Knee Osteoarthritis
Alternative Range of Motion Treatment

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KEYWORDS

• Knee osteoarthritis • Range of motion • Rehabilitation • Total knee arthroplasty

KEY POINTS

- Full range of motion (ROM) in the knee is critical for optimal function. The opposite, normal knee must be examined to establish a baseline for normal ROM.
- Most nonoperative rehabilitation programs for knee osteoarthritis (OA) concentrate on increasing strength, which is difficult to achieve when any ROM loss is present.
- Total knee arthroplasty (TKA) surgery is expected to increase drastically, and an effective nonoperative rehabilitation program is needed to relieve symptoms for patients.
- The Shelbourne Knee Center ROM-based rehabilitation program emphasizes normalizing knee extension (to include hyperextension) first, followed by improving flexion and then strength.
- This ROM-based rehabilitation program was effective for improving ROM, pain, symptoms, and function in patients with OA, and 76% were prevented from undergoing TKA surgery.

INTRODUCTION

Background of Rehabilitation for Osteoarthritis

Because of the increasing prevalence of osteoarthritis (OA) and total knee arthroplasty (TKA) surgeries in the near future, a conservative nonoperative treatment approach is needed. Treating patients conservatively with rehabilitation can improve outcomes as a standalone treatment or to be used to maximize objective measures before a TKA, ultimately leading to better results postoperatively.[1,2] This approach, however, is not just for patients who have radiographic indications for surgery because exercise therapy can lead to positive outcomes regardless of the severity of OA, allowing it to be used by a broader patient population.[3] Most of the previous studies evaluating exercise therapy as a form of nonsurgical treatment of knee OA have looked at a variety of categories. These forms of exercise include stretching for knee range of motion (ROM), aerobic training for cardiorespiratory fitness, resistance training for increasing muscle strength, and performance training for improving activities of daily living.[4,5] All forms of exercise have been shown to improve patient outcomes; however, not all studies have a standard and structured treatment plan for patients with knee OA. Having a systematic approach to treating OA will not only allow the patient to improve but also allow them to maintain their gains for long-term success. It has been shown that gains made in the early phase of rehabilitation can be maintained for up to 6 months after starting treatment before ultimately declining; thus, patients are encouraged to continue treatment beyond the 12-week recommendation.[6] Patient education is important because the individual needs to know how to maintain the gains they achieved by the time of discharge so as to prevent symptoms from returning.

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The authors' preferred nonsurgical treatment of knee OA has been developed based on years of experience treating patients with anterior cruciate ligament (ACL) tears. The senior author (K.D.S.) has performed greater than 6000 ACL reconstructions and has seen only knee patients since the late 1980s. Multiple publications from the authors' center have highlighted the vital role that knee ROM plays in the long-term outcome and development of OA after ACL surgery, with loss of knee extension, flexion, or both consistently leading to a higher incidence of OA.[7–9] Further experience with referral cases to the authors' office of arthrofibrosis after ACL surgery revealed that knee ROM could improve, even when present for long intervals of time.[10] Consequently, a treatment approach was developed to prevent and/or treat knee stiffness.

Current estimates of TKA volume are expected to soar by 673% to 3.5 million by 2030.[11] Consequently, the ability of current infrastructure to handle that volume increase is in question. Furthermore, TKA is far from a certain outcome, with multiple reports of TKA dissatisfaction ranging up to 10% to 30% and beyond.[12–14] The authors have some guidance with regard to the effect of ROM on TKA outcome. Findings from Ritter and colleagues[15] revealed that knee ROM before TKA surgery will dictate postoperative ROM, and greater ROM has a positive impact on TKA outcomes.[16] If preoperative ROM dictates postoperative ROM and postoperative ROM directly influences outcome, it is thus imperative to maximize preoperative ROM before performing TKA surgery. In this way, the patient's chances of successful outcome can be modified and satisfaction maximized.

Initial Evaluation

At the authors' center, patients are seen by a physical therapist (PT) or athletic trainer (ATC) from the moment they enter the office. PT/ATCs serve as clinical assistants, whereby they take the patient's initial history, escort them to obtain radiographs, and then present the findings to the physician. The physician reviews the gathered information before entering the examination room, and both the physician and the PT/ATC evaluate the patient together. This arrangement provides connection and continuity between physician and therapy staff members to coordinate care. Once the physician completes the examination, the PT/ATC is able to listen to the physician/patient interaction, followed by immediately starting the therapy process dictated by the physician.

Radiographic evaluation is done to bilateral knees so side-to-side comparisons can be facilitated. Bilateral anteroposterior, 45° flexed weight-bearing posteroanterior, lateral, and Merchant views are obtained with in-house radiography. Joint space narrowing in all compartments, alignment, and ancillary changes are noted and reported in the medical record as well as reviewed with both the patient and the therapy provider.

Knee ROM assessment is done and reported in the record. Knee ROM is reported as 3 numbers a/b/c, with "a" being the degree of hyperextension, "b" being the degrees short of 0° neutral, and "c" being the degrees of flexion. A patient with 2° of hyperextension and 125° of flexion would be reported as 2/0/125°. A patient with 5° flexion contraction and 125° of flexion would be reported 0/5/125°. The normal knee (if present) is always measured first and serves as the standard of normal ROM. If both knees are involved, full extension is counted as any degree of hyperextension because almost all normal knees will achieve some.

Most studies do not include an evaluation of hyperextension and, instead, consider knee extension of 0° neutral as normal. A patient with 5° short of extension from neutral may not be considered to have much extension loss. However, if normal extension for that person is 5° of hyperextension, the flexion contracture is 10°.[17] DeCarlo and Sell[17] found that the mean degree of extension was 5° of hyperextension for men and 6° for women (Fig. 1). Several studies by Shelbourne and colleagues[7–9] found that even 3° loss of normal hyperextension resulted in lower subjective function scores and increased rate of developing OA in the long term after ACL reconstruction. Loss of normal

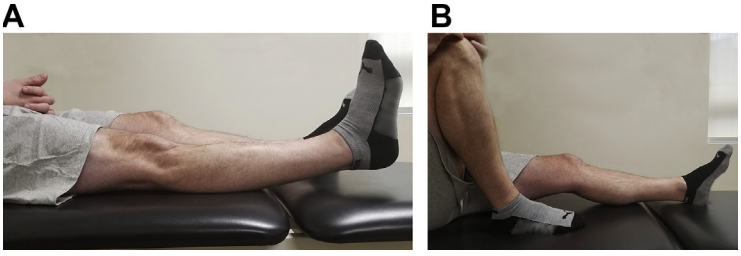

Fig. 1. The patient's right knee has 8° of hyperextension that is normal for him (*A*). His left knee shows 13° short of 0° neutral (*B*). The difference between knees is 21°.

knee extension can cause patients to limp and favor the noninvolved knee with standing and everyday activities of getting up from a chair and climbing stairs. The lack of normal use in the knee perpetuates the problem of loss of knee motion and can make it worse over time, and the patient develops a deconditioned knee. A deconditioned knee is defined as a painful syndrome caused by anatomic or functional abnormalities that result in a knee flexion contracture, functional loss of knee extension, decreased strength, and decreased function.[5] The authors have found that restoring normal knee extension or hyperextension (when present) is the key to reducing symptoms for patients.

When a patient with knee OA is found to have ROM deficits, the authors routinely prescribe physical therapy to restore or maximize ROM improvement before they consider TKA surgery. Nonsteroidal anti-inflammatories, intraarticular steroid injections, oral steroid dose packs, and light analgesics are prescribed by physician discretion.

SHELBOURNE KNEE CENTER APPROACH TO REHABILITATION

Philosophy of Range of Motion–Based Rehabilitation Protocol

Once the patient is evaluated by the orthopedic surgeon, diagnosed with OA, and deemed appropriate for conservative treatment, they are referred to work with a knee rehabilitation specialist. In rehabilitation, the patient has specific goals set for improving function and decreasing pain by restoring normal ROM, decreasing joint effusion, and increasing lower-extremity strength. In patients with unilateral symptoms, the aim is to get the involved knee symmetric with the uninvolved knee in terms of ROM, swelling, and strength. In patients who have bilateral involvement, the goals remain the same; however, without knowing presymptom ROM and strength, the goals are geared more toward a general maximization of all objective measures, while still being focused on maintaining symmetry side to side. To meet these goals successfully, treatment is delivered systematically starting with ROM exercises for knee extension, followed by ROM exercises for flexion and swelling reduction, before eventually starting a strengthening and conditioning program. During each phase of the rehabilitation program, the focus stays on the current principle without progressing to the next step until that particular goal is met. For example, when working toward attaining full knee extension, the patient will not be working on flexion or strengthening exercises. This single-focus rehabilitation approach allows for more predictable progression in each phase, which tends to lead to better short- and long-term success. Once the patient attains symmetric and maximized ROM into extension and flexion, minimal joint effusion, and adequate strength, improvement from a pain and functional standpoint is typically seen. From here, they can be transitioned to a maintenance program for long-term conservative management of their OA.

Knee Extension

The first step to improving the patient's function and pain is creating symmetric extension equal to the other knee. The authors' rehabilitation staff starts by giving the patient a few exercises, including a heel prop with or without weight, towel stretch, and the use of a knee extension device for home use. The heel prop is done with the patient in a long sitting position with their heel on a surface high enough to get the knee suspended in the air, subsequently allowing gravity to pull it into maximum extension (Fig. 2). This heel prop can be done with or without weight added on top of the knee to increase the force going into extension. The towel stretch exercise is also done in a long sitting position with a towel or stretch strap placed around the foot with 1 hand on the strap and the other hand on the distal quad, just superior to the patella (Fig. 3). The patient is instructed to apply pressure down with the hand on the distal quad while the other is pulling the strap toward the chest to maximum tolerance. Applying the pressure down while pulling the strap ensures the exercise is maximizing joint mobility instead of muscle flexibility, which will help reach full extension, including any degree of hyperextension. Two extension device products commonly used in rehabilitation include an

Fig. 2. Heel prop exercise. The patient is in a long sitting position with their heel on a surface high enough to get the knee suspended in the air, subsequently allowing gravity to pull it into maximum extension.

Fig. 3. Towel stretch exercise. The patient is in a long sitting position with a towel or stretch strap placed around the foot, 1 hand on the strap, and the other hand on the distal quad, just superior to the patella. The patient applies pressure down with the hand on the distal quad while the other pulls the strap toward the chest.

Elite Seat (AKT Medical, Noblesville, IN, USA) and IdealKnee (IdealStretch, Park City, UT, USA). The Elite Seat is an extension device that places the patient lying supine with the involved leg elevated and heel propped up. Once in the setup position, 2 straps are placed across the knee both superior and inferior to the joint and firmly attached via a seatbelt mechanism. These straps are connected to a pulley system that is patient directed in terms of applying increasingly more force into extension for up to 10 minutes at a time (Fig. 4). By lying supine, the patient's hamstring muscles can be relaxed while applying pressure. The IdealKnee (Fig. 5) is a device that is used with the patient sitting with his or her legs extended. The device has a strap just above the knee and one behind the ankle that allow the patient to pull back on a handle to bring the knee into maximum extension.

The visit schedule for this stage of rehabilitation is roughly 1 visit every 1 to 2 weeks for

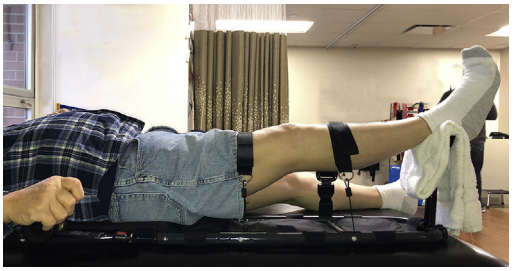

Fig. 4. Elite Seat device. The patient lies supine with the involved leg elevated and heel propped on the stirrup. Two straps are placed across the knee both superior and inferior to the joint and firmly attached via a seatbelt mechanism. These straps are connected to a pulley system that allows the patient to apply increasingly more force into extension for up to 10 minutes at a time. (Kneebourne Therapeutic, LLC, Noblesville, IN.)

Fig. 5. The IdealKnee device. The patient places his or her leg in the device so that 1 strap is just above the knee and one is behind the ankle. The patient pulls back on the handle to bring the knee into maximum extension. (TS Ideal Products, LLC, Irvine, CA.)

ROM progression. In addition to the exercises given to the patient, they are encouraged to avoid favoring the noninvolved knee by purposely standing on the painful side, with the knee locked out into full extension. This standing habit not only maintains the gains made through the exercises but also starts creating a good habit of using the knee normally.

Knee Flexion

Once full extension is achieved, flexion exercises are started, such as heel slides, wall slides, and flexion hangs. Heel slides are done by the patient bringing the heel to the hip in a seated position and holding for a short period. Wall slides are done similarly, only that the patient lies supine with the involved foot placed on a wall, allowing gravity to bring the knee into a flexed position (Fig. 6). Flexion hangs are similar to the wall slides; instead, gravity brings the heel down without the

Fig. 6. Wall slide exercise. The patient lies supine with the involved foot placed on a wall. The patient gradually allows gravity to bring the knee into a flexed position.

aid of the wall, getting the knee into a flexed position to tolerance independently (Fig. 7). The visit schedule, like in the extension stage, is 1 visit every 1 to 2 weeks to assess and progress ROM. During this stage, the patient also uses cryotherapy, compression, and anti-inflammatory medication as needed to reduce swelling.

Low-Impact Conditioning

Once knee flexion will allow for a full and comfortable revolution on the bicycle or elliptical, low-impact conditioning commences. Performing conditioning exercises that are low impact in nature, such as biking, elliptical, swimming, or using a StairMaster, allows for light strength and conditioning gains without worry for acute flareups of pain or swelling that high-impact exercises would cause. Patients are encouraged to start a low-impact conditioning program every other day with minimal resistance, adding resistance and frequency as pain and swelling allow.

Strengthening

Once ROM and swelling are back to normal levels, strength is assessed unilaterally on both an isokinetic quadriceps strength test (Cybex) and an isometric single-leg press test. This assessment quantifies any deficit that they may have, making it easier to develop a strength program. The patient is given specific strength exercises to be done unilaterally to make up for the deficit that they have until they reach symmetry to within 10% of the contralateral side as measured on the isokinetic and single leg-press tests. Exercises used in this phase can be modified body weight exercises such as step-ups, step-downs, and single-leg partial squat or traditional gym exercises, such as single leg press, single knee extensions, and hamstring curls.

Fig. 7. Flexion hang exercise. The patient lies supine with the involved leg lifted in the air. The patient gradually relaxes their leg to allow the knee to bend, and gravity brings the heel down into a flexed position as tolerated.

The visit schedule during this stage is typically 1 visit every 4 to 8 weeks depending on the strength deficit to assess and progress their program. During this strength stage, the patient is still monitored for maintenance of adequate ROM and swelling, treating as needed. Once the patient is tested to be symmetric within 10% of the contralateral knee, a maintenance program is prescribed to continue treating the knee conservatively with rehabilitation long term.

Indications for Total Knee Arthroplasty Surgery

Progression to TKA is dictated by the patient's progress with the therapy protocol. Patients who make initial symptomatic improvements continue to follow-up with the PT/ATC until their goals are achieved, or a steady-state symptomatic plateau is achieved. Patients who are pleased with their progress and symptomatic improvement continue their home program on a maintenance basis. For those who are not pleased with their improvement, consultation with the surgeon is recommended by the PT/ATC, or by discussion with the treating surgeon.

Patients who have continued pain and symptoms are considered candidates for surgery if they have complete loss of joint space in at least 1 compartment. Rare cases of near-complete joint space loss are referred for surgery if they have not progressed or if they have moderate changes in multiple compartments. At this surgical consultation visit, the surgeon, therapist, and patient discuss the progress, or lack thereof, as well as the patient's expectations for their postsurgical outcome. Ideal candidates for a successful TKA are those who have made measureable functional gain with ROM and strength but continue to have pain. In this case, all are convinced that focused nonsurgical management has not been totally effective, that patient compliance is demonstrated by functional gains, and that pain relief that is reliably attained by TKA surgery will not be hindered by lack of full functional progression. Patients are asked to secure a caregiver for the first postoperative week; a preoperative talk and testing visit is scheduled; preoperative medical consultation by a hospitalist is sought, and a surgical date is selected.

RESULTS OF SHELBOURNE KNEE CENTER REHABILITATION PROTOCOL

The authors initially tested the effectiveness of their ROM-based protocol in 50 patients with

deconditioned knees unilaterally.[5] The mean age of patients was 53.2 years, and 41 of 50 (82%) had a diagnosis of knee OA. Knee extension improved from a mean deficit between knees of 10° to 3° and flexion improved from a mean deficit of 19° to 9°. Patients had statistically significant improvements in both quadriceps muscle strength and subjective function. After some early anecdotal success with treating arthritic knees in this manner, in 2013, the authors began enrolling patients in a study to determine if these same symptomatic gains were possible specifically for patients with knee OA.

Between 2013 and 2017, 451 patients with knee OA and candidates for TKA surgery enrolled into a prospective study to determine whether the authors' ROM-based rehabilitation protocol could effectively improve knee ROM, reduce subjective symptoms, and prevent patients from undergoing a TKA surgery. Radiographs were graded in the medial, lateral, and patellofemoral compartments as mild, moderate, or severe according to International Knee Documentation Committee criteria. Mild OA was defined as minor detectable narrowing of joint space width or presence of small osteophytes and/or slight sclerosis or flattening of the femoral condyle. Moderate OA was defined as joint space width of 2 to 4 mm or narrowing up to 50%, and presence of sclerosis or osteophytes. Severe OA was defined as joint space of less than 2 mm or greater than 50% of joint space narrowing, and/or presence of large osteophytes. Knee ROM was measured consistently throughout rehabilitation and follow-up. Subjective function was evaluated at enrollment and at 1-, 3-, 6-, and 12-months follow-up with the Knee Injury and Osteoarthritis Outcome Score (KOOS) subjective survey, which evaluates pain, symptoms, activities of daily living, sport, and quality of life.

Fifty-five patients dropped out of the study, of which 11 had health issues, 2 died, and 42 dropped out for other reasons. Of the 396 remaining patients, there were 206 women and 190 men. The average age was 62 years old; 275 had unilateral knee symptoms, and 121 had bilateral symptoms.

Radiographic Grade

For patients with unilateral OA, the highest radiographic grade in any knee compartment was 48% severe, 33% moderate, and 19% mild. Patients with bilateral knee OA had more severe OA, with the highest grade of OA being severe in 69%, moderate in 17%, and mild in 14%. Bilateral OA patients also had more compartments in their knees with OA, with 45% having 1 compartment involved, 40% having 2 compartments involved, and 13% having all 3 compartments involved, whereas patients with unilateral OA had 61% with 1 compartment involved, 33% had 2 compartments involved, and 6% had all 3 compartments involved.

Knee Range of Motion

The mean knee extension at enrollment was 4° short of 0° for both unilateral and bilateral knees; extension in the normal knee of unilateral patients was 2° of hyperextension. Significant improvement in mean extension was achieved by 1 month after treatment (4° for unilateral patients; 3° for both knees of bilateral patients) and was maintained through 1 year after treatment.

The mean knee flexion at enrollment was 117° for unilateral patients and 116° for the left knee and 117° for the right knee in bilateral patients. Knee flexion in the normal knee of unilateral patients was 131°. Statistically significant improvement in flexion was found in the unilateral group at 1 month after treatment and was maximized at 3 months at 128°. The improvement in the unilateral group was maintained through 1 year after treatment. For bilateral patients, mean knee flexion statistically significantly improved to 121° in both knees at 3 months after enrollment. Flexion was maintained through 6 months after enrollment but was found to be 117° at 1 year of follow-up.

Mean arc of motion was statistically significantly improved between enrollment and 1 month and was maintained through 1 year of follow-up (Table 1).

Knee Injury and Osteoarthritis Outcome Score Subjective Scores

Statistically significant improvement in KOOS scores was found for both the unilateral and the bilateral groups at 1 month after enrollment, and scores were maintained through 1 year of follow-up (Fig. 8).

Table 1
Mean arc of motion in the involved knees at enrollment and through follow-up after treatment

Group	At Enrollment	1 mo	3 mo	1 y
Unilateral	114	125[a]	128[a]	124[a]
Bilateral, left knee	112	118[a]	120[a]	116[a]
Bilateral, right knee	113	119[a]	120[a]	115[a]

[a] Significantly improved statistically from enrollment.

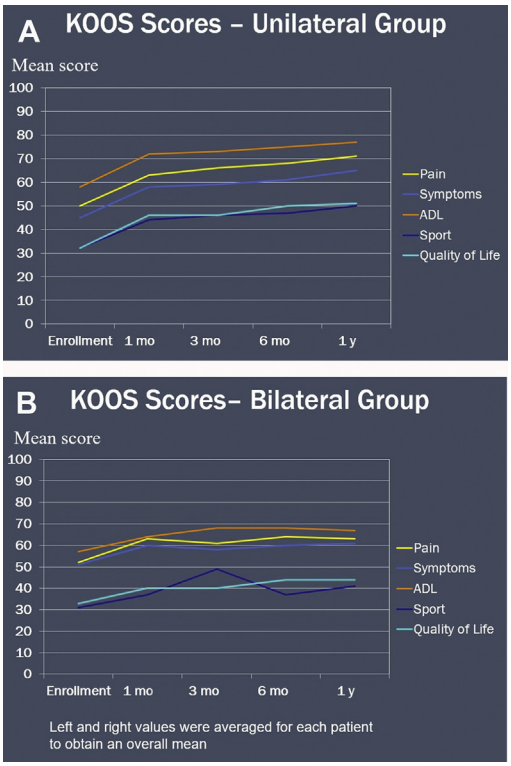

Fig. 8. Knee OA outcome score results for patients with (*A*) unilateral and (*B*) bilateral involvement. Scores show improvement in all categories between enrollment and 1 month after treatment; the scores are maintained through 1 year of follow-up. ADL, activities of daily living.

Subsequent Total Knee Arthroplasty Surgery

The purpose of providing the rehabilitation program was to improve patients' symptoms enough that they would not want to undergo TKA surgery. Of the 396 patients, 110 (24.4%) went on to undergo TKA surgery at a mean of 10.7 ± 7.1 (range 3.5–29 months after enrollment). The data of these patients up to the point when they had TKA surgery were included in the summary of results in this report.

DISCUSSION

The ROM-based rehabilitation program presented in this review has been effective and successful in the authors' practice for treating patients with a variety of knee conditions nonoperatively. Given the expected and alarming increase in the number of patients expected to undergo TKA surgery, the authors are encouraged by the success of the ROM-based program. The most important caveat of the program is that the clinician must evaluate for and recognize the patient's knee hyperextension and then subsequently institute exercises to maximize its improvement before concentrating on other rehabilitation goals. Patient education of daily monitoring of ROM is also a key for long-term effectiveness. The principles of the rehabilitation are simple for patients to follow. If symptoms for the patient continue despite improvements in ROM, surgery can then be performed, and those improvements should yield better results with ROM after surgery.

SUMMARY

Full ROM in the knee is critical for any person to function at their highest level. Even a few degrees of extension or flexion loss can affect function and cause pain. The opposite, normal knee must be examined to establish a baseline for normal ROM. In patients with knee OA, most nonoperative rehabilitation programs concentrate on increasing strength, which is difficult to achieve when any ROM loss is present. The Shelbourne Knee Center ROM-based rehabilitation program emphasizes normalizing knee extension (to include hyperextension) first, followed by improving flexion and then strength. This ROM-based rehabilitation program has been effective for improving ROM, pain, symptoms, and function in patients with OA, and 76% were prevented from undergoing TKA surgery.

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