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# The Feasibility of a 3-Month Active Rehabilitation Program for Patients With Knee Full-Thickness Articular Cartilage Lesions: The Oslo Cartilage Active Rehabilitation and Education Study

● **STUDY DESIGN:** Case series.

● **OBJECTIVES:** To evaluate the feasibility of an active rehabilitation program for patients with knee full-thickness articular cartilage lesions.

● **BACKGROUND:** No studies have yet evaluated the effect of active rehabilitation in patients with knee full-thickness articular cartilage lesions or compared the effects of active rehabilitation to those of surgical interventions. As an initial step, the feasibility of such a program needs to be described.

● **METHODS:** Forty-eight patients with a knee full-thickness articular cartilage lesion and a Lysholm score below 75 participated in a 3-month active rehabilitation program consisting of cardiovascular training, knee and hip progressive resistance training, and neuromuscular training. Feasibility was determined by monitoring adherence to the program, clinical changes in knee function, load progression, and adverse events. Patients were tested before and after completing the rehabilitation program by using patient-reported outcomes (Knee injury and Osteoarthritis Outcome Score, International Knee Documentation Committee Subjective Knee Evaluation Form 2000) and isokinetic muscle strength and hop tests. To monitor adherence, load progression, and adverse events, patients responded to an online survey and kept training diaries.

● **RESULTS:** The average adherence rate to the rehabilitation program was 83%. Four patients (9%) showed adverse events, as they could not perform the exercises due to pain and effusion. Significant and clinically meaningful improvement was found, based on changes on the International Knee Documentation Committee Subjective Knee Evaluation Form 2000, the Knee injury and Osteoarthritis Outcome Score quality of life subscale, isokinetic muscle strength, and hop performance ( $P < .05$ ), with small to large effect sizes (standardized response mean, 0.3-1.22).

● **CONCLUSION:** The combination of a high adherence rate, clinically meaningful changes, and positive load progression and the occurrence of only a few adverse events support the potential usefulness of this program for patients with knee full-thickness cartilage lesions. This study was registered with the public trial registry ClinicalTrials.gov (NCT00885729).

● **LEVEL OF EVIDENCE:** Therapy, level 4.  
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● **KEY WORDS:** chondral injury, neuromuscular exercises, strength exercises, tibiofemoral joint

**K**nee articular cartilage lesions occur frequently and are a major clinical challenge in orthopaedic and sports medicine, as well as in physical therapy.<sup>2,59</sup> Patients often experience restrictions of daily, recreational, and sports activities due to functional impairments and disabilities. Clinically, patients often present with pain and effusion,<sup>31,33</sup> as well as muscle weakness, poor neuromuscular control, and low self-reported knee function.<sup>40,45</sup> Joint effusion reduces range of motion, alters proprioceptive input, and potentially leads to muscle reflex inhibition.<sup>4,8,25</sup> Knee function has been shown to be significantly worse in patients with articular cartilage lesions compared to patients with anterior cruciate ligament (ACL) injury. Furthermore, quality of life has been shown to be affected to the same extent in patients with articular cartilage lesions as in those with knee osteoarthritis (OA)

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scheduled for total knee replacement.<sup>33</sup>

There is strong evidence that rehabilitation programs, including progressive resistance and neuromuscular training, have beneficial effects on pain and knee function in patients with different musculoskeletal disorders of the lower limb, such as knee and hip OA and rupture of the ACL.<sup>22,28,40,51</sup> However, to our knowledge, no studies have yet evaluated the effect of active rehabilitation programs in patients with articular cartilage lesions or compared the effect of rehabilitation alone to that of surgical interventions followed by postoperative rehabilitation. It has been stated that nonsurgical treatment for patients with articular cartilage lesions scheduled for cartilage repair is considered inappropriate, because most symptomatic patients are likely to be nonresponders to nonsurgical management.<sup>52</sup> However, to our knowledge, no study has yet shown that these patients are nonresponders. Furthermore, there is a lack of evidence-based criteria to determine patients' eligibility for cartilage repair.<sup>23</sup> No studies have investigated the effect of an evidence-based nonsurgical rehabilitation program in patients eligible for cartilage repair.<sup>39</sup>

The multimodality approach in physical therapy requires a thorough description of the specific exercises that are used, including progression, adherence, and tolerance to the program. There is some evidence that the level of adherence to an exercise program is associated with effectiveness.<sup>50,66</sup> Hence, factors influencing adherence should be considered thoroughly when designing a rehabilitation program. In particular, for patients with full-thickness articular cartilage lesions, tolerance for progression based on pain and effusion needs to be described.<sup>69</sup> Furthermore, current knowledge on cartilage lesion type, size, and location should be implemented when selecting specific exercises and loading.<sup>10</sup> Cartilage tissue has been shown to be sensitive to loading, and maintenance of its composition and unique biomechanical properties requires optimal loading.<sup>47</sup>

Altered composition of cartilage tissue and reduced biomechanical properties have been shown to result in pain and effusion.<sup>1,3</sup> In vitro experiments have shown that the metabolism of chondrocytes can be enhanced by dynamic loading, whereas static loading leads to reduced synthesis of proteoglycans and potentially to a breakdown of proteoglycans, fibrillation of the surfaces, and possible cell death.<sup>47,60</sup> These in vitro findings are consistent with results of animal studies and investigations in humans.<sup>20,35,64,67</sup> The absence of mechanical stimulation has been shown to lead to a decrease in cartilage thickness, leading to some process of cartilage atrophy.<sup>35,64,67</sup> However, it is still unclear whether and how these findings can be directly implemented in the conservative management of patients with articular cartilage lesions, particularly full-thickness articular cartilage lesions.

To our knowledge, no studies have examined either the feasibility or effectiveness of rehabilitation programs that aim to target specific dysfunctions in patients with knee articular cartilage lesions. Prior to investigating the effectiveness of a rehabilitation program in a randomized controlled trial, the feasibility of such a program to target muscle weakness and neuromuscular deficits should be examined. The feasibility of a rehabilitation program should be tested by monitoring patients' adherence to the program, clinical changes, and potential dose responses, as well as tolerance and safety (adverse events). If feasibility is demonstrated, the program's effectiveness compared to other programs and eventually to surgical repair needs to be investigated.

The overall purpose of this study was to implement a specific nonsurgical rehabilitation program for patients with knee full-thickness articular cartilage lesions who were eligible for cartilage repair. The specific aims were to evaluate the feasibility of the program as determined by (1) adherence to the rehabilitation program, (2) clinical changes in knee function, (3) progression of the rehabilitation pro-

gram, and (4) the occurrence of adverse events.

## METHODS

### Patients

FIFTY PATIENTS CONSECUTIVELY ASSESSED and considered by an orthopaedic surgeon to be candidates for cartilage repair were eligible for the study. All patients had received physical therapy interventions prior to the orthopaedic surgeon's assessment. However, no information was available on the physical therapy interventions that had been previously provided. Prior to inclusion, all eligible patients underwent a knee arthroscopy to assess the cartilage lesion and any associated injuries. The arthroscopy was purely diagnostic, and no "wash-out" of the joint or medication was used other than routine medication for diagnostic arthroscopy. Patients were eligible for inclusion if they had an arthroscopically verified, focal full-thickness cartilage lesion (grade 3 or 4 according to the classification of the International Cartilage Repair Society) with a diameter of 1.5 cm or greater and an area of 6 cm<sup>2</sup> or less located on either femoral condyle. Additional inclusion criteria were that patients had to be between 17 and 50 years of age, to have no ligamentous instability, and to have a Lysholm score of less than 75. Exclusion criteria were untreated meniscal injury and inability to participate in the rehabilitation program due to geography or workload (not able to exercise 2 or 3 times per week).

Prior to inclusion, all patients signed a written informed-consent form. The study was approved by The Regional Ethical Committee for South-Eastern Norway and was performed in accordance with the Declaration of Helsinki.

### The Oslo Cartilage Active Rehabilitation and Education Program

The feasibility study for the Oslo Cartilage Active Rehabilitation and Education program was designed to examine adher-

ence to the program, clinical changes, progression during the program, and adverse events, as well as to teach patients specific exercises they would potentially need to perform postsurgery, as these patients were all eligible for cartilage repair surgery. It was determined that, without a patient's high level of adherence to the program, orthopaedic surgeons would not perform the surgical repair, based on the need for a long and systematic rehabilitation program postsurgery to obtain good long-term outcomes.<sup>16,49,57</sup> Based on clinical experience, it may take some patients a long time to understand and adhere to a rehabilitation program. Furthermore, studies have shown that, for other musculoskeletal injuries, good preoperative function is essential for good postoperative results.<sup>21,38,41,65,68</sup> Hence, teaching patients appropriate exercises to perform and using a structured exercise program to optimize preoperative knee function could also be of potential benefit for patients with full-thickness articular cartilage lesions who require a surgical repair.

The exercises used in this study are provided in the **APPENDIX**. The program was individualized according to patients' impairments (pain, swelling, muscle strength, and neuromuscular control), activity limitations, and specific goals. The exercises incorporated loading levels sufficient to induce both muscle strength and neuromuscular control. To improve impairments in patients with articular cartilage lesions, the exercise parameters should be adequate to target muscle weakness and neuromuscular control, without exacerbating swelling and pain. Improved neuromuscular control and muscle strength could potentially decrease the likelihood of further functional decline and increase confidence to safely engage in a more physically active lifestyle, ultimately resulting in better long-term function.

The rehabilitation program started immediately after patients were included in the study. The duration of the program was 3 months. During the program, the

physical therapist focused on explaining why the exercises were important and how the exercises should be performed and adjusted based on pain response and other symptoms. The 3-month active rehabilitation program consisted primarily of cardiovascular and knee and hip progressive resistance and neuromuscular training, including balance and plyometric exercises.

Progressive resistance training for the hip and the knee was included to address the muscle weakness that is believed to play a role in the pathogenesis of OA and to precede degenerative changes.<sup>34</sup> Muscle weakness, in particular of the quadriceps, may lead to abnormal joint loading and potential structural damage, as the quadriceps plays a significant role in load absorption.<sup>36,42</sup> Several studies have shown that quadriceps and hamstrings strength is directly related to knee function and disability.<sup>37,41,48</sup> In addition, hip muscle weakness may influence loading patterns in the knee that could be detrimental for patients with articular cartilage lesions.<sup>13</sup> Rehabilitation programs that focus on muscle strengthening in patients with knee OA have demonstrated improved pain and knee function, along with substantial strength gains.<sup>7,27,40</sup>

Neuromuscular training consisting of balance and plyometric exercises has been shown to improve dynamic knee stability and knee function in patients with knee OA, after ACL reconstruction, or with ACL-deficient knees, by enhancing coordinated muscle activity.<sup>12,26,32,55,56</sup>

### Phases of the Rehabilitation Program

The rehabilitation program was divided into 3 phases: (1) accommodation, (2) rehabilitation, and (3) return to activity. The goal of the accommodation phase was to restore joint homeostasis by reducing pain and effusion, to normalize range of motion, and to regain quadriceps control. This phase included interventions such as cryotherapy; compression; electrical muscle stimulation; muscle activation of the quadriceps, hamstrings, gastrocnemius, and gluteal muscles; and

gait retraining. In this phase, 2 to 3 supervised physical therapy sessions were scheduled for each patient, and attending these sessions was the criterion to fulfill adherence to the program. Prerequisites for progressing to the next phase were no pain and swelling during activities of daily living (ADL); 90° of knee flexion; and clinical evaluation of normalized quadriceps activity during the initial loading, initial contact, and midstance phases of gait.

The goal of the rehabilitation phase was to resolve knee impairments related to range-of-motion deficits, to normalize muscle strength compared to the uninjured limb, and to achieve dynamic joint stability during ADL. Cardiovascular training on a stationary bike and progressive knee and hip resistance and neuromuscular training were performed in this phase. Attending 2 or more supervised physical therapy sessions per week was used as the criterion for evaluating adherence to the program during the rehabilitation phase. In addition, patients were asked to perform 1 or 2 unsupervised training sessions per week. Criteria for progression to the next phase were the absence of pain and effusion during and after the training sessions, equally distributed weight on the lower limbs during weight-bearing exercises with no shift of the trunk (visually assessed by the physical therapists), and the ability to stand on 1 limb on a flat surface for at least 10 seconds.

The return-to-activity phase was individualized according to the goals for each patient. The criterion for adherence during the return-to-activity phase was the patients' attendance of 1 or more supervised sessions per week. Patients were also asked to perform resistance training for a minimum of 2 and a maximum of 4 sessions per week, whereas cardiovascular and neuromuscular training could be performed daily. The training diary was also used to monitor the unsupervised training sessions. Cardiovascular training was performed on a stationary bike, a treadmill, or a cross-trainer, de-

pending on availability. The knee and hip resistance training consisted of both weight-bearing and non-weight-bearing, single- and multiple-joint, as well as concentric and eccentric exercises. The following exercises were used for knee strengthening: leg press, knee extension (sitting position), squats (knee bendings) with and without external resistance, and a stepper. The following were used for hip strengthening: abduction/adduction machine (sitting) and standing on 1 limb while performing both resisted hip abduction and hip adduction with the other limb, using a pulley-and-weight system. All strengthening exercises were performed with both the injured and uninjured limbs.

For resistance training in the rehabilitation and return-to-activity phases, the patients performed 2 hip and 3 knee exercises per session. The exercise dosage, frequency, intensity, and duration for resistance training were based on strength training guidelines for patients with knee OA and on recommendations published by the American College of Sports Medicine.<sup>7,29</sup> Resistance training performed at an intensity of 40% to 60% of the 1-repetition maximum (1RM) has been shown to reduce pain and improve knee function in patients with moderate knee OA.<sup>7,42</sup> But there are no clinical guidelines for resistance training for patients with articular cartilage lesions in general or for full-thickness articular lesions in particular. Therefore, in this program, the patients performed 3 to 4 sets of 8 to 10 repetitions using a tolerable load, based on the patients' experience with resistance training. Load increase was advised if patients were able to perform more than 10 repetitions in the previous set. Patients ceased exercising for the specific exercise if pain or effusion occurred during the exercise sessions. They were advised to come to every exercise session because the exercises were tailored to the patients' impairments (pain and swelling).

Neuromuscular training consisted of 1- and 2-legged balance and plyometric

exercises. Balance exercises were performed on various surfaces (flat and wobble boards), with the aim of maintaining balance and optimal lower-limb alignment (hip, knee, and ankle). Plyometric exercises included double- and single-leg hops (APPENDIX). Three of 5 balance exercises were performed per session, with 3 repetitions of each exercise. Three sets of 5 repetitions of either double- or single-leg hops were performed during each session.

### Adherence

To monitor adherence to the rehabilitation program, including both the intended supervised physical therapy and unsupervised training sessions, all patients kept training diaries. These diaries were completed during and after each supervised physical therapy session and after each unsupervised training session, to provide information about frequency, type of exercise, load progression, and number of repetitions. To further document adherence and the occurrence of adverse events, patients responded every second week during the 3-month rehabilitation program to an online survey (QuestBack Version 9692; QuestBack AS, Oslo, Norway). The 3 following questions were asked: (1) Have you attended physical therapy sessions during the last 2 weeks? (2) How many times a week have you visited your physical therapist? and (3) If you haven't attended the physical therapy or training sessions, was it due to the knee or other reasons? All questions were followed by several predefined answers (closed answers), but it was also possible to provide open comments if desired.

Adherence was quantified as the number of completed supervised physical therapy and unsupervised training sessions during the 3 phases compared to the intended number of supervised physical therapy and unsupervised training sessions for each phase.

### Outcome Measures

The patients' activity level was classified

on a 0-to-100 scale proposed by Barber-Westin et al,<sup>5</sup> where 0 was no sport participation and severe problems during ADL and 100 was participating without any problems in high-level pivoting sports at a competitive level.

Patient-reported outcome measures, isokinetic muscle strength tests for quadriceps and hamstrings, and single-leg hop tests were used to examine changes in knee function from preintervention to postintervention. Preintervention testing was performed within  $15 \pm 5$  days after inclusion in the study but always prior to the start of the rehabilitation program. Postintervention testing was performed  $10 \pm 3$  days after completion of the last session of the rehabilitation program.

Before testing, patients performed a standard 10-minute warm-up on a stationary bike. An isokinetic muscle strength test for the quadriceps and the hamstrings was performed with an isokinetic dynamometer (Biodex 6000; Biodex Medical Systems, Inc, Shirley, NY). The test was performed using 5 repetitions at an angular velocity of  $60^\circ/\text{s}$ .<sup>15</sup> Muscle strength was quantified based on peak torque (Nm).

The procedure for single-leg hop tests was adapted from the protocol by Noyes et al,<sup>53</sup> using the 1-leg hop and the triple hop for distance. One practice trial was followed by 3 test trials, always testing the uninjured leg before the injured leg. The average distance of the 5 test trials was used for analysis. Hop distances were measured in centimeters.

Prior to performing the single-leg hop tests, the patients completed the 2 self-report outcome questionnaires: the Knee injury and Osteoarthritis Outcome Score (KOOS) and the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC 2000). The KOOS consists of 5 dimensions, which are reported separately: pain, symptoms, ADL, sport, and quality of life.<sup>58</sup> The IKDC 2000 includes self-evaluation of knee pain, stiffness, swelling, and instability during daily life and sport activities.<sup>30,31</sup> Both of these patient-reported

outcome measures have been shown to be valid and reliable questionnaires to measure knee function in patients with articular cartilage lesions and after cartilage repair.<sup>6,30</sup> The pain subscale of the KOOS and a standard 10-cm visual analog scale were used to record pain at preintervention and postintervention.

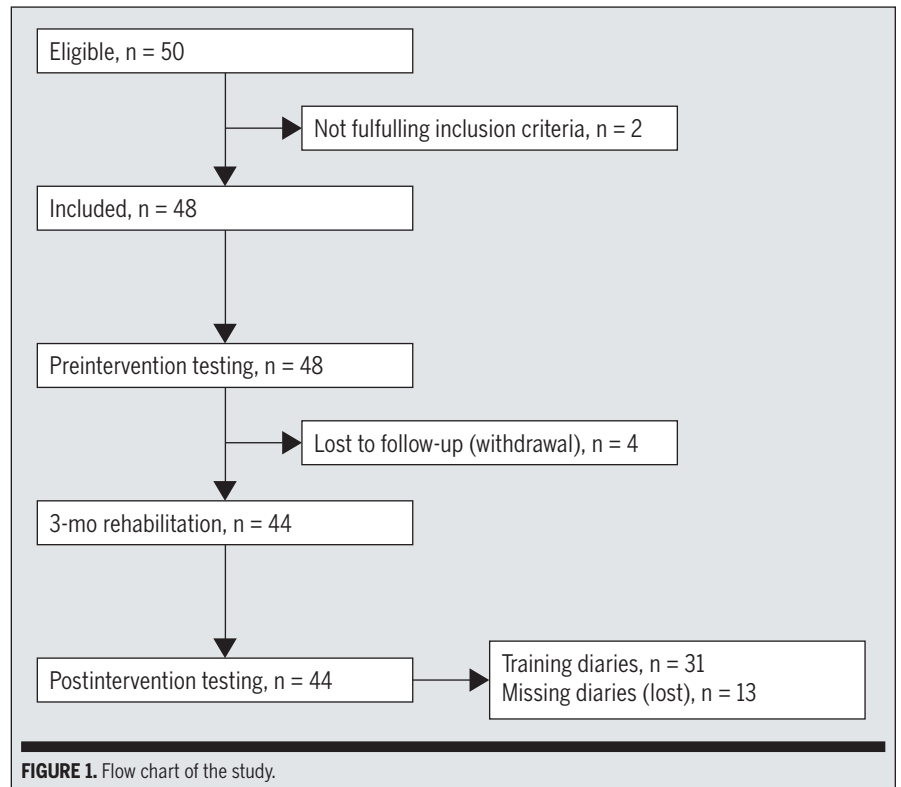
## Data Analysis

To characterize the cohort and to evaluate the training diaries and the online survey, descriptive data were calculated as frequencies, mean values, and standard deviations. Changes from preintervention to postintervention for muscle strength, hop performance, and the patient-reported outcomes (KOOS and IKDC 2000) were analyzed using a paired *t* test. An unpaired *t* test was used to evaluate significant differences in the outcome measures between those patients who returned their training diaries (*n* = 31) and those who did not return their diaries (*n* = 13). The standardized response means (SRMs) were calculated for the isokinetic muscle strength tests, single-leg hop tests, and the KOOS and IKDC 2000 scores. SRMs between 0.5 and 0.8 are considered moderate and those above 0.8 large.<sup>9</sup> For all data, a probability level of *P* < .05 was used to determine statistical significance.

## RESULTS

### Patient Characteristics

**T**HE MEAN ± SD AGE OF THE PATIENTS (*n* = 48) was 34.1 ± 13.4 years. The average ± SD size of the articular chondral defect was 2.9 ± 1.3 cm<sup>2</sup>, with 37 of the lesions located on the medial and 11 on the lateral femoral condyle, respectively. Four patients did not complete the rehabilitation program or the postintervention testing session (FIGURE 1). Our data indicated that these 4 patients attended the supervised physical therapy sessions during the accommodation phase and completed some unsupervised training sessions during the rehabilitation phase. They then declined



further participation in the study due to a reduction in symptoms. There were no differences in the baseline data of those 4 patients compared to the 44 patients who completed the rehabilitation program.

Thirteen patients lost their training diary; however, data from the online surveys and physical therapy clinical records documented that these 13 patients attended all 3 rehabilitation phases. The characteristics of all 44 patients who completed the program and the subset of 31 patients who also returned their training diaries are provided in TABLE 1. There were no significant differences in the characteristics of those 31 patients who returned the training diaries versus the 13 who did not.

Based on self-report, for all 44 patients, a significant improvement (*P* < .001) in activity level<sup>5</sup> was noted from preintervention (mean ± SD, 39.1 ± 28.0; range, 0-90) to postintervention (52.6 ± 24.9; range, 20-90).

Thirty-one patients (65%) postponed the planned surgery after finishing the

3-month active rehabilitation program, whereas the other 17 patients (35%) decided to proceed with cartilage repair surgery.

### Adherence

The response rate to the online survey was 82% (36 of 44), and 70% (31 of 44) of the patients returned their training diaries. The patients who returned their diaries (*n* = 31) completed on average 2.7 (range, 1-5) supervised physical therapy sessions per week during the accommodation phase (weeks 1 and 2). During the rehabilitation phase (weeks 3-8), an average of 2.3 (range, 1-5) supervised physical therapy sessions and unsupervised training sessions were completed. Therefore, 88% of the intended sessions (both supervised physical therapy and unsupervised training sessions) were completed by the participants (*n* = 31). During the return-to-activity phase (weeks 9-12), an average of 2.3 (range, 1-5) supervised physical therapy and unsupervised training sessions were completed, indicating an adherence rate of 77%. The total adherence

**TABLE 1**

**CHARACTERISTICS OF ALL PATIENTS AND THOSE WHO RETURNED THE TRAINING DIARIES**

	All Patients (n = 44)	Diary Patients (n = 31)
Gender (female/male), n	13/31	9/22
Age, y*	34.0 (17-50)	34.6 (17-50)
Body mass index, kg/m <sup>2</sup>	26.8 ± 5.1	26.1 ± 4.4
Defect size, cm <sup>2</sup>	2.9 ± 1.3	3.0 ± 1.4
Defect location (medial/lateral), n	33/11	23/8
Duration of symptoms, mo <sup>†</sup>	46.6 ± 52.0	42.1 ± 52.0
Previous surgeries <sup>†</sup>	1.9 ± 0.8	1.9 ± 0.8

\*Values are mean (range).

†Values are mean ± SD.

ed in the training program were unable to perform the resistance and neuromuscular training portions of the program due to pain and effusion. Therefore, these patients only completed the cardiovascular portion of the training. These 4 patients did not differ in any way from the other subjects (lesion type, location, range of motion, or muscle strength).

**Knee Function**

**TABLE 2** provides data on changes in knee function and their related SRMs for the patient-reported outcomes, the isokinetic muscle strength tests, and the single-leg hop tests for all patients who completed the 3-month rehabilitation program (n = 44) and the subset of these patients who also returned their training diaries (n = 31). There was no significant difference between the changes in the 31 patients who returned their training diaries and those in the 13 patients who did not (P>.05).

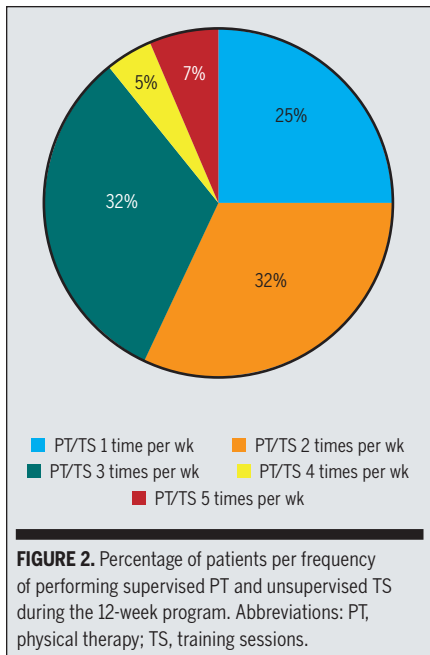
**Patient-Reported Outcomes**

The IKDC 2000 score significantly improved from preintervention to postintervention (P<.001). This change was considered clinically important, as the minimum detectable change (MDC) for the IKDC 2000 in patients with cartilage injuries and after cartilage surgery is reported to be 6.3 points.<sup>30</sup>

**FIGURE 5** illustrates the KOOS scores at preintervention and postintervention for all patients. The changes and related SRMs for all subscales of the KOOS are presented in **TABLE 2**. There were moderate effect sizes (SRM, 0.5-0.8) for the sport and quality of life subscales. Significant improvement only occurred for the quality of life (P<.0001) subscale.

**Quadriceps and Hamstrings Muscle Strength**

There was a significant improvement (P<.001) in quadriceps and hamstrings muscle peak torque of the injured knee, with corresponding large SRM values (greater than 0.8), from preintervention to postintervention (**FIGURES 6 and 7**). The

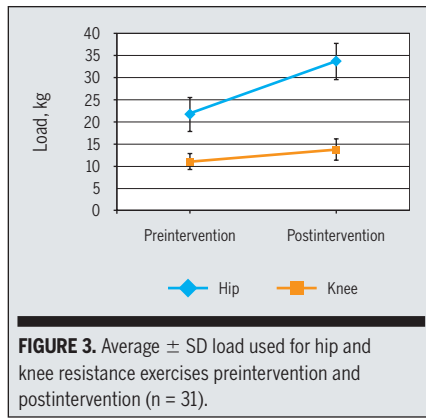


**FIGURE 2.** Percentage of patients per frequency of performing supervised PT and unsupervised TS during the 12-week program. Abbreviations: PT, physical therapy; TS, training sessions.

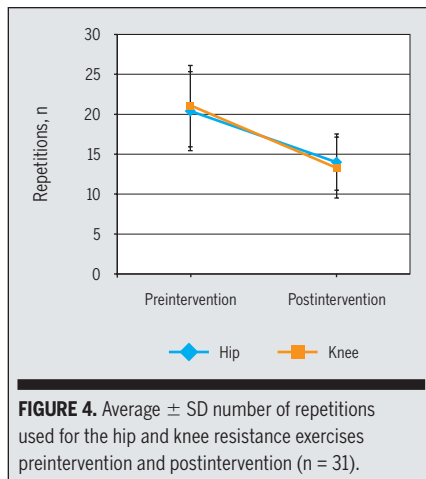
rate for the rehabilitation and return-to-activity phases was 83% (**FIGURE 2**).

**Progression**

During the first week, patients performed cardiovascular training primarily on a stationary bike for an average ± SD duration of 84 ± 177 minutes per week. During the 12th week, the patients decreased the time of cardiovascular training to 76 ± 115 minutes per week. Neuromuscular training was initiated with performing 82 ± 42 repetitions per week and increased to 99 ± 45 repetitions per week at week 12, with the number of repetitions being evenly distributed over the 4 different ex-



**FIGURE 3.** Average ± SD load used for hip and knee resistance exercises preintervention and postintervention (n = 31).



**FIGURE 4.** Average ± SD number of repetitions used for the hip and knee resistance exercises preintervention and postintervention (n = 31).

ercises. For the knee and hip resistance exercises, repetitions decreased and load increased through the course of the training program (**FIGURES 3 and 4**).

**Adverse Events Related to Training**

Four of 44 patients (9%) who participat-

mean changes in quadriceps and hamstrings muscle strength for all patients and for those returning the diaries were above the measurement error (quadriceps, 22.76 Nm; hamstrings, 15.44 Nm) (TABLE 2).<sup>4,5</sup>

## Single-Leg Hop Tests

TABLE 2 presents the changes for all patients and for those who returned the diaries for the 1-leg hop and the triple hop tests for the injured leg. For the 1-leg hop, there was a significant increase in distance from preintervention to post-intervention ( $P < .001$ ), with a moderate effect size (SRM, 0.66). The mean improvement for all patients was 28.7 cm, and 26 cm for those who returned the diaries. Both values are higher than the previously reported 12.78-cm MDC for patients with meniscal and cartilage lesions.<sup>4,5</sup> For the triple hop tests, the mean changes of 101.9 cm for all patients and 100.3 cm for those returning the training diaries were significant and larger than the previously reported 30.96-cm MDC.<sup>4,5</sup>

## DISCUSSION

**T**O OUR KNOWLEDGE, THIS IS THE first study to evaluate the feasibility of a rehabilitation program for patients with full-thickness articular cartilage lesions affecting the femoral condyles of the knee. We determined that the Oslo Cartilage Active Rehabilitation and Education program was feasible in terms of adherence to the rehabilitation program, led to clinically meaningful changes in knee function, allowed progression of exercise load and repetitions, and resulted in only a few joint-specific adverse events related to training. We were able to improve knee function in the majority of these patients, and 65% of them postponed their appointment for cartilage repair at least short term. These patients with knee full-thickness articular cartilage lesions had symptoms 3 to 4 years prior to entering the program, a low Lysholm score (less than 75), and a low activity level.<sup>5</sup> They had

TABLE 2	CHANGE FROM PREINTERVENTION TO POSTINTERVENTION AND THE SRM FOR ALL OUTCOME MEASURES	
Outcome Measure/Group	Change*	SRM
KOOS pain (0-100)		
All patients <sup>†</sup>	5.9 ± 16.4	0.36
Diary patients <sup>‡</sup>	4.9 ± 16.8	0.30
KOOS symptoms (0-100)		
All patients <sup>†</sup>	7.6 ± 15.4	0.49
Diary patients <sup>‡</sup>	5.8 ± 14.2	0.41
KOOS ADL (0-100)		
All patients <sup>†</sup>	5.6 ± 16.4	0.34
Diary patients <sup>‡</sup>	3.4 ± 17.4	0.19
KOOS sport (0-100)		
All patients <sup>†</sup>	16.1 ± 24.5	0.65
Diary patients <sup>‡</sup>	11.6 ± 21.7	0.53
KOOS QL (0-100)		
All patients <sup>†</sup>	12.2 ± 16.4 <sup>§</sup>	0.74
Diary patients <sup>‡</sup>	10.5 ± 15.5 <sup>§</sup>	0.67
IKDC 2000 (0-100)		
All patients <sup>†</sup>	10.6 ± 15.8 <sup>§</sup>	0.68
Diary patients <sup>‡</sup>	8.7 ± 14.8 <sup>§</sup>	0.59
Quadriceps peak torque, Nm		
All patients <sup>†</sup>	41.3 ± 33.8 <sup>§</sup>	1.22
Diary patients <sup>‡</sup>	33.7 ± 33.8 <sup>§</sup>	1.00
Hamstrings peak torque, Nm		
All patients <sup>†</sup>	23.3 ± 21.5 <sup>§</sup>	1.09
Diary patients <sup>‡</sup>	18.9 ± 19.1 <sup>§</sup>	0.99
1-leg hop, cm		
All patients <sup>†</sup>	28.7 ± 43.2 <sup>§</sup>	0.66
Diary patients <sup>‡</sup>	26.0 ± 49.4 <sup>§</sup>	0.53
Triple hop, cm		
All patients <sup>†</sup>	101.9 ± 135.7 <sup>§</sup>	0.75
Diary patients <sup>‡</sup>	100.3 ± 154.3 <sup>§</sup>	0.65

*Abbreviations: ADL, activities of daily living; IKDC 2000, International Knee Documentation Committee Subjective Knee Evaluation Form; KOOS, Knee injury and Osteoarthritis Outcome Score; QL, quality of life; SRM, standardized response mean.*

*\*Values are mean ± SD for the injured limb.*

*<sup>†</sup>n = 44.*

*<sup>‡</sup>Those who returned the training diaries (n = 31).*

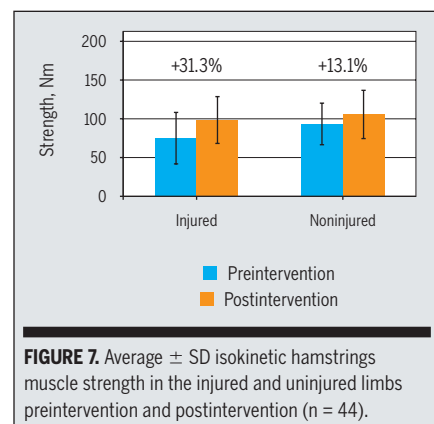
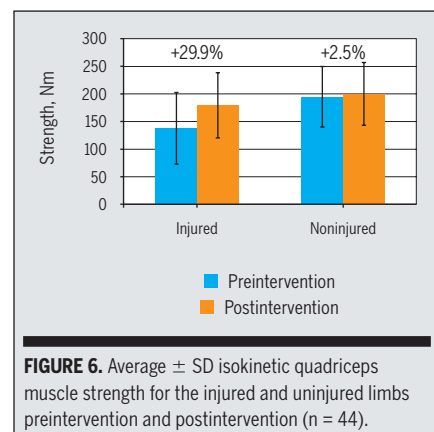
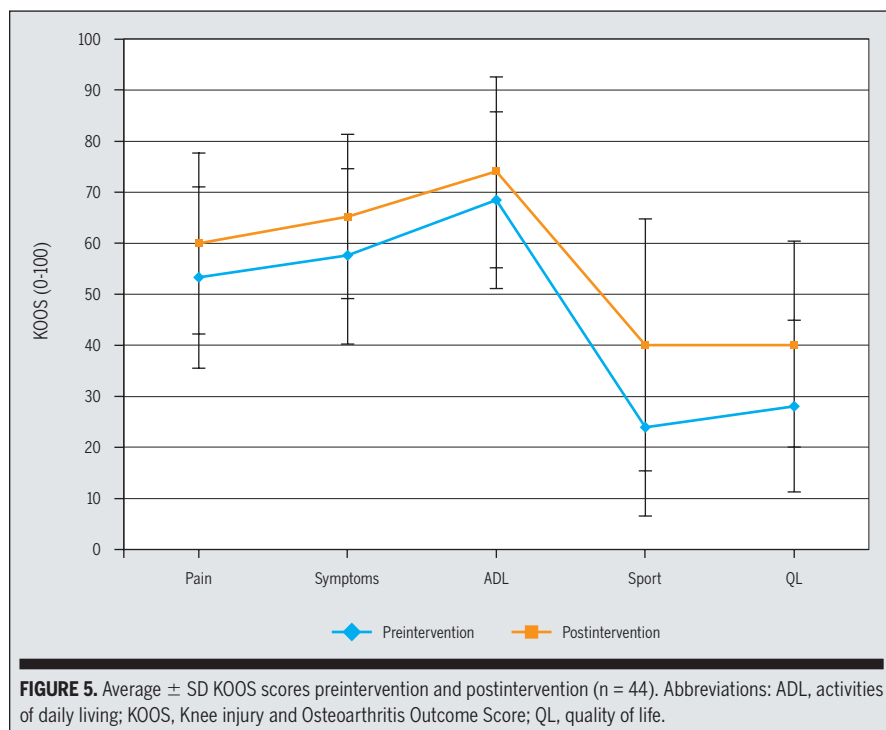
*<sup>§</sup>Changes are statistically significant (P < .05).*

an average self-reported score of 39 out of 100 preintervention and 53 out of 100 postintervention but showed a large variation in scores on both testing occasions (0-90).

Adherence to this program was monitored by the use of training diaries and an online survey. The return rate of these diaries was 70%, although we have data

that those who did not return their training diaries attended physical therapy sessions and came to the posttesting. The response rate of the online survey was 82%. The online survey provided information about the adherence to the supervised physical therapy sessions, indicating that all intended supervised physical therapy sessions were complet-





ed. The reason for implementing both the online survey and the training diaries was to gain more information about adherence to the rehabilitation program. Most patients reported that the training diaries were easy to complete, and that the online survey would likely not be needed to monitor adherence during such a program.

The total adherence to the rehabilitation and return-to-activity phases was 83%, which is comparable to a previously reported<sup>24,54</sup> adherence rate of 85% for a 3-month exercise program for patients with knee OA. Adherence to rehabilitation has been shown to be crucial to preserving physical performance, self-reported knee function, and pain reduction in patients with knee OA.<sup>50</sup> Adherence to a rehabilitation program also influences pain, quality of life, and physical performance in patients with knee OA.<sup>50,62</sup> Few studies have been designed to investigate factors that influence adherence to a program.<sup>50</sup> One major factor seems to be the duration of the program, with a progressive decline in adherence (85% for a 3-month program, 70% for a 9-month

program, and 54% for an 18-month program) as the intervention becomes longer.<sup>24,54</sup>

The high adherence rate in our study may also be attributed to the study's focus on patient education, which has previously been shown to be an important factor to increase adherence in patients with knee and hip OA.<sup>50</sup> Qualitative studies have also demonstrated that some patients express doubt as to whether exercise will be beneficial or detrimental to their injury. Such doubt could reduce patients' willingness to exercise.<sup>11,63</sup>

Clinically significant improvements in both quadriceps ( $41.3 \pm 33.8$  Nm) and hamstrings ( $23.3 \pm 21.5$  Nm) muscle strength were found in this study. The MDCs for quadriceps and hamstrings strength have been reported to be 22.76 and 15.44 Nm, respectively.<sup>45</sup> To our knowledge, no previous studies have reported changes in isokinetic muscle strength after exercise interventions in patients with articular cartilage lesions in general or in those with full-thickness articular cartilage lesions in particular. However, studies evaluating the effect of

resistance training have been reported in patients with knee OA.<sup>40,42</sup> King et al<sup>42</sup> evaluated the effects of a 12-week, high-intensity muscle strength program for patients with medial knee OA. They found an improvement in isokinetic quadriceps strength (60°/s) of 33.6 Nm and in hamstrings strength of 23.5 Nm after 12 weeks of resistance training.<sup>42</sup> Another study<sup>40</sup> compared the clinical effects of high- and low-resistance training for patients with knee OA. The high-resistance training group demonstrated an increase in isokinetic quadriceps strength (60°/s) of 6.7 Nm and hamstrings strength of 14.4 Nm. The low-resistance group had an improvement in quadriceps strength of 11.5 Nm and hamstrings strength of 14.2 Nm.<sup>40</sup> Our patients with full-thickness articular cartilage lesions had a larger improvement in both quadriceps and hamstrings muscle strength after a 3-month exercise program compared to these patients with knee OA.

Resistance exercises for patients with articular cartilage lesions should involve sufficient loading to induce central and peripheral changes to increase muscle strength and neuromuscular control without aggravating pain and effusion. One rationale for including resistance exercises was that quadriceps muscle strength deficits have been outlined as a major issue in the long-term evaluation of patients after cartilage repair.<sup>17,44,46</sup> However, detailed exercise prescription in terms of exercise dosage (type, frequency, intensity, duration) and criteria for progression for patients with articular cartilage lesion is missing in the literature. The basic concept of exercise dosage used in our rehabilitation program was based on strength training guidelines for patients with knee OA and on recommendations for healthy adults published by the American College of Sports Medicine.<sup>7,29</sup> Muscle strength training guidelines recommend that exercises for the major muscle groups be performed 2 to 3 times per week. Performing exercises at 40% to 50% of the 1RM has been shown to be efficient in improving muscle strength in sedentary people, and exercising at 60% to 70% of the 1RM has been shown to improve muscle strength for individuals at novice to intermediate levels of fitness. In addition, performing 2 to 4 sets of 8 to 12 repetitions has been recommended to increase strength and power in adults. McKnight et al<sup>51</sup> assessed the effectiveness of combining self-management and resistance training in middle-aged patients with early knee OA. The participants started with 2 sets of 6 repetitions and increased to 2 sets of 10 repetitions using the same resistance.<sup>51</sup> Jan et al<sup>40</sup> compared the effects of high- and low-resistance exercises in elderly people with mild to moderate knee OA. The low-resistance group performed 10 sets of 15 repetitions using 10% of the 1RM. The high-resistance group performed 3 sets of 8 repetitions using 60% of the 1RM. They demonstrated that both high- and low-resistance training significantly improved clinical outcomes such as pain,

function, walking time, and muscle torque.<sup>40</sup> We did not measure the 1RM in our study due to concerns that high joint loads might aggravate pain and effusion. The initial load for the resistance exercises was based on the patients' perception of their maximum tolerable load to complete 3 sets. The physical therapist adjusted the weights based on input from the patient and to ensure progression over time. In future studies, the 1RM of the uninjured leg could provide the basis of an initial load for the injured leg. Alternatively, the 8RM to 10RM for the injured leg could be assessed and used. Our data indicated that load progression was possible with improvement in knee function and without aggravating pain and effusion.

The Oslo Cartilage Active Rehabilitation and Education program included both knee and hip resistance exercises. The quadriceps is the most studied muscle group in patients with knee OA or other knee injuries. The rationale for implementing hip resistance exercises in patients with knee articular cartilage lesions was based on recent literature demonstrating that hip muscle weakness may change knee loading patterns in patients with knee OA.<sup>13,34</sup> This could have consequences for patients with articular cartilage lesions as well. Furthermore, a correlation between knee pain/function and hip muscle strength has previously been reported.<sup>13</sup> Hip muscle resistance exercises were well accepted and tolerated by our patient group, as shown by the reported load progression (**FIGURE 3**). Load progression was higher for the hip resistance exercises compared to the knee resistance exercises. The initial position of the hip resistance exercises (mainly sitting) exerts less load across the knee than the initial position of the knee resistance exercises (mainly standing). Because we did not measure hip strength, we could not provide information on whether hip muscle strength had an impact on our results. Thus, we suggest that further investigations include hip muscle strength tests to evaluate clinically meaningful

changes and to examine the effect of hip muscle strength compared to knee muscle strength in patients with articular cartilage lesions.

The mean KOOS and IKDC 2000 scores preintervention were comparable to the preoperative KOOS scores of patients included in studies evaluating patients undergoing cartilage repair.<sup>14,18,19,44</sup> We found improvement in the IKDC 2000 and all subscales of the KOOS from preintervention to postintervention. However, statistically significant improvement was only noted for the IKDC 2000 and the quality of life subscale of the KOOS. In addition, the change on the IKDC 2000 was 10.6 points, which is greater than previously reported measurement error.<sup>30</sup> The MDC of the IKDC 2000 score for patients with cartilage injuries and after cartilage repair has been reported to be 6.3 points.<sup>30</sup> Ebert et al<sup>19</sup> reported outcomes 1 year after matrix-associated autologous chondrocyte implantation that showed improvements in the KOOS subscales of pain, symptoms, ADL, sport, and quality of life of 16, 14, 11, 33, and 23 points, respectively. In a study evaluating the clinical effects of scaffold-assisted autologous chondrocyte grafts, Kreuz et al<sup>44</sup> reported improvements in the KOOS subscales of pain, symptoms, ADL, sport, and quality of life of 16, 8, 17, 36, and 25 points, respectively. Based on results of previous studies, it is likely that these changes on the KOOS are clinically relevant. In contrast to these large changes, some studies of patients after cartilage repair have indicated smaller short-term changes on the KOOS, similar to those reported in our study.<sup>14,18</sup>

This study showed that the active rehabilitation program was feasible for patients with full-thickness articular cartilage lesions and could be used to improve knee function in this patient population, irrespective of further decision on surgical treatment. As a preoperative rehabilitation program, it can be used to determine adherence to rehabilitation, as adherence to a rehabilitation program postsurgery is considered es-

sential for optimal long-term outcome after cartilage repair.<sup>16,49</sup> Previous studies on patients with total knee arthroplasty, high tibial osteotomy, and following ACL reconstruction have shown that good pre-operative knee function significantly influences postoperative outcomes.<sup>22,38,41,65</sup> However, this study cannot establish whether this program is optimal, as it was not compared to other more or less aggressive options.

Based on the significant improvement in knee function demonstrated in these patients, one should consider whether a rehabilitation program alone could be a reasonable and successful treatment option for patients with articular cartilage lesions. Compared to the success rate of treatment of other knee disorders, surgical treatment of articular cartilage lesions has not shown convincing results in reducing symptoms.<sup>33,43,61</sup> In addition, which surgical technique provides the best long-term outcome for patients with articular cartilage lesions is debated. These results could provide a basis for investigating the effectiveness of various rehabilitation programs and comparing nonsurgical versus surgical intervention in this population.

### Limitations

An inherent limitation of this study is that it did not include a control group and did not have a randomized controlled design, and could not, therefore, provide evidence that this rehabilitation program is superior to other treatment regimes. Furthermore, this study did not provide information about the effect of exercises on structural disease progression. Despite the small number of patients (9%) who experienced joint-specific adverse events during the training period, we cannot conclude that this program is safe in terms of preventing further damage to the articular cartilage tissue. Therefore, we are not able to state whether an active rehabilitation program in patients with articular cartilage lesions would help reduce the likelihood of progressive development of OA.

## CONCLUSION

**A** 3-MONTH ACTIVE REHABILITATION program for patients with full-thickness articular cartilage lesions of the femoral condyle is feasible and demonstrated clinically meaningful changes, few joint-specific adverse events related to the training, load progression, and good adherence. A nonsurgical intervention approach in this patient population should, therefore, be considered, regardless of the intent of having surgical cartilage repair. ●

### KEY POINTS

**FINDINGS:** This 3-month active rehabilitation program for patients with full-thickness articular cartilage lesions of the femoral condyle was feasible, as determined by good adherence, clinically meaningful changes, load progression, and few adverse events related to the training.

**IMPLICATIONS:** A nonsurgical rehabilitation program should be considered in this population, regardless of the intent of eventually having surgery.

**CAUTION:** This single-group prospective study precludes comparisons with a control group or alternate rehabilitation programs. No evaluation of the cartilage was performed postintervention.

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APPENDIX

REHABILITATION PROGRAM

Cardiovascular Exercises



Stationary bike



Treadmill



Cross-trainer

Resistance Exercises for the Hip



Seated resisted adduction



Seated resisted abduction



Standing on 1 leg  
with pulley resistance

## APPENDIX

### Resistance Exercises for the Knee



Seated knee extension



Squats with weights



Step-ups



Hamstring curls



Hip extension on Fitball



Leg press

APPENDIX

Balance Exercises



Squat on wobble board



Squat on a BOSU



Single-leg squat on wobble board



Balance exercises on wobble board

Plyometric Exercises



Double-leg hops

Single-leg hops