2017

Physical Therapy Treatment and Management of a Patient Following Total Knee Arthroplasty: A Case Report and Literature Review

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ABSTRACT

Background: An increasing number of total knee arthroplasties (TKAs) are performed each year, making it a commonly seen post-operative diagnosis in an outpatient orthopedic setting. However, rehabilitation to restore optimal function continues to be a challenge, as research regarding the most effective interventions remains limited. The purpose of this case is to examine the efficacy of physical therapy interventions on range of motion (ROM) and functional outcomes following TKA, as well as demonstrate the need for further research in determining optimal exercise prescription. **Case Description:** Patient was a 65-year-old male who underwent a right TKA. He presented to therapy with associated post-operative range of motion limitations, decreased lower extremity strength, soft tissue restrictions, and impaired gait. **Intervention:** Interventions were primarily focused on regaining ROM and lower extremity strength, and included manual therapy, stretching, progressive resistive strengthening, and a home exercise program. **Evidence Based Component:** A literature review was performed to examine what types of interventions resulted in the most successful outcomes in regards to ROM, pain, quality of life, and reported function following TKA. **Outcomes:** The patient made gradual progress with physical therapy, but still demonstrated significant ROM deficits and functional mobility impairments after five weeks of formal therapy. Further physical therapy treatment was postponed at this point, as the patient elected to undergo manipulation under anesthesia. **Discussion:** Outpatient physical therapy is commonly prescribed to patients following TKA. However, regaining function and ROM postoperatively continues to be a challenge for both patients and physical therapists. Further research is needed to determine which therapeutic interventions result in the most successful outcomes in terms of reported function and ROM.

BACKGROUND

Total knee arthroplasty (TKA) is one of the most commonly performed orthopedic procedures in the United States. In 2010 alone, an estimated 700,000 total knee replacements were performed.[1] As the general population continues to age, these figures are expected to steadily rise, with current research projecting a 673% increase in the number of procedures performed annually by the year 2030.[1,2] The most common reason for TKA is osteoarthritis (OA) of the knee joint. This degenerative process is estimated to affect 10-15% of older adults above the age of 60, and can result in significant joint pain, stiffness, range of motion limitations (ROM), and functional mobility impairments.[3] When conservative treatment options such as weight loss, regular exercise, or medical interventions fail to provide adequate symptom relief, TKA is considered.

While the majority of patients who undergo this procedure will report high levels of satisfaction, approximately 20% will still demonstrate substantial ROM, strength, and functional deficits following TKA.[4,5] Furthermore, current research suggests that a discrepancy exists between subjective reports of function and objective measures obtained during performance based tests. For example, following TKA, the most dramatic improvements are seen in reported pain levels and perceived function. However, objective functional performance tests such as stair-climbing or walking tests, show only modest improvements following TKA, with substantial residual deficits when post-surgical TKA patients are compared to age and gender matched peers.[5,6] Approximately three quarters of patients with a history of TKA report difficulty negotiating stairs and the average stair-climbing speed is only half as fast compared to healthy counterparts.[6-9] Furthermore, significant differences between TKA patients and healthy age matched peers persist at six months post-surgery in regards to active knee ROM, isometric quadriceps strength, and 6 Minute Walk Test distances.[4,8,9]

Immediately following surgery, physical therapy is initiated within the hospital, and often times continues after the patient is discharged in an outpatient setting. Rehabilitation is aimed at reversing the limitations and impairments associated with the TKA procedure with a focus on pain management, ROM, strengthening, gait mechanics, and functional activity training. Although physical therapy is considered an important part of post-surgical TKA management, there is a general lack of consensus and high level evidence indicating optimal interventions for rehabilitation, especially in an outpatient orthopedic setting. A statement released by the National Institute of Health in the early 2000s highlights this point, indicating that the role and use of rehabilitation services in the care and management of patients following TKA is lacking critical research needed to adequately care for this patient population.[10] Since this statement's release, several studies have been conducted to critically analyze the various aspects of physical therapy management after TKA. Specific areas of research include timing and intensity of exercise, effects of continuous passive motion, and different forms of exercise interventions. Despite this, there is still a lack of evidence supporting which interventions are the most effective. As a result, physical therapy protocols vary in exercise types as well as frequency, intensity, and duration of interventions. This case report presents the clinical reasoning, examination, and interventions used in the treatment of a patient following TKA. Furthermore, the purpose of this case is to examine the efficacy of physical therapy interventions on ROM and functional outcomes following TKA, as well as demonstrate the need for further research in determining optimal exercise prescription.

CASE DESCRIPTION

History

The patient was a 65-year-old male who was referred to outpatient physical therapy following an elective left TKA. The patient remained in the hospital following the procedure for four days and three nights. Physical therapy was initiated on the day of surgery following the procedure, with formal sessions on each of the subsequent days that the patient was hospitalized. The patient was seen for initial evaluation in the outpatient setting seven days after the TKA surgery.

The patient reported an extensive past medical history including morbid obesity, history of myocardial infarction, coronary artery disease, hypertension, chronic low back pain, pacemaker

implantation, and primary osteoarthritis of bilateral hips and feet. Additionally, the patient's orthopedic surgical history was significant for a L4-S1 lumbar fusion thirty-two years prior, a right TKA four years prior, and a left total hip arthroplasty (THA) six months prior to the current surgery. The patient underwent formal physical therapy following his right TKA procedure with good reported success. Prior to the left TKA procedure, the patient was able to ambulate without the use of an assistive device, but did report limiting ambulation distances due to knee pain. During the time of the initial evaluation, the patient reported average pain levels in the left knee at 5/10, with pain reaching up to a 7/10 at its worst. The patient's stated goal for therapy was "to gain full ROM and strength of the left leg and to walk again without an assistive device."

Examination and Evaluation

Prior to the physical examination, the patient completed the Knee Injury and Osteoarthritis Outcome Score Joint Replacement (KOOS JR) form. The KOOS JR was developed from the original KOOS survey, and consists of seven questions that address three main areas of disability including stiffness, pain, and activities of daily living. This short form survey is thought to better capture an accurate assessment of knee health in patients with end stage knee osteoarthritis who have undergone a TKA. Statistical analysis demonstrates construct validity of the KOOS JR to be excellent (Spearman correlation coefficient 0.54-0.91) when compared to other commonly used patient reported outcome measures (KOOS and WOMAC). Furthermore, responsiveness of the KOOS JR has been found to be excellent as well (SRM 1.70), making it a relevant measure of patient reported function following TKA.[11] The KOOS JR is scored by summing the patient's raw score responses (range 0-28) and then converting it to an interval score (range 0-100) to represent total knee disability.[11] The patient scored a 15/28 on the initial KOOS JR translating to a 50% disability.

Upon examination, the patient was found to have significant levels of post-operative pain, decreased ROM, strength, functional mobility, and altered gait mechanics. ROM measurements were taken bilaterally at the hip, knee, and ankle using a standard goniometer. Specific attention was given to active knee ROM measurements, as deficits in knee motion following TKA have been shown to affect functional activity performance.[4,5,6] Knee ROM measurements were performed with the patient in a supine position. The greater trochanter and lateral malleolus were used as alignment points for the stationary and movable arms of the goniometer respectively. The midline of the knee joint was used to align the axis of rotation. Extension ROM measurements were recorded as positive values to indicate lack of full knee extension, whereas negative values were documented to indicate knee hyperextension. Intra-tester reliability for knee flexion AROM has been reported to be excellent in both experienced and inexperienced testers (>0.8) for measuring knee ROM following TKA. Furthermore, a change of at least 6.6 degrees between two measurements has been found to reflect a true change in knee ROM.[12] The patient's active ROM measurements of the right knee were all within normal limits, with extension to 0 degrees and flexion to 130 degrees. When compared to the non-surgical limb, the patient's left knee active ROM was significantly limited with active knee extension +8 degrees (+2 degrees passively) and active knee flexion reaching only 62 degrees (72 degrees passively). ROM at the hip and ankle were found to be within functional limits bilaterally.

The patient demonstrated strength deficits to manual muscle testing of the left lower extremity. Specific areas of weakness identified on examination included hip flexion (2+/5), hip abduction (3/5), knee flexion (4/5), and knee extension (4-/5). The patient also presented with post-surgical swelling and edema, with a 7.0 centimeter difference in limb girth measurements between left and right at the mid-patella level. During the examination, the patient ambulated with the use of a front wheeled walker. He demonstrated an antalgic gait pattern with decreased left knee flexion during swing phase, decreased left terminal knee extension during stance, and decreased step length on the left lower extremity. Palpation to the left knee complex elicited subjective reports of pain and tenderness to the left lateral quadriceps, proximal thigh, patellar margins, and left gastrocnemius-soleus complex. Further objective testing performed on this date included the Timed Up and Go Test (TUG). The TUG is most commonly used to evaluate gait and balance disorders in the geriatric population.[13] Following TKA, it is often used

as an objective measure to gauge progress and functional ability.[4,5,8,9] This test specifically measures the time it takes an individual to stand up from a standard chair, walk 3 meters, turn around, walk back to the chair, and sit down. No specific statistical values have been validated with use of this measure in patients following TKA, but it has been shown to have excellent interrater reliability (0.87) in patients with OA of the hip or knee.[13] Furthermore, studies in patients with moderate OA of the knee indicate a minimal detectable change (MDC) of 1.10 seconds.[13] The patient performed two tests runs which were then averaged as his recorded score. The patient was able to complete the TUG in 13.0 seconds with fair stability and no overt loss of balance. Further examination for post-surgical complications was negative, as the patient did not display any signs or symptoms suggestive of deep vein thrombosis or infection at the site of the surgical incision.

The results and measures performed during the examination were consistent with the typical ROM, strength, and functional mobility deficits found following TKA. This patient specifically demonstrated significant weakness proximally at the hip, most likely a residual impairment from his prior THA. He also demonstrated substantial knee ROM deficits as well as lower extremity swelling. The patient's reported functional deficits included ambulation, stairs, driving, and sit to stand transfers.

INTERVENTIONS

The patient attended outpatient physical therapy three times per week over the course of a five-week period, for a total of 15 sessions. The patient's progress was monitored at each session, with a formal reassessment performed at the 15th visit. Each therapy session lasted approximately 45 minutes and all outcome and objective measures were assessed and performed by the same therapist.

Treatment over the five-week period consisted of a variety of techniques including manual therapy, strengthening exercises, aerobic exercise, stretching, and gait/functional training. Initially within the first two weeks, interventions were primarily focused on pain management and regaining normal ROM. During this time frame, each session typically began with a 5-10 minute warm up on the NuStep to increase blood flow and extensibility of the surrounding knee musculature. This was then followed by manual therapy techniques to help restore normal tissue mobility and joint ROM. Early manual interventions utilized included soft tissue mobilization to the muscles surrounding the knee joint (rectus femoris, vastus lateralis, vastus medialis obliquus, and gastrocnemius/soleus), therapist assisted manual stretching, and passive ROM (knee flexion and extension). Therapeutic exercises were focused on knee ROM, active stretching, and early quadriceps activation/strengthening. Exercises were performed during therapy sessions with cueing throughout for correct form and technique, and were also incorporated into a home exercise program for the patient. Exercises included quadriceps sets, short arc quads, straight leg raises, gluteal sets, hamstring curls, long arc quads, heel slides, wall slides, hamstring stretching, gastrocnemius and soleus stretching, and prone knee extension stretching. The patient performed one to three sets of 10 repetitions for all strengthening exercises. Addition of increased weight or external resistance was progressed to maintain a 10 repetition maximum intensity and only if the patient was able to demonstrate proper form and technique with the added resistance. Active stretches were prescribed at a frequency of three repetitions of 30 second static holds. The patient's home exercise program was reviewed and updated at each visit, and consisted of no more than six exercises and stretches at one time. During the first two weeks, the patient was instructed to perform his home exercise program two times daily when he did not have scheduled therapy appointments, and one time daily on days that he attended formal therapy. Functional activity and gait training with an assistive device was also performed, with verbal cueing and emphasis on normal heel strike, equal stance time and step length, and normal knee joint excursion. By the end of the second week, the patient was able to transition from use of a front wheeled walker for mobility to use of a single end cane. Time during each 45-minute session was focused on active therapeutic exercise, with up to 15 minutes of manual therapy techniques or 15-20 minutes of gait/functional activity training per the treating therapist's discretion and assessment of the patient's presentation. Ice was used following sessions as needed for pain relief and edema control. Left knee

active ROM measurements by the end of the second week were recorded at 70 degrees of knee flexion and +6 degrees of knee extension.

In the following weeks (weeks three to five), physical therapy treatment was continued at a frequency of three times a week. Despite consistent use of scheduled pain medications and ice, the patient continued to report moderate to high levels of pain in the left knee, especially when actively bending or straightening it. Furthermore, objective ROM measurements showed a slow progression for both knee flexion and extension. Treatment interventions during this time continued to follow an impairment based approach, with the therapist making adjustments and modifications to interventions according to the patient's response and presentation. As left knee ROM continued to be one of the patient's primary impairments, treatment included interventions that targeted this deficit. During this time frame, the patient began use of the upright bike as a warm up (5-10 minutes) with both forward and backward pedaling at half to full revolutions for ROM and general conditioning. A more aggressive approach to manual therapy techniques was also introduced and included grade III - IV mobilizations at the tibiofemoral, proximal tibiofibular, and patellofemoral joints. Specific mobilization performed included anterior/posterior glides of the tibia, anterior/posterior glides of the femur, tibiofemoral distraction, superior/inferior glides of the patella, medial/lateral glides of the patella, and anterior/posterior glides of the fibular head. Soft tissue mobilization continued to address areas of identified tissue restriction and cross fiber friction massage was performed along the surgical incision to break up adhesions and allow for normal skin and tissue mobility. Further progression of the patient's exercise program included the addition of proximal hip strengthening as well as gradual progression of quadriceps strengthening from open chain to closed chain exercises that mimicked functional tasks. Exercises included hip abduction (side-lying and standing), bridges, standing terminal knee extension, mini squats, sit-to-stands, step ups, step downs, standing marches, standing hamstring curls, heel raises, total gym lower extremity exercises, and the leg press machine. The patient performed one to three sets of 10 repetitions of the prescribed strengthening exercises. Again, criteria for progression included correct performance of the exercise and resistance and weights added to maintain a 10 repetition maximum intensity. In order to progressively strengthen and challenge the patient, resistance was progressed from body weight, to small ankle weights and resistance bands, to strength training machines in order to reach muscle fatigue. The patient was instructed to perform his home exercise program once daily during weeks three to five. The types of exercises prescribed as part of the home exercise program were similar to the strengthening exercises performed during supervised sessions, but also continued to include ROM based exercises. Time during the 45 minute sessions was typically focused on active therapeutic exercises, however, up to 15 minutes of manual therapy techniques was incorporated to address knee ROM deficits.

By the end of week three, the patient's active knee flexion ROM showed only a 5-degree improvement from measures obtained during the second week, and was officially documented at 75 degrees. Although the patient continued to present with knee ROM deficits in subsequent weeks, he did demonstrate better pain control and management. Reported pain levels at rest during weeks four and five were on average rated at a 1/10. At the end of the fourth week (visit 12), the patient had achieved 76 degrees of active knee flexion, but was still lacking 8 degrees of full extension.

OUTCOMES

Due to significant differences in results of subjective reported measures of function and objective performance based tests following TKA, a combination of subjective and objective measures were utilized as primary outcome measures in this case. Specific objective measures and functional tests utilized included active knee ROM and the TUG. Although it may not always align with the results of objective testing, it is still important to consider and acknowledge the patient's perceived status and progress. As such, the KOOS JR was also used as a primary outcome measure in this case.

A formal reassessment was performed to gauge the patient's overall progress and functional status at the end of the fifth week (visit 15). Besides the three main outcome measures detailed above, re-evaluation of several other objective and subjective areas was performed. Despite consistent

attendance at therapy sessions and adherence to his prescribed home exercise program, the patient continued to demonstrate lower extremity ROM and strength deficits. Furthermore, the patient reported continued difficulty with stairs, ambulation, and actively bending and straightening the knee. Manual muscle testing of the left lower extremity demonstrated weaknesses in hip flexion (3+/5), hip abduction (3+/5), and knee extension (4+/5). The patient was able to ambulate within the home and community with the use of a single end cane and improved gait mechanics, although ambulation distance was still limited at this time due to pain in the knee and fatigue with exertion.

Reassessment of the three primary outcome measures was also performed on this date. The patient's active ROM measurements of the left knee showed 79 degrees of flexion (85 degrees passively), and +6 degrees of extension (0 degrees passively). Although there was some improvement from his initial measurements of 62 degrees of flexion and +8 degrees of extension, his current ROM values at this point in the rehabilitation process fell well below expected norms.[19] The patient's perceived and reported functional status also showed minimal improvement as evidenced by a KOOS JR score on this date of 13/28 (45% functional disability). Finally, reassessment of the TUG showed modest improvement from his initial time of 13.0 seconds, to his current time on the date of reassessment of 12.4 seconds. This change was well below any MCD or minimal clinically importance difference (MCID) values for the TUG in any patient population.[13] Formal discussion between the patient, orthopedic surgeon, and therapist took place with dialogue and education about the patient's overall progress, current deficits, and treatment options. The patient eventually decided to pursue a manipulation under anesthesia. At this point, further physical therapy sessions were postponed until after the manipulation procedure.

EVIDENCE BASED COMPONENT

Following TKA, three of the most common modifiable impairments addressed with post-operative therapy interventions include pain, knee ROM, and quadriceps strength.[14] In the vast majority of cases, TKA provides adequate symptom relief of knee pain, however, long term deficits in knee ROM are not uncommon. Current research is inconclusive as to which interventions lead to the greatest recovery of normal knee motion, and some research even calls into question the validity and use of knee ROM as an outcome measure.[15] However, generally speaking, attainment of active knee ROM between 105-110 degrees is used as a common standard following TKA, as this ROM has been shown to provide the necessary joint excursion and mobility to perform the majority of tasks of daily living.[16,17] Due to the fact that the patient's recorded knee ROM measurements consistently fell well below these reported norms, interventions during his course of therapy were targeted at improving his ROM.

Much of the research in regards to interventions focused on knee ROM examine the use of continuous passive motion machines as a primary intervention. Continuous passive motion refers to the use of a machine that passively and repeatedly moves the knee through a specified ROM. Proponents of this intervention cite its usefulness in recovery of knee ROM, reduction in risk of manipulation under anesthesia, and reduction in risk of adverse events following surgery. However, current studies and meta-analysis suggests that continuous passive motion does not in fact have clinically important effects on active knee flexion ROM, pain, or function.[14,16,17,18] Due to the absence of supporting evidence as well as the lack of physical and financial feasibility of its use, this treatment option was not pursued.

Although restricted knee ROM is a common post-operative impairment encountered following TKA, more recent research indicates that therapeutic interventions should be focused on active, high intensity quadriceps and lower extremity strengthening to restore optimal function and mobility. A longitudinal study specifically examining the effects of a more intense rehabilitation program following TKA, found improved functional and impairment based outcomes when progressive strengthening exercises were performed as a central component of the plan of care. This specific protocol initiated outpatient based therapy within four weeks following surgery, and consisted of progressive, high intensity exercise with a focus on lower extremity strength. Following a six week course of physical therapy, patients demonstrated improved quadriceps strength and significant improvements in objective measures of function including the TUG and Stair Climb Test (SCT) at intervals throughout a six-month

time period.[14,19] A related study looked at the effects of resistive exercises targeting the knee extensors, knee flexors, hip extensors, and ankle plantar flexors with progression based on a 10 repetition maximum. Interventions were performed two to three times per week for a total of six weeks and produced similar results in terms of improved quadriceps strength, 6 Minute Walk Test distances, TUG times, and SCT scores for up to a year post-surgery.[20] Another recent systematic review and meta-analysis showed that supervised physical therapy exercise with a focus on functional weight bearing activities resulted in greater initial increases in knee ROM when compared to traditional isometric exercises. These therapeutic effects in measures of ROM, function, and pain were significant for up to six months post-surgery.[21.22] Finally, a recent, larger scale randomized control trial compared the effects and functional outcomes of a high intensity and low intensity rehabilitation protocol following TKA. Similar to previous studies, the high intensity intervention mainly consisted of a progression based program of targeted lower extremity strengthening exercises. Unique to this study was the inclusion of balance, agility, and a consistent walking program. The low intensity protocol had an initial focus on isometric strengthening and ROM exercises, with a much slower transition to full weight bearing exercises. However, unlike the other studies, there was no noted superior benefits of the higher intensity protocol compared to the lower intensity protocol in terms of performance on the SCT, TUG, 6 Minute Walk Test, and active ROM.[23] Although research at this time remains inconclusive, general trends tentatively point towards progressive resistance exercises as an effective and safe means of restoring normal function and mobility following TKA. As such, interventions chosen during this case aimed to incorporate higher intensity strengthening exercises into the plan of care to address the impairments the patient presented with throughout the course of therapy.

One understudied area of physical therapy intervention following TKA is the use of manual therapy techniques as an adjunct to active exercise. Its use in other orthopedic conditions has been examined with formal clinical research, but less evidence is available in regards to its use in knee pathologies. One commonly cited study of interest indicates that the addition of manual therapy to supervised exercise and a home exercise program showed greater symptomatic relief and objective functional outcomes than a home exercise program alone in patients with OA of the knee joint.[24,25] Despite the scarcity of formal evidence supporting its use, manual therapy continues to be a part of many TKA protocols.[19] Due to the overall trauma and disruption of both bone and soft tissue structures surrounding the knee following TKA, a valid argument can be made for the potential usefulness of targeted manual techniques to help promote normal healing, joint motion, and soft tissue mobility. However, further research is warranted to investigate the effectiveness of manual therapy in addition to active exercises in individuals after a TKA.

Based on the literature cited above, the patient's course of physical therapy included interventions that addressed his main impairments to restore optimal functional performance and mobility. Incorporation of progressive resistance and strengthening exercises was included and progressed in a manner following basic overload and training principles as detailed above. Manual therapy techniques were also consistently included in each treatment session mainly to address the patient's ROM deficits, although its effectiveness and place within the TKA rehabilitation protocol is less well researched and clearly understood.

DISCUSSION AND CONCLUSIONS

The patient described in this case study presented to outpatient physical therapy with many of the expected strength, ROM, and functional impairments present following TKA. The scores and measurements achieved by the patient on the three main outcome measures (KOOS JR, TUG, and AROM) showed only modest improvements after a five week course of physical therapy. Interventions performed were consistent with current research recommendations in regards to incorporation of quadriceps and progressive lower extremity strengthening. The exercise program was specifically tailored to meet the needs of this specific patient, and supervision and monitoring during sessions allowed for appropriate exercise progression. The addition of manual therapy techniques as an adjunct to active exercise was also included as a means of restoring normal joint mobility, tissue extensibility,

and muscle length to the affected knee joint. The patient's overall lack of knee ROM and reported difficulty and pain with basic functional activities prompted consideration and eventual pursuit of a closed manipulation under anesthesia. It is unclear what factor or factors played a role in the patient's overall lack of progress following the procedure, as he had prior success with the same surgery on the opposite limb and adequate adherence and attendance to scheduled therapy sessions. Some literature suggests that stiffness following TKA has been related to obesity, keloid or hypertrophic scar formation, poor pain management, and formation of arthrofibrosis.[26] In this specific patient, poor ROM and functional recovery could have in part been due to inadequate early pain management. The increased knee pain, swelling, and inflammation present after the procedure, could have led to a phenomenon known as arthrogenic muscular inhibition, or a decreased neural drive to the surrounding musculature. As a result, this could have possibly prevented the patient from achieving the necessary intensity of exercise needed to improve functional performance and ROM.[27] Furthermore, some research suggests that pre-operative ROM serves as the most important predictor of final post-operative knee ROM and function.[19,28] Unfortunately, exact measures in respect to the patient's preoperative ROM, strength, and objective functional outcome scores were not known. However, it is plausible that the patient's prior orthopedic and surgical history may have complicated the clinical course of rehabilitation as his post-surgical impairments could have been compounded by his pre-surgical status.

Despite the relative frequency of TKAs performed each year, and the known functional limitations and impairments that present post-surgery, there is a lack of evidence based research in regards to the most effective approaches to TKA rehabilitation, especially in an outpatient orthopedic setting. Current research suggests that pain and self-reported functional ability steadily improves following surgery, however objective tests and measures of long term function typically fall well below age and gender matched population norms.[4,5,12] Regaining strength and ROM following a TKA may be achieved through a combination of different therapeutic interventions. However, as demonstrated by this case, not all interventions may be appropriate for every patient or result in the level of expected functional recovery. Although each physical therapy plan of care should be individualized to the specific goals and deficits of the patient, a lack of conclusive and concise research supporting TKA rehabilitation techniques could possibly contribute to decreased functional outcomes. Further areas of research in regards to post-TKA rehabilitation should address the effectiveness of manual therapy as an adjunct to active exercise as well as continued research into the efficacy and safety of high intensity strengthening exercises. Further research in these areas is needed to determine optimal exercise prescription and interventions following TKA particularly in regards to attaining normal knee ROM and overall function.

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