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SIMULTANEOUS BILATERAL TOTAL KNEE ARTHROPLASTY AND THE EFFECTS OF PHYSICAL THERAPY IN THE OUTPATIENT SETTING: A CASE STUDY

by

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Bachelor of Science in Kinesiology

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This Scholarly Project, submitted by Erin Syverson in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

Cindy Flom-Meland

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title	SIMULTANEOUS BILATERAL TOTAL KNEE ARTHROPLASTY AND THE EFFECTS OF PHYSICAL THERAPY IN THE OUTPATIENT SETTING: A CASE STUDY
Department	Physical Therapy
Degree	Doctor of Physical Therapy

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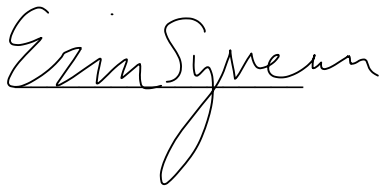
Signature 

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ABSTRACT

Background and Purpose: A bilateral total knee arthroplasty (TKA) is a surgical procedure that has seen success in managing end-stage osteoarthritis of the knee joint. This case study evaluates the usefulness of physical therapy following bilateral TKA and deliberates the outcomes the patient experienced. **Case Description**: The patient was a 62-year-old male who received post-operative physical therapy in an outpatient orthopedic clinic for a total of 8 weeks. The patient demonstrated decreased bilateral knee range of motion (ROM), decreased bilateral gross lower extremity (LE) strength, increased pain and swelling in both knees, and decreased endurance for ambulation. **Intervention**: Therapy provided to the patient emphasized the use of traditional TKA exercises as well as functional exercises. These exercises were used to assist in increasing bilateral knee ROM, bilateral knee strength, and the overall functional mobility of the patient. **Outcomes**: Throughout the course of treatment, the patient was able to increase his knee ROM bilaterally, LE strength, decrease his pain and swelling, and increase his endurance for ambulation. **Discussion**: The patient responded favorably to treatment, and many of the goals created were achieved. A clinical practice guideline on the management of total knee arthroplasty was recently released during the writing of this case study, and it can be referenced for the most current research on the examination and treatment for patients with total knee replacement.

CHAPTER I

INTRODUCTION: BACKGROUND AND PURPOSE

Total knee arthroplasty (TKA) is one of the most common and cost-effective orthopedic surgical procedures performed in the U.S.[1] According to Martin and Harris[2], over 600,000 TKAs were completed yearly in the U.S. as of 2010, and they are becoming more frequent. Among older patients in the U.S., increases in the number of TKAs have been determined by an increase in the number of people enrolled in Medicare and per capita utilization.[3] This growth is likely determined by a combination of influences. These influences include the types of patients who are considered likely to benefit from receiving a TKA, an older patient population, and a growing frequency of certain conditions that predispose patients to osteoarthritis (OA), the most common being obesity.[3] Another reason more individuals are opting for a TKA is outcomes show significant improvements in pain relief, restoring function, and improving quality of life.[1] One study states that TKA has become the gold standard to control the loss of function as well as pain caused by OA, as it is one of the leading causes of disability leading to decreased function and quality of life in the U.S.[4] Currently, there is no evidence-based criteria to determine whether a patient should undergo TKA, however, knowledge on the outcomes of TKA can assist the patient in the decision making process.[5]

Other factors to consider when making the decision to receive a TKA are the different styles and approaches used in the procedure. Uni-compartmental, bi-compartmental, and tri-compartmental are different types of TKAs. Uni-compartmental knee replacement is also called

a “partial” knee replacement, meaning only a portion of the knee is resurfaced instead of the entire knee joint.[6] This option is excellent for patients whose osteoarthritis or other disease is located in one area of the knee.[6] Bi-compartmental knee replacement is where two of the three compartments are replaced.[7] The three compartments are the medial tibiofemoral, lateral tibiofemoral, or patellofemoral.[7,8] All three of these compartments are resurfaced and replaced in a tri-compartmental knee replacement, otherwise known as a total knee arthroplasty. Tri-compartmental is the most common knee replacement and is indicated for patients with severe osteoarthritis, rheumatoid arthritis, posttraumatic degenerative joint disease, or other pathologic conditions.[8,9] These conditions account for more than 95% of TKA procedures.[9] Materials used for the knee implants include components made of ultra-high molecular weight polyethylene, ceramic, and metal. These materials try to imitate the natural knee, with the plastic components making up the tibial articulating surface as well as the patella, and the metal component making up the femoral component and tray on the tibia. The metals are usually titanium alloys, stainless steel, or cobalt chromium molybdenum.[10] (See Figure 1.)

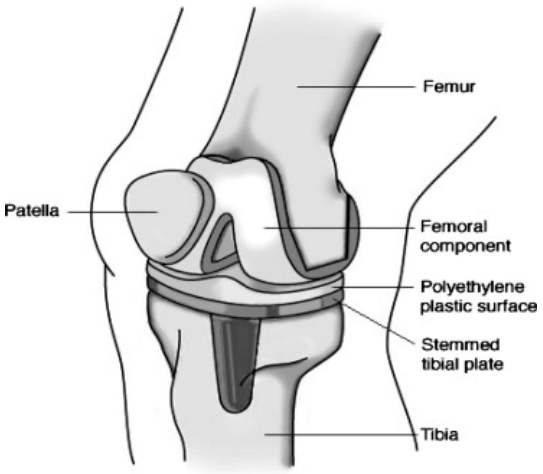

Figure 1: A knee implant *in vivo*[10]

Reprinted from *Knee Implants—Review of models and biomechanics*

Many patients suffer from osteoarthritis in both knee joints, thus leading to bilateral total knee arthroplasty (BTKA). An individual must consider how they want the surgery done: simultaneously or staged. Simultaneous BTKA are performed during the same procedure. Staged BTKA are spread out over a specific time interval, but according to Gabr et al[11], the ideal time interval between the two procedures has yet to be identified. A meta-analysis examined studies where the staged BTKA ranged from 3.6 days to 5.9 years between the two procedures.[12] The purpose of the study was to compare peri-operative complication rates, infection rates, and mortality outcomes between staged and simultaneous BTKA. They found the mortality incidence was significantly higher in the simultaneous group at 30 days, 3 months, and 1 year after the patients' surgery, but the infection and complication rates compared to the staged BTKA group were similar.[12]

Seol and colleagues[13] compared postoperative complications and clinical outcomes between simultaneous or staged BTKAs. They found that there was not a statistical difference of major complications between the two groups, but there was a significant difference in the minor complication rate, which was higher in the staged BTKA group compared to the simultaneous TKA group.[13] They also found that length of hospital stay was longer in the staged BTKA group. There was no significant difference in clinical outcomes between the groups using the Knee Society Score, Western Ontario and McMaster Universities Arthritis Index (WOMAC), and range of motion (ROM). The study concluded that simultaneous BTKA has some advantage compared to the staged BTKA group, such as shorter length of stay in the hospital.[13] A recent systematic review done by Fu et al[14], found mortality prevalence 30 days post-surgery, pulmonary embolism, and the rate of blood transfusion were significantly higher in the simultaneous BTKA group. These findings are consistent with the previous studies that show

there is more of a difference between staged and simultaneous BTKA regarding major complications of the procedure, especially regarding mortality.

As with any surgery, there are complications to consider post-operatively with a TKA. Members of the Knee Society responded to a survey to test the applicability and reasonableness of proposed TKA complications. They determined and agreed upon 22 TKA complications and adverse events. Some of these include blood clots, such as a deep vein thrombosis or pulmonary embolism; infection; wound and bleeding complications; arterial injuries; neural injuries; stiffness of the knee and loss of range of motion; and implant problems.[8,15] This list does not encompass all 22 TKA complications, but Appendix 1 contains the entire list.

There are many functional outcome measures used for the knee joint to assess a patient's outcome or prognosis. Impellizzeri et al[16] compared the reliability, responsiveness, and construct validity of different questionnaires for evaluating outcomes after a TKA. The four different questionnaires were the Western Ontario McMaster Universities Osteoarthritis Index (WOMAC), Knee Outcome Survey Activities of Daily Living (KOS-ADLS), Oxford Knee Score, and the 12 Item Short Form Health Survey. They found reliability was high for all the instruments, but the Short Form Health Survey did not indicate a significant improvement in the patient's condition at the 6-month follow-up compared to the other three measures.[16] The study also found that the change scores for the KOS-ADLS function, symptoms, and total score were highly correlated with those of the WOMAC pain and function subscales, indicating the KOS-ADLS is a reliable and valid outcome measure.[16] This case study utilized the KOS-ADLS for a functional outcome measure, and it inquired about how the patient's knee symptoms effect their ability to perform general daily activities as well as how their knee condition affects their ability to perform specific functional tasks. Six symptoms are measured: pain, stiffness, swelling, giving

way or buckling of the knee, weakness, and limping. Eight functional limitations are measured, such as: walking, going up and down stairs, standing, kneeling on the front of the knee, squatting, sitting with the knee bent, and rising from a chair. The KOS-ADLS was chosen for the reliability and validity of the questionnaire, and it gave the best assessment for where to focus treatment sessions for the patient.

Initially, after surgery, the patient remains in the hospital and receives acute rehabilitation services. The patient is limited in function and mobility, which is the focus of therapy services in order to return the patient home, or to prepare them for outpatient rehabilitation to further increase their function and mobility, as well as their independence. Therapy services are provided by both acute physical and occupational therapists. Continuous Passive Motion (CPM) machines have been utilized in acute post-operative rehabilitation. These machines passively move a joint, in this case the knee, into flexion and extension without active movement from the patient. A randomized clinical trial compared the effectiveness of three in-hospital rehab programs with and without CPM for ROM in knee flexion and extension, functional ability, and length of stay (LOS) after a primary TKA.[17] Patients were randomly assigned to one of three groups: the control group, which received conventional physical therapy (PT) intervention only; experimental group 1, which received conventional PT and 35 minutes of CPM daily; and the experimental group 2, which received conventional PT and 2 hours of CPM daily. The researchers found no significant differences in outcomes among the three groups, indicating that the use of CPM may not be necessary for patients in acute rehabilitation for TKA.[17] According to the recently published clinical practice guideline for TKA, Physical Therapist Management of Total Knee Arthroplasty[9], CPM machines should not be used because results for outcomes in function were nonsignificant, as well as hospital length of stay. Risks associated with CPM

machines are that bed rest may be prolonged, and it is inconvenient.[9] The patient in this case study did not receive CPM as an intervention while he was in the hospital. Conventional PT interventions included isometric knee extension exercises, active and passive knee flexion, hip adduction and abduction in a horizontal plane, and other knee extension exercises, such as long arc quads (LAQ) and short arc quads (SAQ). Knee ROM exercises are considered a standard of care, and they may assist with better pain management, a higher score on the Knee Society Score (KSS), ambulation score, and stair navigation 3 to 5 years after the procedure.[9] Transfer training and gait training with an appropriate assistive device were then begun, as well as functional exercises such as stairs. This case report focuses on outpatient management of a patient who received BTKA, and a lot of the conventional PT interventions used in this study as well as the clinical practice guideline were utilized in the patient's plan of care as well.

The patient in this case study underwent a simultaneous bilateral total knee replacement. The surgeon resurfaced the weight-bearing portions of the tibia and femur due to the patient's progression of osteoarthritis in both knee joints. The purpose of this case study is to deliberate and review the responsibility of outpatient physical therapy rehabilitation services in the treatment of a patient who underwent bilateral total knee arthroplasty. This case study demonstrates how physical therapy can improve a patient's knee range of motion, strength, and functional mobility, including walking, stair climbing, and standing up from sitting in order to improve the patient's overall quality of life and function.

CHAPTER II

CASE DESCRIPTION

The patient is a 62-year-old Caucasian male who had osteoarthritis in both of his knees for the past 8 years. He had a mildly active lifestyle involving sports throughout high school and college, and more recently, keeping up with his 3-year-old granddaughter, whom he and his wife take care of during the day. The home environment for the patient is a two-story town house, which he and his wife moved into during the time of treatment. There are three stairs to get into the home and 12 stairs to get to the second floor. There is a railing on both sides for the set of stairs outside and a railing on the right side for the stairs inside the house. According to the patient, his bedroom, main bathroom with a shower, and laundry room are on the second floor. There is an additional bathroom on the first floor, but there is no shower. Prior to moving into the townhouse, the patient and his wife lived in a single-story home with six stairs to get into the house with a railing on the right. These six stairs were becoming an issue due to pain and general mobility, such as walking for long distances. These issues were affecting the patient's overall quality of life.

The patient had not received conservative treatment for his knee pain and osteoarthritis prior to this physical therapy episode of care. He was taking ibuprofen or Aleve when necessary for pain management, as well as utilizing cryotherapy, which he stated had been helpful at times. The patient did not use an assistive device for ambulating, but he was finding that he was unable to walk as long of distances in places like the grocery store or on walks with his wife and

granddaughter. The ibuprofen and Aleve were causing adverse effects on the inside of his stomach, as he noticed an increase in stomach pains. Due to this occurrence, he discontinued taking the medications and his knee pain was becoming unmanageable, and he could no longer tolerate his limits for walking. Imaging was completed on both patient's knees, indicating progressive OA. This led him to receive a bilateral TKA after discussion with the surgeon in October of 2019.

The patient stood at 6 feet 0 inches and weighed 259 pounds. At his height and weight, the patient's body mass index (BMI) was 35.1, placing him in the obese category according to the CDC.[18] Mulhall et al[19] studied the effects of a higher BMI and weight on the durability of TKA as well as functional outcomes and quality of life following a revision of the TKA. They found that BMI and weight were significant predictors of failure of the survival of a primary TKA.[19] Exact causes for the early failure are not proven, but it was hypothesized that there is increased stress at the bone-prosthesis articulation. Throughout the patient's treatment sessions, he was actively trying to lose weight in order to take stress off the knee joints. In the eight weeks of treatment, he was successful in his weight loss, as he had lost 5 pounds overall, and he was going to continue.

Past medical history for the patient included: type II diabetes, high blood pressure, general osteoarthritis, and gout. He also had a rotator cuff and long head of biceps tendon repair and a left knee arthroscopy. The left knee arthroscopic surgery alleviated his symptoms for approximately two years, but the pain returned. According to a systematic review that looked at the likelihood of being the recipient of a TKA following arthroscopic surgery for osteoarthritis, the annual incidence of TKA after arthroscopy for osteoarthritis was 2.6%.[20] They also found the average time between the two surgeries was 3.4 years. Patients who were older or had more

advanced radiographic osteoarthritis at the time of their arthroscopic surgery had twice the risk of needing a TKA.[20] Osteoarthritis severity and age are associated with TKA, and progressive OA is a distinctive indicator for TKA, as encompassed in guidelines such as the American Academy of Orthopedic Surgeons.[20]

The patient's chief complaint was of pain in both knees, unable to stand for long periods of time, and having to now walk with a front wheeled walker (FWW). He also found activities of daily living (ADLs) and functional activities such as sit-to-stands, showering while standing, sleeping in his own bed, and performing stairs to be painful and difficult. Precautions the surgeon discussed with the patient were to not twist or cross his legs, do not stand for long periods of time, do not sit for more than one hour at a time, and to climb one stair at a time, for the time being. The surgeon did not give an approximate time frame but gave the physical therapist judgment on allowing for these activities. The patient worked as a claim's adjuster for a local insurance company, which means he sat at his desk all day.

The patient was initially seen four days after his surgery. The surgery had no complications to either knee, except for the neurological system discussed later in this paper. Initial examination and first treatment were performed that day at an outpatient physical therapy facility. As stated previously, he was using a FWW for ambulating that he was not using prior to surgery, and he had been fully independent with walking. The patient stated his goal was to be able to walk independently without using the FWW and decrease his pain levels.

During the initial evaluation, a review of systems was completed. There were direct complications to the musculoskeletal and integumentary systems. The muscle and bone surrounding the knee joints were affected by the incision for surgery, as well as the integumentary system. At the time of initial evaluation, the patient's cardiopulmonary system

was unassessed due to time constraints, but the patient remarked that his blood pressure is in the normal range as well as his heart rate. The neurological system was affected by loss of sensation at the lateral aspect of the knee joints due to the injury of the infrapatellar branch of the saphenous nerve.[21]

After completing the patient's history, the patient was considered a candidate to receive outpatient physical therapy. This was due to his manageable pain levels, overall functional limitations, and the patient's motivation to begin treatments. An examination plan was created to evaluate and assess the musculoskeletal system of the patient, relating to his bilateral TKAs. This plan would involve range of motion (ROM), strength, and mobility testing. The safest and most feasible treatment plan was based on the outcomes of the tests and measures to be performed.

Examination

The patient was initially seen seated in the waiting room of the outpatient facility. He was filling out paperwork and was seated next to his wife with the FWW next to him. Upon standing, the patient required the use of both of his upper extremities (UE) to push himself into standing, and in the late phase of the sit-to-stand, he grabbed his walker to pull himself the rest of the way into upright standing. While walking to the treatment room, the patient demonstrated a noticeable limp on the right lower extremity (LE) and was dragging his left LE, indicating antalgic gait and a slower gait velocity. In the examination room, the patient was seated for subjective questioning and history taking, and after completing this section of the examination, the patient was asked to perform a sit-to-stand. Again, he struggled without the use of both UE and the FWW, and he noticed an increase in pain in his knees. The patient was asked to report a pain level based on a scale of 0 to 10 (0 being no pain and 10 being the worst possible pain). He stated that at rest, his pain was at a 4 out 10 and with activity, it was an 8 out of 10. There was no

difference in pain between the two knees at rest, but during walking, the patient stated that his right knee was more painful than the left, which was indicated by his limp.

Examination was based on Dutton's Orthopedic Examination, Evaluation, and Intervention of the knee joint complex.[22] While examining the patient's lower extremities and incision sites, noticeable swelling and bruising were seen at both knee joints and into the calf area. There was more bruising noted on the left LE than the right. There was also pitting edema seen around both ankle joints measured at 1+ grade. He had gauze pads applied over both sites with compression sleeves to hold the pads in place as well as assist with decreasing swelling. During the initial evaluation, there was not a significant amount of drainage around the incision sites, and the pads were changed at the end of the treatment for the patient to clean the minimal drainage. There was tenderness with palpation around both incision sites as well as muscle tightness noticed in bilateral quadriceps and calves. Sensation testing was performed at the LE while in supine to assess neurological integrity, and there was decreased sensation at the lateral aspect of both knees. According to Black[21], 26.9% of patients in their study reported they had loss of sensation at the lateral aspect of the knee at which they received a TKA. The patient in this case study was aware of the neurovascular complication associated with his surgery, and he was aware that there was a likelihood his sensation would not return.

After inspection of the incision sites, integumentary surrounding the surgical area, and sensory testing, the patient's ROM was tested while in supine on the treatment table. Hip ROM was not evaluated through full range, but the patient had at least 100º in order to perform a sit-to-stand and transfer from supine to sitting. Knee ROM bilaterally was assessed using a goniometer and found to be limited in both flexion and extension. Using a goniometer to measure range of motion at the knee joint is both reliable (r = 0.98; ICC = 0.99) and valid (r = 0.97-0.98; ICC =

0.98-0.99).[23] Initial measurements of knee extension and flexion are found in Table 1. During ROM testing, there was pain elicited with passive range of motion (PROM) going into both flexion and extension. Measurements for extension are from full extension, or 0 degrees.

Table 1.
Initial Knee Passive Range of Motion (in Degrees)

	Right	Left
Flexion	90	100
Extension	24	30

Formal strength testing involving manual muscle testing (MMT) was not performed due to increased pain in both knees and wanting to maintain the integrity of the incision sites. Special tests were also not performed, as this patient was post-operative and did not require a specific diagnosis. Gross strength was tested observing a sit-to-stand transfer, which the patient had difficulties performing without the use of his upper extremities, arm rests of the chair, or his FWW. A sit-to-stand has been shown to be both selective and have functional content validity. To be selective, the test is able to differentiate between healthy subjects from TKA patients, and to have a high functional content validity, the test was relatively insensitive to pain scores.[24] The sit-to-stand is used as a biomechanical instrument seeing how overall function of the knee is affected.[24]

The objective and subjective information gathered at the initial evaluation can be placed in a disablement model such as the International Classification of Functioning (ICF) to relate the patient's overall health condition to his activity limitations and participation restrictions. This model was also used as a tool for clinical decision making (See Appendix 2).

Evaluation, Diagnosis, and Prognosis

The initial examination revealed current activity limitations and participation restrictions the patient was facing pertinent to the patient's TKA. Pain and limited ROM were the most evident problems. Other problems the patient faced are included in a problem list created after finding limitations the patient was having (See Table 2). The patient's pain was preventing him from standing for long periods of time, such as while cooking or cleaning in his home. His decreased knee ROM and LE strength made it difficult to ambulate independently and perform a proper sit-to-stand from any chair or navigate stairs. The patient's decreased endurance also made it difficult to ambulate for a long period of time like he was doing prior to surgery, which was limiting him on the walks he could go on with his wife and granddaughter.

Table 2: Problem List

Problem List
• **Pain** • **Decreased Knee ROM** • **Decreased LE Strength** • **Decreased Endurance** • **Decreased Functional Mobility** • **Unable to Sleep Comfortably in Bed**

Addressing the Guide to Physical Therapy Practice, the patient was most closely related to the Practice Pattern of 4H: Impaired Joint Mobility, Motor Function, Muscle Performance, and Range of Motion Associated With Joint Arthroplasty (bilateral TKA) and 7D: Impaired Integumentary Integrity Associated With Full-Thickness Skin Involvement and Scar Formation (surgical wounds).[25]

Treatment sessions were scheduled three times a week for eight weeks. The patient had great potential for a good prognosis despite his current limitations due to the resources he had available to him at home, and strong motivation to gain his motion and strength back. A few short-term goals for this patient included increasing knee ROM into flexion and extension and increasing gross functional knee strength in order to perform a proper sit-to-stand to be able to transfer from any chair. Another short-term goal was to decrease pain and swelling in order to be able to stand for longer periods of time to cook and clean in his home as well as sleep more comfortably in his bed. These were to be reached in approximately 2-4 weeks. Decreasing muscle tightness and spasms in bilateral LE muscles was a long-term goal in order to help decrease pain so the patient would be able to sleep with fewer disruptions and discomfort. Lastly, decreasing the level of assistance for the patient to ambulate was the last goal so he could ambulate independently without the use of his FWW. The long-term goals were to be met in 6-8 weeks (See Goals located in Appendix 3).

After assessing the examination data, the patient was deemed appropriate to complete an intervention program with outpatient physical therapy. This program would include increasing bilateral knee ROM, strength, functional mobility, and decrease pain and swelling in both knee joints. The goals created were lofty but achievable, because the patient was determined to meet them. Every two weeks, re-evaluation of objective data such as ROM and pain were recorded and sent to the physician. Revisions were made to the program based on the patient's progression or regression in therapy, and they were discussed with the patient prior to implementation.

CHAPTER III

INTERVENTION

The interventions chosen for this patient involved traditional post-operative TKA exercises as well as exercises emphasizing function. The traditional post-operative exercises included exercises chosen from a protocol based on the University of Wisconsin-Madison Health Joint Replacement Surgeons in conjunction with The Specialty Team for Arthroplasty Rehabilitation (STAR) Team.[26] This group developed the rehabilitation guidelines followed for this case report. The protocol was presented in a criterion-based progression, meaning there were general time frames given for the average patient and they moved onto the next phase after meeting the criteria in the previous phase.[26] There were, however, specific time frames, precautions, and restrictions for the protection of the incision site.[26] Traditional post-operative exercises consisted of open-chain activities that worked to strengthen muscles surrounding the knee joint as well as stretch into flexion and extension in order to increase ROM. Functional exercises included sit-to-stands, gait training, and stairs.

The patient was seen three days a week for 45-minute sessions. Therapy sessions lasted for a total of eight weeks. Interventions implemented in the first week, which were included in the first phase of the protocol, involved ROM into flexion and extension while on a recumbent bike doing half revolutions. This was generally performed for about 10 minutes. Also completed were bilateral calf stretches on a 6-inch wedge to help straighten the knee and inhibit the calf muscles in order to gain more ROM into extension. Mini squats, LAQ, and SAQ were

incorporated to begin strengthening quadriceps for functional mobility such as sit-to-stands and stair climbing. According to Walsh et al,[27] stair climbing ability in men after a TKA was 51% slower than individuals without knee pathologies. They also found that men with TKA were 37% to 39% weaker and completed 36% to 37% less overall work of their knee extensors compared with the control participants.[27] These exercises were generally performed doing two sets of 10 reps, bilaterally for the LAQ and SAQ. Balance exercises were completed in parallel bars, including narrow base of support (NBOS), tandem stance, and single leg stance (SLS) bilaterally. He started on an even surface with eyes open (EO) progressing to eyes closed (EC). Eventually the patient progressed to uneven surface starting with EO then EC after approximately 2 weeks. Generally, they were completed for 30 seconds or as long as the patient tolerated before his knee pain increased. These exercises were included because balance exercises have been shown to significantly improve functional single leg stance, sit-to-stands, the time to climb stairs, 10 meter walk time, the timed-up-and-go (TUG) test, and the WOMAC.[28] Stair climbing was important for this patient because he was having a difficult time performing them properly with alternating feet and without pain. Supine knee extension stretches were done bilaterally and held for 1 minute each. These stretches were done on a therapy mat with a round bolster that was approximately 10 inches in diameter. The patient also did supine heel slides with slider under his feet to work on knee flexion and hamstring activation. These were completed for dynamic stretching into flexion to gain ROM as well as strengthening of the hamstrings for functional activities like stairs and walking independently. Quadricep sets were done in supine, holding for 6-8 seconds, 8-10 times. Tactile cues were applied to the distal quadricep muscles, and a verbal cue used was, “Try to push your knee down into the mat and tighten your thigh muscles.” Treatment sessions ended with soft tissue mobilization (STM) with a warm lotion to decrease

pain and swelling, or ice massage was applied for 5-7 minutes for the same purposes. The patient seemed to respond better to ice massage, and he was educated on how to make them at home using small paper cups from the grocery store filled with water, then frozen in the freezer overnight. A home exercise program was created to be done two to three times a day. This included recumbent bike that the patient had at home, quadricep sets, heel slides, LAQ, SAQ, and ice pack or massage when needed for pain relief.

The second week of treatment included the recumbent bike for ROM and knee mobility, for 8-10 minutes. At that time, the patient was able to complete full revolutions. The physical therapist instructed the patient to begin the leg press machine with approximately 40 lbs. for gentle ROM and strengthening. This was done for 2 sets of 10 reps in order to continue to challenge and strengthen the quadriceps and now gluteus maximus muscles. Sit-to-stands were also completed as a functional exercise. These were done because the patient had difficulty performing them at the initial evaluation and being able to complete a sit-to-stand with minimal pain and discomfort would assist the patient with more functional activities like getting up from his chair at work to go the printer or getting onto or off of the toilet. Knee flexion and extension machines doing 2 sets of 10 reps, using 30 lbs. for flexion and 10 lbs. for extension were also added this week. Strength of the quadriceps is related to functional performance, and according to Petterson et al[29], it was the single, best predictor of function in their sample. Functional performance measures included getting up from a chair, climbing stairs, and distance walked. These were all activities the patient wanted to get better at performing. The same balance exercises were completed as in week one, but this time adding head turns to the right and left while in tandem stance to mimic walking, as well as standing with a wider base of support (WBOS) due to pain in the lateral knee joint bilaterally. These were still completed in

approximately 30 seconds. Stretches included calves bilaterally on the wedge, and knee flexion and extension bilaterally, holding for 30 seconds to 1 minute. For a more challenging extension stretch, in supine, the patient placed both of his ankles on the round bolster to use gravity to assist with stretching. The therapist attempted slight overpressure, but it was too painful at that time. Heel slides were performed with a strap to have the patient control a greater stretch into flexion. The patient began gait training with a cane, because he was able to ambulate with his walker using minimal weight through his upper extremities. This included gait training on a 4-inch step as well, performing step ups bilaterally. STM or ice massage was still done after each treatment to reduce pain and swelling.

The third week of treatment was focused on increasing ROM into extension. The recumbent bike was still utilized for warm up, as well as the leg machines, including knee flexion with 40 lbs., knee extension with 10 lbs., and leg press with 50 lbs. All exercises were done in 2 sets of 10-15 reps. Terminal knee extension using a TheraBand was performed to increase quad control into knee extension while going down a flight of stairs and to help reduce pain with quadricep contraction, doing 2 sets of 10 reps bilaterally. Greater emphasis was put on PROM into flexion and extension, as the patient claimed he was not pushing himself as hard as he was during therapy. The importance of stretching was discussed with the patient, especially into extension, to avoid stiff knees. He was not having as much trouble with flexion as he was extension. Retro-walking on a treadmill going 0.5 mph for 1 min intervals was done to help increase quad control and knee extension. This was usually done two to three times for a total of 2 to 3 minutes. Supine extension stretch was completed on the bolster again, but instead of PT overpressure, 2 lb. ankle weights were applied to his distal thighs and held until patient could not tolerate anymore.

The fourth week until the end of treatment included the recumbent bike for general knee ROM and mobility for 8-10 minutes. At that time, the patient was coming to therapy sessions early and would complete this on his own so there was more time in therapy to focus on strengthening, stretching, and balance. Balance exercises were completed on an uneven surface using a foam pad in tandem and single leg stance for 30 seconds to 1 minute. Leg machines were still completed, 15 lbs. for knee extension and 40 lbs. for knee flexion. Towards the end of treatment, leg press was increased to 80 lbs. All of these machines were completed for 2-3 sets of 10-15 reps. Four-way hip with TheraBand for balance and hip strength and stability was completed into flexion, extension, adduction, and abduction. The patient had to use a walking stick for balance. One set of 10 reps was completed for each direction. Lateral step ups on 4-inch step, side steps with TheraLoop, and monster walks with TheraLoop were done for greater hip strength and stability to assist with stair navigation. Generally, 20 steps were done on each leg. Core strengthening and stability was done as well for greater pelvic and core control while performing these exercises. These included straight leg raises, bridges, and marching, usually 2 sets of 10-15 reps. STM was utilized for scar mobilization and decreasing muscle spasms and tightness around the incision and in the surrounding muscles. The patient tolerated these exercises well and had minimal complaints of pain, just occasional stiffness with some of the exercises, specifically the balance and four-way hip. He began performing the balance and four-way hip exercises at home at week four. This patient was discharged from PT after 8 weeks of therapy; however, the physician gave the patient permission to discontinue therapy after 7 weeks based on his progressions and meeting all of his goals. The patient wished to continue with PT services for the full 8 weeks because he was highly motivated to continue improving in his goals.

CHAPTER IV

OUTCOMES

At discharge, the patient had very favorable outcomes after completing 7 weeks of outpatient physical therapy, and his physician stated that the patient was able to discontinue PT services due to his progress. However, the patient wished to continue working the physical therapist for all his sessions, scheduled for 8 weeks total. Objective outcome measures utilized to assess the effectiveness of PT were knee ROM into flexion and extension, knee strength for flexion and extension, and level of assistance for ambulation and sit-to-stands. Pain was the only subjective outcome measure used.

Knee ROM for flexion and extension were tested with a goniometer bilaterally every 2 weeks. Active assisted ROM (AAROM) into flexion was completed in supine because the patient would flex his knees as far as he could then PT would provide assistance to reach the patient's maximum flexion. Active ROM (AROM) into extension was performed in supine as well. The patient would extend his knee out as far as he could, and he was given a verbal cue to, "Push your knee down as far as it can go." The initial measurement at the left knee was 100º of flexion and 30º from full extension. Final measurements at the left knee were 124º of flexion and 11º from full extension, increasing his total arc of motion to 113º. The initial measurements at the right knee were 90º of flexion and 24º from full extension. At discharge, the final measurements at the right knee were 124º of flexion and 10º of extension, increasing his total arc of motion to 114º. At the initial evaluation, strength was not measured formally with MMT, but

at 4 weeks, measurements were taken for an objective measurement. They were then taken again every 2 weeks and at discharge, the patient tested a 5/5 strength for knee flexion and extension upon the completion of PT. At the first visit, the patient rated his pain a 4/10 at rest and an 8/10 with activity, on a scale of 0-10 (0 = no pain, 10 = the worst possible pain). His pain varied at each session, but at discharge, his final report of pain was a 2/10 with activity and a 0/10 at rest. Because of reaching this goal, the patient was able to sleep in his own bed with fewer disturbances, as well as stand for longer periods of time for cooking, cleaning, and playing with his granddaughter. Level of assistance was measured for the patient's ambulation. This was also one of the patient's goals: to be able to walk without his FWW. At the initial evaluation, the patient required the use of a FWW for ambulation, but he eventually progressed to using a single point cane after gait training. Final measurements of the use of assistive devices for ambulating was independent or without an assistive device. Table 3 discusses the progression of the documented measurements.

Table 3: Documented Measurements (every 2 weeks)

Week	R Knee ROM (degrees)	L Knee ROM (degrees)	Strength	Assistive Device Use	Pain
1	0-24-90	0-30-100	Deferred	FWW	8/10-activity 4/10-rest
2	0-20-110	0-25-110	Deferred due to pain	Single point cane	7/10-activity 3/10-rest
4	0-17-115	0-15-118	4-/5	Independent	5/10-activity 3/10 rest
6	0-12-120	0-10-121	5/5	Independent	4/10-activity 2/10-rest
8	0-10-124	0-11-124	5/5	Independent	2/10-activity 0/10-rest

The patient's goals of being able to ambulate independently were met approximately halfway through outpatient therapy sessions at 4 weeks, and his goal of reducing pain in order to stand for longer periods of time and sleep more comfortably were met by the conclusion of the episode of care. Physical therapy goals that were met at discharge included bilateral knee flexion of 120º, bilateral knee extension of 10º, and gross functional strength to perform a sit-to-stand independently. Formal strength was eventually assessed at the halfway mark and the patient reached maximum strength for MMT by discharge. Another goal that was met consisted of decreasing overall pain while at rest and with activity. One therapy goal that was not met was decreasing overall muscle spasms and tightness in bilateral LE muscles. There was noticeable progress with decreasing muscle tightness, but the patient still had muscle guarding in bilateral LE.

There were no adverse effects from the interventions, and most of the exercises were tolerated well by the patient. During knee extension stretches in supine using the bolster and with PT overpressure, the patient did complain of increased pain and soreness, especially after the stretch. There were also complaints of pain during other exercises, such as balance training and 4-way hip. Occasionally this pain would cause the patient to discontinue the activity, but most of the time the pain was tolerable. Compliance was relatively good, but the patient admitted to not stretching as much as the physical therapist had instructed him. Education was provided on the importance of gaining back knee ROM, especially extension, to avoid stiff knees and be able to perform functional tasks and leisure activities he enjoys. Overall, the patient stated he was very satisfied with the care he received, and he was especially glad to have achieved his goals for recovery.

CHAPTER V

DISCUSSION

Results of this case study show implications of the potential risks from bilateral TKA and implementing interventions that address preventing these risks. Outpatient physical therapy had significant impact on the patient's improvements and progress. Significant gains in ROM in both knee flexion and extension were noted, as well as gross functional LE strength. Even though LE strength was not formally measured during the initial evaluation, by the end of the treatment sessions, the patient had 5/5 strength in bilateral knee strength for flexion and extension. The patient was able to return to his job as an insurance claims adjuster, playing with his granddaughter, and performing his normal ADLs. Navigating stairs was also significantly easier than prior to his surgery, as subjectively reported by the patient. This patient was a very motivated individual, so this can be attributed to his progress and improvements. He did, however, require encouragement to further challenge himself at home, especially with stretching into extension, as he said he was not pushing as hard as the physical therapist was in the clinic. This was seen also when measurements taken biweekly were plateaued. Education was provided to the patient on the importance of post-operative knee ROM and how it is a vital factor that will influence his satisfaction with his surgery.[30] Limited flexion and extension ROM will impede the patient's activities of daily living, which this patient eagerly wanted to get back to. The patient was reminded why he was working towards these goals, and he stated that he understood the importance of stretching. After this plateau of ROM, gains were being seen again as he was more

compliant at home with his flexion and extension stretches. It is important to note that not all patients will need extra encouragement to achieve their goals, but not all patients will possess the necessary motivation either.

One PT goal that was not entirely met was the decrease in muscle spasms and tightness around the knee joint. This might have been due to the constant work the patient was doing in therapy sessions, such as strength and balance exercises that causes the muscles to continuously work. The lasting tightness could also have been attributed to muscle guarding around the knee joint and incision site to help reduce pain, especially while walking or performing ADLs like stairs. Even though tightness did not entirely subside, STM and ice massage was still used to try and alleviate pain, stiffness, tightness, and swelling. According to Brosseau[31], ice massage showed significant results compared to a control group in improvements of ROM in knee flexion, function, and quadriceps strength. This study was completed on patients with OA in the knee joint and not in those after TKA, but results were seen in the patient in this case study as well. Cryotherapy is used in rehabilitation to decrease inflammation, pain, and edema, all of which this patient possessed. According to Jette and colleagues,[9] cryotherapy should be used for early post-surgical pain management for patients who have had TKA procedure because there are no increased complications, it is inexpensive, and it helps with pain management. With the reduction in these issues, improvements in function were facilitated, such as improved ambulation and stair climbing.

Even though there was one goal not met completely, according to Ranawat et al[32], following surgery, PT goals are to maximize ROM and strength, improve ambulation, reduce pain, and improve overall function. These were all goals the patient met, which were goals for both the patient and the physical therapist. Having documented measurements of ROM helped

the patient have goals to reach every two weeks, and it gave him an objective measurement to reference. Every two weeks, the physical therapist gave the patient a ROM goal to reach, which also assisted with the patient's compliance at home for continuing to stretch. The overall goal for the patient was to continue to make improvements in each category, such as ROM, strength, pain, and ambulation. Since there were continued improvements, it showed there was a progression from the physical therapy he was receiving. For the patient's ambulation, it continued to improve each week, and he was able to walk independently by the end of therapy. He demonstrated a proper heel strike on both feet, adequate knee flexion during initial contact, and a proper step through pattern. Occasionally, after a treatment session, there was a slight limp noted on the right, but the patient said his pain was manageable. Stairs were another challenge for the patient, but this was an obstacle he was willing to tackle. Each week, the patient progressed from using a 4-inch step, an 8-inch step, and eventually a staircase that consisted of 22 stairs with a railing on both sides. By the end of therapy, the patient had achieved proper eccentric quadricep control for descending stairs, correct knee alignment while ascending and descending stairs, and had little to no pain, as subjectively reported by the patient.

One aspect of comprehensive patient care that was not formally assessed was psychological issues. Even though this was not assessed, it is important to keep in mind, and clinicians should screen for the presence of psychological issues that might require treatments outside of the scope of practice for physical therapists, such as a psychologist. According to King[33], one risk factor that may limit a patient's outcome is chronic pain conditions as well as depression and/or anxiety, which may be linked to chronic pain. Usually, pain after surgery has been treated mechanically and biologically using analgesic treatments and physical therapy.[34] Recently, there has been increasing awareness of the potential for psychological interventions to

be implemented post-operatively to hopefully improve postsurgical outcomes, especially chronic pain. Chronic pain after TKA is correlated with limitations in function and a reduction in activity levels, which can ultimately lead to a decreased quality of life. Some of these interventions include cognitive-behavioral therapy (CBT), music therapy, guided imagery and music therapy, hypnosis, progressive muscle relaxation with biofeedback, pain coping skills, and motivational interviewing.[34] This is not a comprehensive list of psychological interventions to include in post-operative TKA treatments for pain, but they can be included to help manage pain and potentially reduce psychological symptoms that can follow surgery, such as anxiety, depression and pain catastrophizing.[34]

When considering outcome measures to utilize for a patient post-operative TKA, it is important to consider all options and their benefits and drawbacks. According to a clinical summary on TKA, patient-reported functional outcome measures, such as the KOS-ADLS which was used in this case study, tend to understate early losses of function and overstate long-term improvements.[33] Scores are generally tied to the pain and effort needed during tasks completed. Performance-based functional measures, such as the Timed "Up & Go" (TUG) and 6-Minute Walk Test (6MWT), are suitably responsive acutely, and they more closely follow specific impairments post-operatively.[33] The clinical practice guideline for TKA suggest collecting patient data using the Knee Osteoarthritis Outcomes Survey Joint Replacement (KOOS JR) as a patient-reported outcome measure, as well as the 30-Second Sit-to-Stand and TUG tests as performance-based outcomes. Using these suggested outcome measures will help show the effectiveness of the therapy provided.[9]

There are limitations seen in this case study that need improvements to support outpatient interventions after a bilateral TKA. It would have been more beneficial to record progress more

frequently, especially the patient's strength, as well as ROM weekly instead of biweekly. This would have given the therapist and the patient more objective information to utilize for reaching weekly goals, as well as given the patient more motivation to work at home. Little research was completed on the physical therapist's end, and more evidence-based practice could have been utilized. The clinical practice guideline, Physical Therapist Management of Total Knee Arthroplasty, referenced in this paper can be used for the future management of patients with TKA.

If this case study was completed again, there would be changes made and aspects of care completed differently. Throughout the course of treatment, questions regarding the patient's pain and psychological state should have been asked to make sure that the patient was not pain catastrophizing or developing other psychological issues related to postoperative TKA, such as depression and anxiety. This would have created a more patient-centered approach to care rather than simply following traditional treatment plans for TKA. Utilizing a functional scale throughout therapy would have been beneficial as well, instead of just at the beginning and end of the 8 weeks. This would have given the physical therapist an idea on how the patient was progressing with his functional abilities and ADLs. Since the KOS-ADLS was used, this scale would have been used throughout, but this is not the only outcome measure available. Gross strength testing was performed within the first week of treatment, but formal strength testing was not performed until the end of treatment. Important information could have been gathered, especially to assist with goal writing, as well as giving the patient something to work towards. Strength is an important aspect for many of the functional activities the patient was completing.

The patient and his family, as well as the physical therapist, were satisfied with the effectiveness of the therapy provided. However, further research must be done on comparing the

long-term progress of a staged bilateral TKA versus a simultaneous bilateral TKA. This research will allow for a better understanding on the differences between the two, as well as give patients more evidence for which option is best for them.

APPENDIX I

Appendix 1: Complications with TKA[14]

TKA Complications	
• Bleeding • Wound complication • Thromboembolic disease • Neural deficit • Vascular injury • Medial collateral ligament injury • Instability • Malalignment • Stiffness • Deep joint infection • Fracture • Extensor mechanism disruption	• Patellofemoral dislocation • Tibiofemoral dislocation • Bearing surface wear • Osteolytes • Implant loosening • Implant fracture/tibial insert dissociation • Reoperation • Revision • Readmission • Death

APPENDIX II

Appendix 2: ICF Disease Taxonomy

HEALTH CONDITION

- Arthritis in bilateral knees
- Bilateral TKA
- Type II diabetes
- High blood pressure
- Gout

BODY STRUCTURES/FUNCTION (IMPAIRMENTS)

1. **Body structure Impairments**
   - Bilateral total knee arthroplasty
   - Increased swelling
   - Incision sites
   - Increased bruising
2. **Body function Impairments**
   - Decreased strength in hamstrings
   - Decreased strength in quadriceps
   - Decreased ROM in knee flexion/extension
   - Decreased balance
   - Diminished dermatomes in L3 bilaterally

ACTIVITY (TASKS)

Abilities	Limitations
Standing balance • Able to stand statically with support from assistive device **Ambulation** • Able to walk with assistive device ~100 ft. **Transfers** • Can transfer into/out of car with slight difficulty	**Standing balance** • Unable to stand without assistive device for more than 30 sec. **Ambulation** • Unable to walk without assistive device **Stairs** • Unable to ascend/descend stairs **ADLs** • Difficulty with sit-to-stands, showering while standing, sleeping in bed

PARTICIPATION

Abilities	Restrictions
Sitting activities • Watch television • Ride recumbent bike • Able to sit and cook with wife **Mobility** • Walk to and from bedroom to bathroom • Walk for short distances in grocery store	**Mobility** • Unable to participate in sports with granddaughter • Unable to walk longer distances in grocery stores • Unable to stand for long periods of time to cook with wife **Work** • Unable to go to work at this time

ENVIRONMENTAL

Personal (internal)		Environmental (External)	
Facilitators	**Barriers**	**Facilitators**	**Barriers**
▪ Very motivated	▪ Stress about work ▪ Stress about the surgery recovery ▪ Gets discouraged occasionally	▪ Supportive wife ▪ Supportive granddaughter ▪ Support from third party payer for rehabilitation ▪ Support from work with PTO ▪ Available resources at home (recumbent bike, TheraBands, weights)	▪ PMH of diabetes ▪ Previous knee surgery ▪ Stress of family about surgery recovery ▪ Pressing matters at work ▪ Weather changes (starting to snow)

APPENDIX III

Appendix 3: Short-term and Long-term goals

Short-Term Goals **Following PT intervention, the patient will be able to: (to be met within 2-4 weeks)**	**Long-Term Goals** **Following PT intervention, the patient will be able to: (to be met within 6-8 weeks)**
1. Increase right knee flexion ROM from 90º to 105º and left knee flexion ROM from 100º to 110º in order walk with a step through gait to be able to walk independently in the community (to be met in 2-4 weeks)	1. Increase right knee flexion ROM from 90º to 120º and left knee flexion from 100º to 120º in order to navigate the stairs in his home with proper alternating stepping pattern to be able to get to his bed on the second floor.
2. Increase right knee extension ROM from 24º from full extension to 17º from full extension and left knee extension ROM from 30º from full extension to 20º from full extension in order to navigate the stairs with alternating his feet in his new townhouse. (to be met in 2-4 weeks)	2. Increase right knee extension ROM from 24º from full extension to 10º from full extension and left knee extension ROM from 30º from full extension to 10º from full extension in order to navigate the stairs in his home with proper alternating stepping pattern to be able to get to his bed on the second floor.
3. Perform a sit-to-stand independently by increasing gross LE strength in order to safely get out of his recliner. (to be met in 2-4 weeks)	3. Decrease muscle tightness and spasms in bilateral LE muscles in order help decrease pain so the patient is able to sleep in his own bed instead of his recliner.
4. Decrease pain at rest in bilateral knees from 4/10 at rest to 0/10 at rest in order to sleep with fewer disturbances while in his recliner. (to be met in 2-4 weeks)	4. Decrease pain during activity from 8/10 to 4/10 to be able to cook and clean in his home with his wife, as well as play with his granddaughter.

REFERENCES

1. Varacallo M. Total Knee Arthroplasty (TKA) Techniques. StatPearls [Internet]. https://www.ncbi.nlm.nih.gov/books/NBK499896/. Published March 15, 2020. Accessed May 28, 2020.

2. Martin GM, Harris I. Total knee arthroplasty. UpToDate. https://www.uptodate.com/contents/total-knee-arthroplasty/print. Published February 24, 2020. Accessed May 28, 2020.

3. Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991-2010. *JAMA*. 2012;308(12):1227-1236. doi:10.1001/2012.jama.11153

4. Zeni JA, Axe MJ, Snyder-Mackler L. Clinical predictors of elective total joint replacement in persons with end-stage knee osteoarthritis. *BMC Musculoskeletal Disorders*. 2010;11(1). doi:10.1186/1471-2474-11-86

5. Gademan MGJ, Hofstede SN, Vlieland TPMV, Nelissen RGHH, Mheen PJM-VD. Indication criteria for total hip or knee arthroplasty in osteoarthritis: a state-of-the-science overview. *BMC Musculoskeletal Disorders*. 2016;17(1). doi:10.1186/s12891-016-1325-z

6. Foran JRH. Unicompartmental Knee Replacement - OrthoInfo - AAOS. OrthoInfo. https://orthoinfo.aaos.org/en/treatment/unicompartmental-knee-replacement. Published April 2016. Accessed May 28, 2020.

7. Sabatini L, Ravera L, Atzori F, Massè A. Outcomes of bicompartmental knee arthroplasty: a review. International Journal of Orthopaedics. http://www.ghrnet.org/index.php/ijo/article/view/764/1024. Published September 29, 2014. Accessed May 28, 2020.

8. DeGruccio AL. Tricompartmental Knee Replacement. Andrew Louis DeGruccio, MD Orthopedic & Sports Specialists of Louisville, P.S.C. https://www.orthopedicandsportsspecialists.com/tricompartmental-knee-replacement-andrew-louis-degruccio-md.html. Accessed May 28, 2020.

9. Diane U Jette, Stephen J Hunter, Lynn Burkett, Bud Langham, David S Logerstedt, Nicolas S Piuzzi, Noreen M Poirier, Linda J L Radach, Jennifer E Ritter, David A Scalzitti, Jennifer E Stevens-Lapsley, James Tompkins, Joseph Zeni Jr, for the American

10. Physical Therapy Association, Physical Therapist Management of Total Knee Arthroplasty, *Physical Therapy*, , pzaa099, https://doi.org/10.1093/ptj/pzaa099

11. Carr BC, Goswami T. Knee implants – Review of models and biomechanics. *Materials & Design*. 2009;30(2):398-413. doi:10.1016/j.matdes.2008.03.032

12. Gabr A, Withers D, Pope J, Santini A. Functional outcome of staged bilateral knee replacements. *The Annals of The Royal College of Surgeons of England*. 2011;93(7):537-541. doi:10.1308/147870811x13137608454803

13. Hussain N, Chien T, Hussain F, et al. Simultaneous Versus Staged Bilateral Total Knee Arthroplasty. HSS Journal ®. 2013;9(1):50-59. doi:10.1007/s11420-012-9315-7

14. Seol J-H, Seon J-K, Song E-K. Comparison of postoperative complications and clinical outcomes between simultaneous and staged bilateral total knee arthroplasty. Journal of Orthopaedic Science. 2016;21(6):766-769. doi:10.1016/j.jos.2016.07.023

15. Fu D, Li G, Chen K, Zeng H, Zhang X, Cai Z. Comparison of Clinical Outcome Between Simultaneous-Bilateral and Staged-Bilateral Total Knee Arthroplasty: A Systematic Review of Retrospective Studies. *The Journal of Arthroplasty*. 2013;28(7):1141-1147. doi:10.1016/j.arth.2012.09.023

16. Healy WL, Della Valle CJ, Iorio R, et al. Complications of total knee arthroplasty: standardized list and definitions of the Knee Society. *Clin Orthop Relat Res*. 2013;471(1):215-220. doi:10.1007/s11999-012-2489-y

17. Impellizzeri FM, Mannion AF, Leunig M, Bizzini M, Naal FD. Comparison of the Reliability, Responsiveness, and Construct Validity of 4 Different Questionnaires for Evaluating Outcomes after Total Knee Arthroplasty. *The Journal of Arthroplasty*. 2011;26(6):861-869. doi:10.1016/j.arth.2010.07.027

18. Denis M, Moffet Hélène, Caron F, Ouellet D, Paquet J, Nolet L. Effectiveness of Continuous Passive Motion and Conventional Physical Therapy After Total Knee Arthroplasty: A Randomized Clinical Trial. *Physical Therapy*. 2006;86(2):174-185. doi:10.1093/ptj/86.2.174

19. Adult BMI Calculator. Centers for Disease Control and Prevention. https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html. Published April 3, 2020. Accessed June 11, 2020.

20. Mulhall K, Ghomrawi H, Mihalko W, Cui Q, Saleh K. Adverse Effects of Increased Body Mass Index and Weight on Survivorship of Total Knee Arthroplasty and Subsequent Outcomes of Revision TKA. *The Journal of Knee Surgery*. 2010;20(03):199-204. doi:10.1055/s-0030-1248043

21. Winter AR, Collins JE, Katz JN. The likelihood of total knee arthroplasty following arthroscopic surgery for osteoarthritis: a systematic review. *BMC Musculoskeletal Disorders*. 2017;18(1). doi:10.1186/s12891-017-1765-0

22. Black R, Green C, Sochart D. Postoperative numbness of the knee following total knee arthroplasty. *The Annals of The Royal College of Surgeons of England*. 2013;95(8):565-568. doi:10.1308/rcsann.2013.95.8.565

23. Dutton M. Dutton's Orthopaedic Examination, Evaluation, and Interventio, 5e New York, NY: McGraw-Hill: http://accessphysiotherapy.mhmedical.com.ezproxylr.med.und.edu/content.aspx?bookid=2707&sectionid=224682855. Accessed December 09, 2019.

24. Gogia PP, Braatz JH, Rose SJ, Norton BJ. Reliability and validity of goniometric measurements at the knee. *Phys Ther.* 1987; 67:192-195.

25. Boonstra M, Malefijt MDW, Verdonschot N. How to quantify knee function after total knee arthroplasty? *The Knee*. 2008;15(5):390-395. doi:10.1016/j.knee.2008.05.006

26. Guide to Physical Therapist Practice. 3rd ed. *Phys Ther*. 2014; 81:9-744???

27. University of Wisconsin Hospitals and Clinics Authority. Outpatient Rehabilitation Guidelines for Total Knee Arthroplasty. UW Health. https://www.uwhealth.org/kneesurgery-rehabilitation/knee-rehabilitation/43167. Published May 2014

28. Walsh M, Woodhouse LJ, Thomas SG, Finch E. Physical impairments and functional limitations: a comparison of individuals 1 year after total knee arthroplasty with control subjects. Phys Ther. 1998;78(3):248–58

29. Liao C-D, Liou T-H, Huang Y-Y, Huang Y-C. Effects of balance training on functional outcome after total knee replacement in patients with knee osteoarthritis: a randomized controlled trial. Clin Rehabil. 2013

30. Petterson SC, Mizner RL, Stevens JE, et al. Improved function from progressive strengthening interventions after total knee arthroplasty: a randomized clinical trial with an imbedded prospective cohort. Arthritis Rheum. 2009;61(2):174–83

31. Mutsuzaki H, Takeuchi R, Mataki Y, Wadano Y. Target range of motion for rehabilitation after total knee arthroplasty. *J Rural Med*. 2017;12(1):33-37. doi:10.2185/jrm.2923

32. Brosseau, L., Yonge, K., Welch, V., Marchand, S., Judd, M., Wells, G. A., & Tugwell, P. (2003). Thermotherapy for treatment of osteoarthritis. *Cochrane Database of Systematic Reviews*, (4), 1-23. doi:10.1002/14651858.cd0045

33. Ranawat CS, Ranawat AS, Mehta A. Total knee arthroplasty rehabilitation protocol: what makes the difference?. *Joint Arthroplasty.* 2003; 18:27-30

34. Jessica King PT. Total Knee Arthroplasty (TKA). https://www.apta.org/patient-care/evidence-based-practice-resources/clinical-summaries/total-knee-arthroplasty-tka. Published June 5, 2020. Accessed 2020.

35. Whale K, Wylde V, Beswick A, Rathbone J, Vedhara K, Gooberman-Hill R. Effectiveness and reporting standards of psychological interventions for improving short-term and long-term pain outcomes after total knee replacement: a systematic review. *BMJ Open*. 2019;9(12):e029742. Published 2019 Dec 4. doi:10.1136/bmjopen-2019-029742