pathology on ultrasound/ MRI, contraindication for MRI. **Interventions & Procedures:** Participants were randomized into either an intervention group which participated in progressive tendon-loading exercises or a control group which participated in pain-provoking eccentric exercise. The intervention was administered for 24 weeks. Investigators and sports physicians were blinded from which exercise program the patient was participating in. Patients consulted an independent sports physician regarding therapy-related questions. The exercise programs were unsupervised, with informational brochures & online videos provided on how to perform exercises. The intervention group progressed through 4 stages during the intervention. The individual was advised to progress to the next stage when their VAS score was ≤ 3/10 and they had completed the exercises for the specific stage for ≥ 1 week. - *Stage 1:* Daily isometric exercises: single-leg leg press or leg extension (quadricep isometric hold), 5 reps of 45 second holds in 60° knee flexion at 70% MVC - *Stage 2*: Isotonic exercises: Single-leg leg press or leg extension, beginning with 4 sets of 15 reps with increasing load and knee angles between 90° flexion and near full extension. Alternating with Stage 1 Isometric exercises on 1 day and Isotonic exercises the next. - *Stage 3*: Plyometric (energy storage) loading and running exercises (jump squats, box jumps, cutting movements). Beginning with 3 sets of 10 reps with both legs and gradually progress to 6 sets of 10 reps on 1 LE. Continuing with stage 1 on the 1st day, stage 2 on the 2nd day, and adding plyometric exercises on the 3rd day.

	- *Stage 4:* Sport-specific exercises. Patients were advised to gradually return to sport-specific training by performing these exercises every 2-3 days to promote adequate recovery from high tendon-loading activities. Stage 1 exercises were performed on days that sport-specific exercises were not. After all the stage 4 exercises were completed within acceptable pain levels, patients were recommended to return to competition. Return to sports involved performing isometric and isotonic exercises 2x/week. The earliest one could return to sport in the experimental group was after 4 weeks. The control group partook in a 2-stage intervention program involving pain-provoking eccentric exercises. Individuals moved on to stage 2 if they completely followed stage 1 exercises and pain with additional weight equated to a VAS score ≤ 3/10 during the single-leg squat. The amount of weight is not mentioned. A decline board with a 25° slope was given to participants in the control group. - *Stage 1* (12 weeks) - single-leg decline squat on a decline board with a 25° slope. The patient would perform the eccentric phase (downward movement) with the symptomatic leg, and the concentric phase (upward movement) using mainly the contralateral extremity. Participants were told to perform the exercises with pain (VAS ≥ 5/10). Load was added to a backpack to progress intensity if no pain or minimal pain was present during the exercise. - *Stage 2* - sport-specific exercises. Exercises from stage 1 were also performed 2x/week. Both groups were also told to perform exercises to address PT risk factors including: improving flexibility in the quadriceps, hamstrings, gastrocnemius, soleus, and strengthening of the hip abductors & hip extensors with a resistance band, calf strengthening, and core stability. Participants with bilateral PT were encouraged to do the exercises on both sides. Both groups were given advice and education on tendon care by a sports physician. They were educated on the condition, what to expect, the benefits of exercise, gradually returning to sport, the relationship between load and pain using the pain-monitoring model, and activity modification. Outcomes were assessed at baseline, 12 weeks, and 24 weeks. Outcomes included the VISA-P, return to sports rate, subjective patient satisfaction, and exercise adherence. The VISA-P was determined to have an MCID of 13 points. Return to sports rate was measured as return to desired sport at pre-injury level; return to desired sport not as preinjury level; return to sport, but not desired sport; did not return to sport. Patient satisfaction was classified as excellent, good, moderate, or poor. Exercise adherence was recorded as a % of the total number of exercise sessions completed. **Outcomes/Results:** No differences were found in baseline characteristics between groups except that the experimental group had longer symptom duration (119 vs 78 weeks) and greater structural erosion of the inferior patellar border. The VISA-P score increased significantly in the experimental group from baseline (56) to post-intervention (84), as well as in the control group (from 57 to 75). The improvement in VISA-P was greater in the experimental group than in the control group after 24 weeks. Additionally, in the experimental group, after 12 weeks 21% returned to sport at pre-injury level, and after 24 weeks, 43% returned to that level. In the control group, at 12 weeks, only 7% returned to sport at pre-injury level, while 27% returned after 24 weeks. **Limitations/ Comments:** Limitations include that blinding of the intervention was not possible and the clinical outcome data varied substantially, meaning that the effects of the exercise program might also vary in individuals. Individualized treatment programs are important for this reason. Also, the participant population was not uniform, being composed of both recreational and competitive athletes. The interventions in the study utilized unsupervised exercise, so the

	information reported regarding adherence to the intervention had to be trusted, rather than being able to check for validity. Additionally, results may have been different had the program been supervised. Progressive tendon loading exercises are demonstrated as effective for PT in improving strength, pain, function and return to sports, and should be utilized clinically.

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