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# A 12-Week Exercise Therapy Program in Middle-Aged Patients With Degenerative Meniscus Tears: A Case Series With 1-Year Follow-up

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Exercise has been shown to be an efficient treatment to reduce joint pain and improve function in patients with knee degeneration and knee osteoarthritis (OA).[34,36,43] However, management strategies are largely palliative, targeting patients with verified symptomatic and radiological knee OA.[25] With the increased

**STUDY DESIGN:** Case series.

**BACKGROUND:** Exercise is a viable treatment alternative to arthroscopic partial meniscectomy in patients with degenerative meniscus tears. No study has reported in detail the type of exercises, progression, tolerance, and potential benefit from an exercise therapy program in these patients who have not had surgery. This case report describes a progressive exercise therapy program aimed at improving neuromuscular function and muscle strength in middle-aged patients with degenerative meniscus tears, the outcome over a 12-week period, and the ability to maintain improvements up to 1 year.

**CASE DESCRIPTION:** The first 20 patients (age range, 38-58 years) included in an ongoing randomized controlled trial.

**OUTCOMES:** Outcomes data included the Knee injury and Osteoarthritis Outcome Score, a 7-point global rating of change scale, isokinetic knee muscle strength tests, and 3 lower extremity performance tests. Postintervention, 16 of 20 patients showed clinically meaningful changes (greater than 10 points) on the Knee injury and Osteoarthritis Outcome Score knee-related quality of life subscale, 19 of 20 patients rated themselves as "a lot better" or "better" on the global rating of change scale, all patients had increased quadriceps muscle strength, and the majority of patients improved on the lower extremity performance tests. At 1 year postintervention, the majority of patients had maintained the improvements and none of the patients had undergone surgery.

**DISCUSSION:** The described neuromuscular- and strength-training program should be considered for rehabilitation of middle-aged individuals with degenerative meniscus tears. However, head-to-head comparison of programs in a randomized design is needed to determine if this specific program is significantly better than other interventions. US trial registration NCT01002794.

**LEVEL OF EVIDENCE:** Therapy, level 4.
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**KEY WORDS:** *arthritis, exercise therapy, knee osteoarthritis, meniscus injury, osteoarthritis*

knowledge of significant risk factors for knee OA, including nontraumatic degenerative meniscus tears,[17] there is a need to develop and evaluate exercise programs for these patients. A common belief is that knee symptoms are attributable to magnetic resonance imaging (MRI) findings of a damaged meniscus. These patients are, therefore, often treated with arthroscopic surgery. However, the long-term value of this surgical treatment approach has been questioned,[18,20] with recent studies showing that exercise is as effective as arthroscopic partial meniscectomy in this population.[22,23,31] In addition, neuromuscular exercise has been shown to improve articular cartilage quality in middle-aged patients postmeniscectomy.[45] These findings indicate that exercise may have important implications for knee OA prevention, and thus exercise may be beneficial for patients at risk of or with early-stage knee OA.[10,46] However, to date, a detailed exercise treatment strategy for use in patients with degenerative meniscus tears has not been established.

A major goal of knee joint rehabilitation is to enhance muscle function.[5] Quadriceps muscle strength is impor-

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tant for absorption of load during weight bearing and providing dynamic joint stability. Several high-quality studies have shown that quadriceps strength training is effective at improving pain and physical function in patients with knee OA.[39] In healthy individuals, muscular efforts of at least 60% of maximal intensity should be used to improve muscle strength.[4] A similar level of exercise intensity has also been found to improve knee muscle strength in patients with advanced knee OA, without a concomitant increase in pain.[26,30] However, traditional quadriceps strength training aims primarily at increasing muscle force output rather than targeting biomechanical contributors to optimal knee load.[9] In contrast, neuromuscular exercises aim to improve the position of the trunk and lower limbs relative to one another, as well as quality of movement performance, while dynamically and functionally strengthening the lower-limb muscles.[9] Neuromuscular exercise programs have been found to be beneficial in patients with knee injury and knee OA,[11,42] and have previously also been reported to be effective in middle-aged patients after meniscectomy.[21,45] Hence, exercises aimed at improving both quadriceps muscle strength and neuromuscular performance should be included in rehabilitation programs for patients with knee degeneration. Previous studies in this patient population have primarily included functional exercises with little or no external loads,[21,22,45] and none has included information on the progression of individual exercises, individual responses to such a program, and the ability of patients to maintain improvements over an extended period.

The primary objectives of this case series were to provide a detailed description of a progressive exercise therapy program aimed at improving muscle strength and neuromuscular function in patients with degenerative meniscus tears, to describe the patients' response to the program, and to evaluate the ability of patients to maintain improvements up to 1 year postintervention.

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## CASE DESCRIPTION

Twenty patients with a history of knee pain and functional limitations and degenerative meniscus tears confirmed with MRI were referred from primary care to the Department of Orthopaedic Surgery at Oslo University Hospital for consideration for arthroscopic surgery. The case series reports on the initial 20 patients (8 female, 12 male), randomized to exercise therapy in an ongoing randomized controlled trial (NCT 01002794, available at www.clinicaltrials.gov) with complete data at baseline, postintervention, and 1-year follow-up. The inclusion criteria were (1) unilateral knee pain for more than 2 months without a history of a significant trauma, (2) a tear in the medial meniscus confirmed by MRI, (3) a Kellgren-Lawrence[28] OA grade of 2 or less, graded with a standing anterior/posterior radiograph of the injured knee held in a fixed, flexed position, using a Plexiglas frame (SynaFlexer; Synarc Inc, Newark, CA),[32] (4) between 35 and 60 years of age, (5) eligible for arthroscopic surgery, and (6) physically able to perform physical activities and exercise. Exclusion criteria were acute locked knee, ligament injury, or knee surgery within the previous 2 years. All patients signed a written informed consent prior to inclusion, and their rights were protected by the Declaration of Helsinki. The study was approved by The Regional Ethical Committee, Health Region South-East, Oslo, Norway.

### Outcome Measures

The outcome measures included the Knee injury and Osteoarthritis Outcome Score (KOOS), a global rating of change (GRC) scale, isokinetic knee muscle strength, and 3 lower extremity performance tests. The KOOS was included as a self-reported questionnaire of knee function[47] and consists of 5 subscales: pain, other symptoms, function in daily living, function in sport and recreation, and knee-related quality of life. The KOOS is valid and reliable for use in patients with different knee injuries and disorders, including meniscal tears.[49,50] A change of 10 points or greater is considered clinically significant.[47]

The GRC scale was used postintervention and at the 1-year follow-up to assess overall efficacy of the rehabilitation program.[27] A 7-point scale (−3 to 3) was used, which included the categories "very much worse" (−3), "much worse" (−2), "worse" (−1), "unchanged" (0), "better" (1), "a lot better" (2), and "completely recovered" (3).

Isokinetic knee extension and flexion strength was tested using an isokinetic dynamometer (Biodex 6000 System; Biodex Medical Systems, Shirley, NY). Testing at 60°/s consisted of 4 practice repetitions, followed by 5 maximum-effort repetitions. The patients were placed in an upright, seated position on the Biodex dynamometer chair and secured with straps to minimize body movements. Arms were crossed over the chest. The tested range of motion was from 90° of knee flexion to full extension. The chair settings were recorded and stored in the Biodex software program during the first test, to duplicate the testing position at the follow-up tests. Isokinetic peak torque values were measured in Newton meters (Nm) and total work in joules (J). Peak torque was defined as the highest value among the 5 repetitions. A change of 15% for peak torque knee extension is considered a minimal detectable change (MDC).[55]

Three tests were used for evaluation of lower extremity function: the maximum number of knee-bendings in 30 seconds,[13,44,48] the 1-leg hop for distance (OLH), and the 6-meter timed hop (6MTH).[7,37] All tests have been shown to be reliable and valid for patients with a variety of knee injuries.[12,13,51] The maximum number of knee-bendings in 30 seconds was used to test the ability to quickly switch from eccentric to concentric muscle actions across the knee joint. This is a task that has been shown to be impaired in patients with meniscal injury with or without knee OA,[48] especially in knee joint positions of 15° to 30° of knee flexion.[24]

Each patient stood with the long axis of the foot on a straight line and toes placed on a perpendicular line. The examiner gave the patient fingertip support to prevent rotation at the pelvis and to provide some balance control. The patient was asked to bend the knee until the line along the toes was no longer visible, without bending forward from the hip (approximately 30° of knee flexion). A stopwatch was used to measure the time, and the number of knee-bendings performed in 30 seconds was recorded. Prior to the test, the patient performed a practice trial with a sufficient number of repetitions to become familiarized with the test, including the desired amount of knee flexion.

The OLH requires acceleration, balance, and functional stability of the knee.[41] The patient stood on 1 foot, with hands behind the back, and was asked to hop as far as possible, landing and balancing on the same foot long enough for the examiner to determine the distance of the jump using a tape measure fixed to the floor. The patient was not allowed to move the foot after landing. Distance was measured in centimeters from the toe in the starting position to the heel in the landing position. The patient performed 2 practice trials to become familiarized with the test, and then 2 test trials. The best trial of the 2 was recorded.

The 6MTH requires the patient to hop for a distance of 6 m using 1 leg. Time (in seconds) from the start to the 6-m line was recorded using a stopwatch. Arms could be used freely, but the other foot was not allowed to touch the ground during the test. One practice trial was performed, followed by 2 test trials. The best trial of the 2 was recorded.

## Examination

At inclusion, patients were examined clinically by 1 physical therapist and 1 orthopaedic surgeon, who examined the MRIs and made the Kellgren-Lawrence scoring based on the radiographs. Included patients were tested at the Norwegian Sport Medicine Clinic. Baseline data were obtained by the same person who trained the patients. The postintervention and follow-up tests were performed by a blinded physical therapist. The 2 therapists followed the same detailed test protocol, and 1 common practice session was performed prior to the start of the study. At each test occasion, patients filled out the questionnaires before completing a standardized 10-minute warm-up on a stationary bike, followed by the muscle strength tests and then the lower extremity performance tests. Physical activities performed between baseline and postintervention, other than those included in the exercise therapy program, were self-reported postintervention. Types of exercise, number of sessions, and the duration and intensity of the sessions were recorded. Intensity of exercises was categorized based on the patients' own perception of low (not warm/sweaty), moderate (a little warm/sweaty), and high intensity (very hot/sweating a lot).

## The Neuromuscular and Strength Exercise Program

The 12-week neuromuscular and strength exercise (**APPENDIX**) program consisted of progressive exercises performed for a minimum of 2 and a maximum of 3 sessions per week (a total of 24 to 36 sessions).

Prior to each exercise session, a warm-up on a stationary bike was performed for 20 minutes using the resistance level of choice. The aim of the neuromuscular exercises was to improve balance and functional stability of the lower extremity.[59] This was achieved through progression of exercises, such as single-leg squats, and by using different surfaces, such as balance pads or the BOSU Balance Trainer (Hedstrom Fitness, Ashland, OH). All exercises were primarily performed in a weight-bearing position. Progression was determined by the patient's neuromuscular function and accomplished by changing the support surface or including more challenging exercises. After 4 weeks, 3 plyometric exercises were included for enhancement of neuromuscular performance and strength development,[14,52] focusing on maintaining the knee-over-foot position with soft landings.

All patients performed single-leg strength exercises on both the injured and the uninjured sides. The program included concentric and eccentric exercises, in both weight-bearing and non–weight-bearing positions (**APPENDIX**). The participants initially performed 2 sets of 15 repetitions, then 3 sets of 12 repetitions, then 3 sets of 8 repetitions, and finally performed 4 sets of 6 repetitions at the end of the program. The progression was based on physiological adaptations that have been shown to occur in a short period among novice individuals[4] and on increases in muscle strength due to muscular and neural adaptations.[1,5] The program is consistent with recent recommendations for training frequency, intensity, volume, and recovery for novice to intermediate individuals.[4] To ensure progressive overload for each patient, we used the "plus-two rule," which stipulates that the last set should be performed with as many repetitions as possible, and if the patient is able to add at least 2 extra repetitions to the set, the load is to be increased at the next training session. This progression method has been previously used successfully in an anterior cruciate ligament rehabilitation program.[16]

The exercise therapy program and the exercise progression strategy were explained individually to the patients. All patients were instructed and supervised individually by the same physical therapist once a week throughout the program. Supervision was needed to ensure the intended performance of the exercises and progression for each individual. The second or third weekly session was performed individually in a gym but without supervision. Compliance with the program was monitored through a training diary, in which the type of exercises and load (in kilograms) for each exercise during each week were documented. Furthermore, self-reported

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pain during and immediately after the training sessions was monitored through the training diary, using a visual analog scale (VAS) ranging from 0 to 10, with 0 to 2 indicating no or minimal pain, greater than 2 to 5 indicating some pain, greater than 5 to 10 indicating high levels of pain, and 10 indicating pain as bad as it can be. Levels 0 to 5 were defined as acceptable pain levels.[56] Adverse events were defined as (1) not attending or not completing a training session because of increased pain or problems with the injured knee related to the exercise therapy program, or (2) self-reported pain greater than 5 on the 0-to-10 scale during or after training. Adverse events were recorded in the training diary and during the weekly supervised session.

## OUTCOMES

The **TABLE** shows descriptive data and outcome scores for all 20 patients. Only the data for the injured leg are provided in this report. The median number of days from the baseline examination to the postintervention test was 107 (range, 91-149 days). During the 12-week exercise therapy program, the patients performed a total of 14 to 32 sessions. Two patients dropped out of the exercise therapy program after week 10 due to work-related reasons and 1 patient dropped out of the exercise therapy program after week 7 for an unknown reason. All patients, except 2, increased their load on all muscle strength exercises throughout the program (**FIGURE 1**). The 2 patients who did not increase their load on all exercises remained with the same load for only 1 of the strengthening exercises (**FIGURE 1**), due to unknown reasons other than knee pain. For the single-leg leg press exercise, the patients increased their load by between 10 and 70 kg (20%-300%), for the single-leg knee extension exercise by between 0 and 30 kg (0%-600%), and for the single-leg leg curl exercise by between 0 and 35 kg (0%-500%). All patients progressed from the simpler to the more complex neuromuscular exercises and incorporated 2 or more plyometric exercises during the exercise therapy program.

Sixteen (16/20) patients reported participating in other physical activities during the intervention period in addition to the exercise therapy program (**TABLE**). The median (range) frequency per week of these other activities was 1.45 (0.5-8), median duration of each session was 82.5 minutes (20-300), and median intensity was moderate (low to high). The most common activities were brisk walking (26%), cross-country skiing (23%), and cycling (12%).

### Patient-Reported Outcomes

There were clinically meaningful changes[47] (of 10 points or greater) in 16 of 20 patients for the KOOS quality of life subscale postintervention. At 1-year follow-up, 15 of these 16 patients had maintained this improvement. Between 10 (KOOS pain subscale) and 18 (KOOS function in sport and recreation subscale) of 20 patients had improved more than 10 points on the other 4 subscales of the KOOS postintervention, and at 1-year follow-up the majority of these patients reported the same or a better score for the different subscales compared to postintervention scores.

Nineteen of 20 patients rated themselves as "a lot better" or "better" on the GRC scale after the exercise therapy program, with the remaining patient selecting "unchanged." At 1 year, 2 of 20 patients rated themselves as "totally recovered," 17 as "a lot better" or "better," and 1 as "unchanged." The patient who self-reported "unchanged" at both postintervention and at 1 year did not display any unusual noteworthy features (**TABLE**).

### Knee Muscle Strength

Changes from baseline to postintervention for peak knee extension and flexion torque for each individual's injured limb are shown in the **TABLE**. Data for total work performed during testing are not included in the **TABLE**, because they did not provide any additional information. All patients improved their knee extension strength by 5% to 74%, from baseline to postintervention, with 14 of them improving by more than 15%. At 1-year follow-up, half the patients showed a further increase ranging from 1% to 22% in their peak knee extension torque compared to postintervention. Eighteen of 20 patients improved their peak knee flexion torque by 3% to 80% from baseline to postintervention, with 13 of these patients improving by more than 15%. At 1-year follow-up, 7 patients had further increased their peak knee flexion torque by 5% to 17%, compared to that at postintervention. Individual data for knee muscle strength on the injured side at baseline, postintervention, and at 1-year follow-up are provided in **FIGURE 2** and compared to reference data from individuals of similar age and gender.[15]

### Lower Extremity Performance

Absolute values for the single-leg tests for the injured limb at baseline, postintervention, and 1-year follow-up are shown in the **TABLE**. There were large individual changes from baseline to the follow-up tests for all 3 tests. For the OLH, 14 of 20 patients improved from baseline to postintervention, ranging from 1% to 65%, with 6 of them improving by more than 15%. Thirteen of the patients sustained or had further improvement at 1-year follow-up. For the 6MTH, 16 of 20 patients improved 4% to 125% from baseline to postintervention, with 12 of them improving by more than 15%. Seven patients sustained or had further improvement at the 1-year follow-up. For the maximum number of knee-bendings in 30 seconds, 19 of 20 patients improved by 5% to 133% from baseline to postintervention, with 15 of them improving by more than 15%. Ten of the patients sustained or had further improvement at 1-year follow-up.

### Adverse Events

There were no adverse events (defined as not attending a training session due to increased problems or pain in the in-

## TABLE — Descriptive Information and Outcomes for All Patients

| | Patient ID | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Descriptive information | | | | | | | | | | |
| Gender | Female | Female | Female | Female | Female | Male | Male | Male | Male | Male |
| Age, y | 48 | 53 | 58 | 39 | 55 | 53 | 45 | 44 | 47 | 46 |
| BMI, kg/m$^2$ | 21.6 | 29.0 | 29.6 | 20.4 | 26.3 | 22.9 | 23.6 | 20.6 | 28.9 | 22.7 |
| Injured side* | Left | Right | Right | Right | Left | Right | Right | Right | Right | Right |
| Duration of symptoms, mo | 8 | 12 | 6 | 7 | 4 | 11 | 18 | 18 | 84 | 9 |
| Exercise sessions,[†] n | 32 | 24 | 21 | 22 | 20 | 18 | 22 | 20 | 29 | 22 |
| Physical activities,[‡] yes/no | no | yes | yes | yes | no | yes | yes | yes | yes | yes |
| VAS[§] pain wk 1 | 6 | 5 | 1 | 0 | 2 | 2 | 1 | 0 | 0 | 1 |
| VAS[§] pain wk 12 | 2 | 4 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| Outcomes | | | | | | | | | | |
| KOOS[‖] pain pre/post | 28/64 | 44/50 | 44/83 | 75/92 | 47/89 | 61/83 | 64/81 | 75/81 | 64/72 | 86/92 |
| KOOS[‖] pain 1 y | 61 | 78 | 94 | 97 | 94 | 89 | 75 | 100 | 89 | 97 |
| KOOS[‖] symptoms pre/post | 32/68 | 61/71 | 50/82 | 75/89 | 57/68 | 68/86 | 68/89 | 75/93 | 86/82 | 89/93 |
| KOOS[‖] symptoms 1 y | 64 | 82 | 100 | 96 | 82 | 89 | 86 | 89 | 82 | 100 |
| KOOS[‖] ADL pre/post | 51/75 | 57/62 | 57/91 | 93/94 | 62/88 | 90/97 | 91/97 | 94/99 | 84/94 | 99/100 |
| KOOS[‖] ADL 1 y | 71 | 85 | 97 | 100 | 91 | 99 | 99 | 100 | 97 | 100 |
| KOOS[‖] sportrec pre/post | 20/55 | 40/40 | 20/45 | 65/90 | 35/70 | 45/80 | 60/75 | 70/70 | 45/80 | 50/90 |
| KOOS[‖] sportrec 1 y | 50 | 60 | 75 | 95 | 80 | 80 | 55 | 95 | 95 | 100 |
| KOOS[‖] QOL pre/post | 19/50 | 31/44 | 6/38 | 63/88 | 38/75 | 44/69 | 50/44 | 44/63 | 50/56 | 44/75 |
| KOOS[‖] QOL 1 y | 50 | 63 | 44 | 100 | 63 | 63 | 38 | 88 | 100 | 81 |
| GRC[¶] scale post | AB | B | AB | AB | AB | AB | AB | B | B | AB |
| GRC[¶] scale 1 y | AB | AB | AB | CR | AB | AB | AB | AB | CR | AB |
| Quadriceps PT pre, Nm | 92.0 | 93.2 | 89.8 | 107.1 | 93.3 | 198.6 | 191 | 149.3 | 243.6 | 166.7 |
| Quadriceps PT post, Nm | 130.0 | 101.5 | 126.3 | 128.4 | 122.7 | 208.9 | 213.8 | 179.9 | 270.7 | 188.1 |
| Quadriceps PT 1 y, Nm | 139.9 | 107.2 | 119.9 | 144.9 | 122.1 | 229.4 | 207.2 | 164.9 | 261.6 | 187.3 |
| Hamstrings PT pre, Nm | 47.0 | 57.6 | 49.3 | 64.5 | 65.3 | 102.2 | 116.7 | 67.8 | 134.6 | 106.5 |
| Hamstrings PT post, Nm | 84.7 | 59.6 | 59.0 | 66.1 | 75.9 | 113.9 | 135.4 | 83.5 | 131.8 | 113.3 |
| Hamstrings PT 1 y, Nm | 69.3 | 59.5 | 65.8 | 76.2 | 70.5 | 120.1 | 121.4 | 81.9 | 141.7 | 105.3 |
| OLH pre, cm | 49 | 42 | 45 | 104 | 43 | 102 | 150 | 109 | 96 | 112 |
| OLH post, cm | 81 | 47 | 49 | 115 | 53 | 155 | 145 | 118 | 105 | 112 |
| OLH 1 y, cm | 66 | 63 | 62 | 117 | 55 | 144 | 132 | 122 | 90 | 103 |
| 6MTH pre, s | 6.40 | 4.25 | 4.25 | 2.16 | 3.30 | 1.83 | 1.56 | 2.20 | 2.10 | 1.96 |
| 6MTH post, s | 2.84 | 3.47 | 3.47 | 2.16 | 2.68 | 1.30 | 1.50 | 1.69 | 2.03 | 1.66 |
| 6MTH 1 y, s | 3.15 | 3.10 | 4.41 | 2.09 | 2.90 | 1.68 | 1.75 | 1.80 | 2.06 | 1.96 |
| Knee-bendings 30 s[#] pre, n | 24 | 18 | 22 | 22 | 38 | 54 | 48 | 27 | 41 | 44 |
| Knee-bendings 30 s[#] post, n | 49 | 23 | 48 | 23 | 44 | 60 | 54 | 43 | 52 | 63 |
| Knee-bendings 30 s[#] 1 y, n | 46 | 26 | 40 | 38 | 44 | 63 | 56 | 40 | 36 | 59 |

*Table continues on page 924.*

jured knee related to training) during the course of the study. All patients were able to perform the training program during the sessions they attended. Based on reporting knee pain greater than 5 on the 0-to-10 VAS, 4 of 20 patients decreased their load during training but for no more than 2 sessions. Two patients reported that the pain was due to other activities they had performed in the days before the training session, 1 patient reported that the pain was due to an excessive increase in load at the time of the previous training session, and 1 patient did not state any reason for the knee pain.

Ninety-six percent (383/398) of the training sessions were performed with acceptable pain of 5 or less on the VAS. On 1

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**TABLE** Descriptive Information and Outcomes for All Patients (Continued)

| | Patient ID | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Descriptive information | | | | | | | | | | |
| Gender | Male | Male | Male | Male | Male | Male | Female | Female | Male | Female |
| Age, y | 54 | 55 | 46 | 57 | 51 | 58 | 48 | 38 | 55 | 46 |
| BMI, kg/m$^2$ | 26.6 | 25.1 | 24.5 | 28.1 | 26.7 | 27.1 | 30.0 | 20.3 | 27.4 | 33.1 |
| Injured side* | Right | Left | Left | Left | Right | Right | Right | Left | Left | Left |
| Duration of symptoms, mo | 24 | 10 | 12 | 4.5 | 17 | 18 | 7.5 | 24 | 7.5 | 5 |
| Exercise sessions,† n | 26 | 31 | 22 | 32 | 27 | 27 | 22 | 16 | 14 | 22 |
| Physical activities,‡ yes/no | yes | yes | no | no | yes | yes | yes | yes | yes | yes |
| VAS§ pain wk 1 | 0 | 2 | 3 | 6 | 1 | 4 | 0 | 2 | 3 | 0 |
| VAS§ pain wk 12 | 0 | 4 | 2 | 2 | 0 | 2 | 0 | 0 | 2 | 0 |
| Outcomes | | | | | | | | | | |
| KOOS‖ pain pre/post | 83/86 | 72/81 | 56/83 | 28/50 | 72/97 | 83/86 | 86/94 | 72/89 | 50/67 | 81/92 |
| KOOS‖ pain 1 y | 89 | 81 | 92 | 81 | 100 | 86 | 92 | 92 | 81 | 78 |
| KOOS‖ symptoms pre/post | 79/93 | 93/93 | 64/96 | 57/71 | 82/93 | 89/89 | 89/86 | 61/93 | 61/86 | 93/93 |
| KOOS‖ symptoms 1 y | 89 | 93 | 89 | 89 | 100 | 93 | 93 | 93 | 89 | 75 |
| KOOS‖ ADL pre/post | 93/97 | 78/97 | 65/94 | 34/60 | 85/96 | 91/97 | 100/99 | 76/96 | 65/94 | 93/96 |
| KOOS‖ ADL 1 y | 96 | 94 | 96 | 91 | 100 | 96 | 100 | 97 | 93 | 91 |
| KOOS‖ sportrec pre/post | 75/85 | 25/60 | 30/85 | 0/25 | 55/95 | 70/85 | 65/75 | 30/80 | 10/50 | 85/95 |
| KOOS‖ sportrec 1 y | 90 | 65 | 70 | 50 | 85 | 80 | 100 | 95 | 65 | 80 |
| KOOS‖ QOL pre/post | 69/75 | 31/50 | 38/75 | 6/25 | 44/88 | 63/63 | 56/75 | 50/69 | 25/50 | 44/56 |
| KOOS‖ QOL 1 y | 88 | 50 | 69 | 50 | 94 | 50 | 100 | 81 | 75 | 75 |
| GRC¶ scale post | B | AB | AB | AB | AB | AB | AB | AB | B | UC |
| GRC¶ scale 1 y | B | AB | AB | AB | AB | AB | B | AB | AB | UC |
| Quadriceps PT pre, Nm | 149.9 | 128.1 | 196.9 | 149.2 | 152.8 | 203.5 | 110.8 | 121.3 | 112 | 136.5 |
| Quadriceps PT post, Nm | 194.5 | 155.7 | 256.4 | 259.3 | 210.4 | 232.0 | 171.2 | 156.9 | 137.3 | 159.1 |
| Quadriceps PT 1 y, Nm | 207.3 | 169.3 | 259.4 | 228.9 | 196.9 | 221.4 | 186.3 | 156 | 176.9 | 167.1 |
| Hamstrings PT pre, Nm | 76.2 | 68.9 | 106.4 | 79.9 | 78.7 | 101.3 | 59.6 | 66.3 | 75.0 | 60.9 |
| Hamstrings PT post, Nm | 126.9 | 101.2 | 136.3 | 120.0 | 123.4 | 115.3 | 101.2 | 81.3 | 68.1 | 74.2 |
| Hamstrings PT 1 y, Nm | 110 | 79.5 | 133.8 | 114.6 | 113.8 | 128.8 | 101.3 | 66.9 | 80.9 | 89.4 |
| OLH pre, cm | 92 | 102 | 90 | 135 | 45 | 67 | 58 | 82 | MD | 63 |
| OLH post, cm | 94 | 99 | 101 | 136 | 69 | 99 | 54 | 101 | 42 | 44 |
| OLH 1 y, cm | 99 | 105 | 105 | 127 | 71 | 100 | 68 | 100 | 47 | 57 |
| 6MTH pre, s | 2.40 | 2.03 | 2.25 | 1.78 | 2.83 | 2.72 | 3.56 | 3.06 | MD | 3.75 |
| 6MTH post, s | 1.85 | 1.88 | 1.85 | 1.72 | 2.40 | 2.25 | 3.6 | 2.13 | 3.18 | 3.81 |
| 6MTH 1 y, s | 1.97 | 1.97 | 2.10 | 1.60 | 2.41 | 2.09 | 2.75 | 2.37 | 2.31 | 3.34 |
| Knee-bendings 30 s# pre, n | 29 | 35 | 23 | 39 | 26 | 31 | 20 | 12 | 21 | 16 |
| Knee-bendings 30 s# post, n | 43 | 50 | 50 | 44 | 57 | 47 | 30 | 28 | 47 | 16 |
| Knee-bendings 30 s# 1 y, n | 47 | 46 | 49 | 50 | 48 | 42 | 42 | 26 | 48 | 19 |

*Abbreviations: 1 y, 1-year follow-up; 6MTH, 6-meter timed hop; AB, a lot better; ADL, activities of daily living; B, better; BMI, body mass index; CR, completely recovered; GRC, global rating of change; KOOS, Knee injury and Osteoarthritis Outcome Score; MD, missing data; OLH, 1-leg hop for distance; post, postintervention; pre, preintervention; PT, peak torque; QOL, knee-related quality of life; sportrec, function in sport and recreation; UC, unchanged; VAS, visual analog scale.*
**Data on the injured side are provided for the muscle strength test and the lower extremity performance tests.*
*†Number of exercise sessions attended during the intervention period.*
*‡Performed physical activities in addition to the intervention (self-reported).*
*§A score of 0 indicates no pain and a score of 10 indicates pain as bad as it can be.*
*‖A score of 0 indicates extreme symptoms and a score of 100 indicates no symptoms.*
*¶A 7-point scale (–3 to 3), with –3 as very much worse, –2 much worse, –1 worse, 0 unchanged, 1 better, 2 a lot better, and 3 completely recovered.*
*#Maximum number of knee-bendings in 30 seconds.*

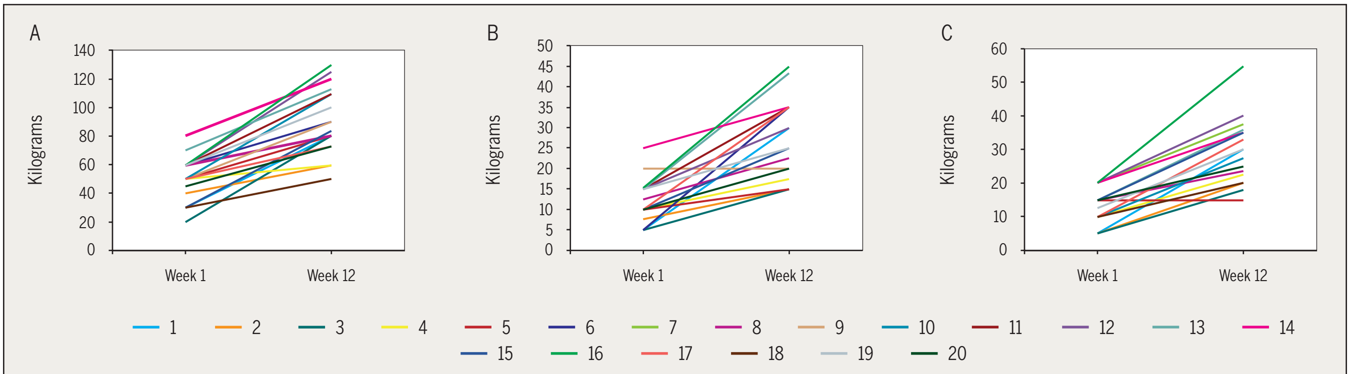


**FIGURE 1.** Increase in load (in kilograms) on the injured side for the strength-training exercises: (A) single-leg leg press, (B) single-leg knee extension, and (C) single-leg leg curl for the 20 patients.

occasion, a patient reported high levels of pain after training (6/10 on the VAS). In addition, 3 of 20 patients reported high levels of pain during 1 training session (6 on the VAS), 1 patient during 2 sessions (6 and 7 on the VAS), and 1 patient during 9 sessions (6-8 on the VAS). The latter patient attended 23 training sessions in total during the training period, and for the last 4 weeks of training an acceptable level of pain (5 or less) was reported. At 1-year follow-up, none of the patients had undergone surgery for their knee injury.

## DISCUSSION

This study provided a detailed description of a progressive neuromuscular and strength exercise program for patients with degenerative meniscus tears, and showed that the majority of the patients reported clinically meaningful changes that were sustained at 1 year. Postintervention, there were clinically meaningful changes of 10 or greater[47] for 16 of 20 patients for knee-related quality of life (KOOS quality of life subscale), and 19 of 20 patients rated themselves as "a lot better" or "better" on the GRC scale. Additionally, 2 patients reported that they were "totally recovered" after 1 year. All patients improved in quadriceps muscle strength during the intervention period, and 14 of 20 patients improved more than the suggested cutoff of 15% for the MDC.[55] In addition, the majority of the patients had increased knee flexor strength and improved lower extremity performance after the 12 weeks of training. At 1 year, compared to postintervention, the majority of patients had either sustained or further improved their knee function as measured with the 5 KOOS subscales, knee muscle strength, and lower extremity performance. The program showed no adverse events, although 5 of the 20 patients occasionally reported pain during training. After 1 year, none of the patients had undergone surgery.

A major challenge for physicians and physical therapists treating these patients, who are at high risk of developing knee OA, is the lack of information on an effective nonsurgical option to treatment.[19] Despite the plentiful and robust literature supporting the efficacy of exercise in patients with knee OA,[3,33,46] to our knowledge there is little evidence on the effect of such training in patients with degenerative meniscus tears. Despite the positive outcomes reported from this case series, randomized controlled trials with long-term outcomes, comparing this exercise therapy program, which focused on neuromuscular and strength training, to other interventions, are needed.

### Intervention Program

The present exercise therapy program consisted of both neuromuscular- and strength-training exercises, which have some inherent differences. Strength training aims at improving muscle force output, and neuromuscular exercise aims at improving dynamic function, alignment, and control.[3] Knee injuries, such as meniscus tears, anterior cruciate ligament tears, and cartilage defects, lead to functional instability and impaired neuromuscular function.[2,3,21] Restoring and improving neuromuscular function are, therefore, crucial, as is quadriceps function, because the quadriceps serves as the body's shock absorber and thus dampens rates of loading in normal and injured knees during activity.[35]

The essential component of neuromuscular exercises is the quality of movement performance. All patients were instructed to try to keep their knee over the foot during the exercises, to avoid excessive medial or lateral positioning of the knee. Supervision was provided to control the quality of the performance during the exercises. The progression (changing the support surface and varying the number of repetitions), direction, or velocity of the movements was based on the patient's ability to control the trunk and lower extremity alignment. Supervision was also needed to teach the patients how to increase the workload during the strengthening exercises, and to reinforce the concept that exercise would not harm the knee joint. We did not perform a 1-repetition-maximum test prior to the exercise program to determine the suitable loads to use with each exercise but instead relied on the patients' feedback of their perceived maximum. We thus had no objective criteria for the patients'

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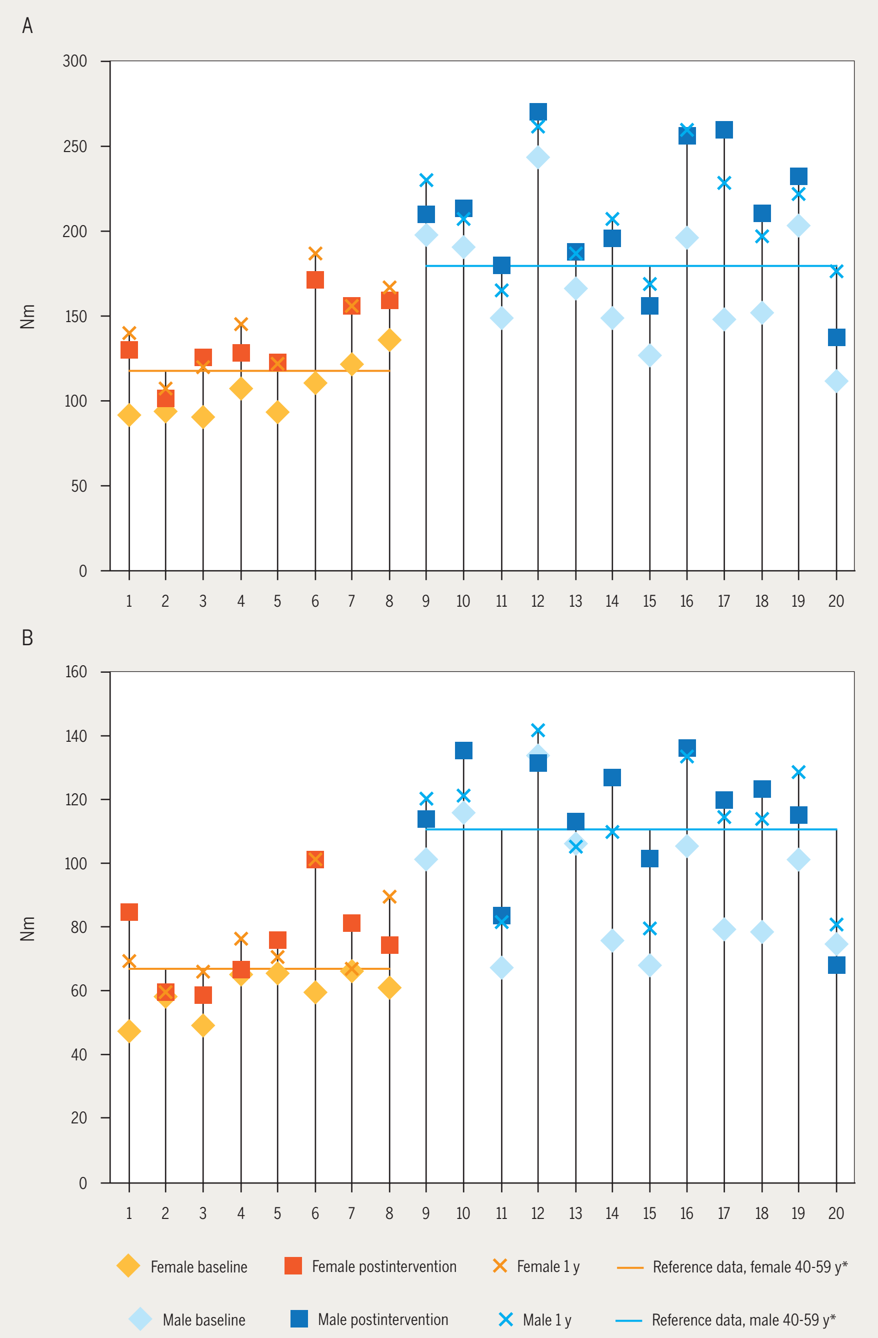


**FIGURE 2.** Isokinetic peak torque data for the injured side at baseline, postintervention, and 1-year follow-up (in Newton meters) for the 20 patients. (A) Peak knee extension torque; (B) peak knee flexion torque. *Age- and sex-matched reference data from Danneskiold-Samsøe et al.[15] Abbreviation: 1 y, 1-year follow-up.

starting load, other than the clinical approach based on the patients' feedback. Therefore, the exact progression for each exercise may not have been accurate. However, the 1-repetition-maximum test could also have given inaccurate results, because most of the patients were unfamiliar with strength training in general and some might have experienced pain during testing.

When introducing patients to exercise therapy programs, it is important that they be able to tolerate the training intensity, particularly patients who have pain. To make sure that the perceived pain did not increase or exceed acceptable levels during the training period, we included a pain-monitoring system used previously in patients with patellofemoral pain syndrome[56] and severe hip or knee OA.[3] Both during and after the training sessions, with a few exceptions, the patients in this study reported what was considered to be a safe level of pain, confirming that the exercises in the program were well tolerated by these patients.

## Muscle Strength and Functional Performance

Quadriceps muscle dysfunction has been suggested to precede degenerative changes in the knee joint.[8,54,57] Although conflicting evidence exists,[46] muscle weakness and lower extremity functional performance have both been associated with OA onset and progression.[38,53,57] It is further suggested that impaired muscle function may be related to increased dynamic knee joint load,[35] and such moving of joint load to areas of the articular surface that are not capable of withstanding increased compressive forces may cause cartilage breakdown.[6] Although there is no consensus, it has also been suggested that muscle weakness may be a unifying feature associated with other established risk factors for OA, such as obesity, sex, age, and joint injury.[46] It is, therefore, important that patients at increased risk for OA and those who are at an early stage of OA regain adequate muscle strength. Thus, it is crucial to tailor the exercise therapy program to monitor pain and ensure progression. In our study, from baseline to postintervention, all patients improved in quadriceps muscle strength and all except 2 patients improved in knee flexion strength (**TABLE**). A change in knee extension strength of at least 15% is considered to be the MDC in young, healthy individuals,[55] and the majority of the patients in our study met this cri-

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terion. However, an MDC is context dependent and may vary with patient group and intervention. In this case, using the same cutoff for middle-aged patients with a knee injury may not apply.

As visualized in **FIGURE 2**, at postintervention the majority of our patients had exceeded the normative mean muscle strength of a healthy age- and sex-matched population-based reference group.[15] Six of 8 women and 7 of 12 men in our study showed values below the reference group for peak knee extension torque at baseline (117.5 and 179.5 Nm for the women and men, respectively), but only 1 woman and 2 men had peak torque values lower than the normative mean postintervention. There were similar findings for peak knee flexion torque (**FIGURE 2**). At 1-year follow-up, the majority of the patients maintained or had further improvements in muscle strength. This suggests that the patients in our study regained adequate knee muscle strength after the exercise therapy program. However, muscle strength data for a healthy population are limited and should be addressed in future studies.

Functional performance tests are commonly used in a clinical setting to assess the progression of a training program and to determine the level of recovery after lower extremity injury or surgery.[51] We included 3 different tests: the OLH, 6MTH, and maximum number of knee-bendings in 30 seconds. Depending on the test, 14 to 19 of 20 patients improved from baseline to postintervention, and approximately half of the patients had either maintained their improvement or further improved at 1-year follow-up (**TABLE**). Some studies have reported MDC for the performance tests,[40,58] but the included populations in these studies were not comparable to our group of middle-aged patients.

Because most patients with symptomatic degenerative meniscus tears typically have surgery, it is important to note that none of the patients in this study required surgery within the first year after inclusion in this study.

### Limitations

Due to the design of the study (case series) and corresponding limited sample size, we could not compare the effect of this particular exercise therapy program to other interventions or to a control group. These data were intended to describe the exercise therapy program, to demonstrate feasibility of the intervention, and to report any adverse events. As highlighted above, a randomized controlled trial with long-term outcomes is needed to determine if this specific program is significantly better than other interventions in patients with degenerative meniscus tears, both clinically and for the progression of knee OA. Another limitation of this study is that the examiner who performed the baseline assessment was different from the one who performed the follow-up assessments postintervention and at 1 year, and this might have caused a systematic tester effect. This bias was minimized by providing detailed testing protocols and arranging 1 practice session for the 2 testers prior to initiating the study. Furthermore, good interrater reliability of isokinetic testing of the knee has previously been reported.[29] Finally, the patients were allowed to do as much physical activity as they wanted in addition to the intervention, which might have impacted the outcomes. However, there were no major differences in outcomes between the patients who performed additional physical activities and those who did not.

## CONCLUSION

These results suggest that the neuromuscular- and strength-training program described in this study should be considered for the rehabilitation of middle-aged patients with degenerative meniscus tears. Twelve weeks of exercise resulted in improvements in self-reported outcome measures, muscle strength, and functional tests immediately postintervention, which for most patients were maintained 1 year later, with 19 of 20 patients reporting that they were "totally recovered," "a lot better," or "better." Only a few minor adverse events of a temporary increase in pain were reported during the course of the 12 weeks. None of the patients required surgery within the first year postintervention. Future adequately powered and designed clinical studies should address whether the specific exercise program in the present study would be significantly better than other interventions at improving short- and long-term clinical outcomes in patients with degenerative meniscus tears. ◉

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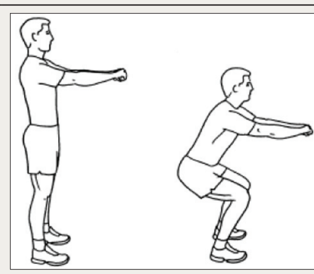
## APPENDIX*

| Exercise | Description | Sets × Repetitions | Figures |
|---|---|---|---|
| Stationary cycle | Continuous warm-up at preferred resistance | 20 minutes |  |
| Squat | Maintain knee-over-toe position | 3 × 10 |  |



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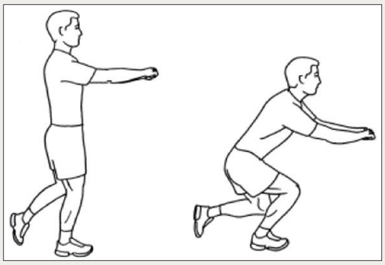
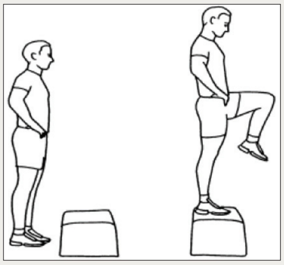
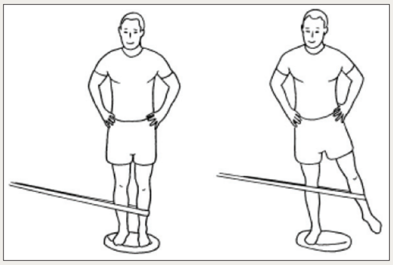
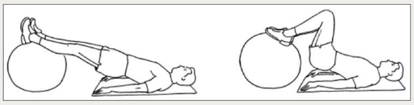
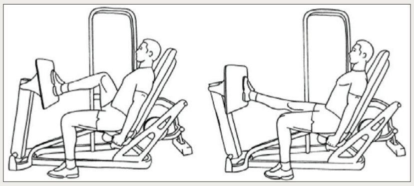
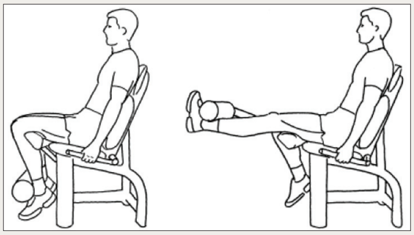
## APPENDIX*

| Exercise | Description | Sets × Repetitions | Figures |
|---|---|---|---|
| Single-leg squat | Maintain knee-over-toe position | 3 × 10 |  |
| Step-up | Maintain knee-over-toe position | 3 × 10 |  |
| Knee stability in pull loop | Maintain balance with or without balance pad | 3 × 10 |  |
| Hamstring on Fitball | Both feet on top of the ball. Lift back and pelvis. Pull ball toward you | 3 × 8 |  |
| Single-leg leg press | Start in 90° of knee flexion | 2-4 × 15-6 (+2)[†] |  |
| Single-leg knee extension | Start in 90° of knee flexion | 2-4 × 15-6 (+2)[†] |  |

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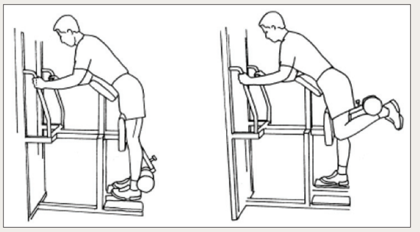
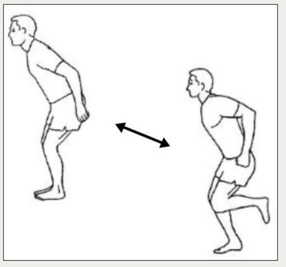
## APPENDIX*

| Exercise | Description | Sets × Repetitions | Figures |
|---|---|---|---|
| Single-leg leg curl | Lift quickly up, then slowly down to full extension | 2-4 × 15-6 (+2)† |  |
| Skating | Start on 1 leg, hop sideways, perform a soft, deep, and steady landing on 1 leg, hop back to the other side. Maintain knee-over-toe position | 3 × 10 |  |
| Limping cross | Stand in the middle of a cross on 1 leg. Hop straight forward and back to the center, right and back to the center, backward and back to the center, left and back to the center. Maintain knee-over-toe position | 3 × 3 rounds |  |

*Minimum 2, maximum 3 training sessions per week, Progression based on increasing loads for the strengthening exercises, and changing the support surface or including other more challenging variations for the neuromuscular/plyometric exercises.

†Initially, the participants performed 2 sets of 15 repetitions, then 3 sets of 12 repetitions, then 3 sets of 8 repetitions, then 4 sets of 6 repetitions at the end of the program. The "plus-two rule" (+2) indicates that the last set should be performed with as many repetitions as possible, and if the participants is able to add at least 2 extra repetitions to the set, the load is to be increased at the next training session.

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