EXERCISE ADHERENCE POST TOTAL KNEE ARTHROPLASTY

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Lay Abstract

Total knee replacement (TKR) surgery costs the Canadian Health care system millions of dollars per year. Exercise is an effective method for improving function and decreasing pain after surgery. However, it is unclear how much patients perform exercise as recommended by health care providers. The purpose of this study was to understand exercise behaviour after knee surgery.

The first study was a scoping review that looked at exercise adherence and the characteristics of exercise treatments delivered after knee surgery in previously published clinical trials. The study found that most studies did not report enough information for replication of exercise treatment protocols (e.g. description of provided exercises/progression, who implemented the intervention, etc.). Similarly, exercise adherence was also poorly reported (e.g., definition, how adherence was measured). Poor reporting of exercise treatment methods, and how well participants complete exercises decreases the ability of researchers and therapists to apply the results of these trials.

In the second study, patients were interviewed after knee surgery to understand why patients do or do not exercise after surgery. There were several factors, both positive and negative, that patients identified that affected their ability to exercise (e.g. self-regulation (referring to the ability to control thoughts, emotions and behaviour to pursue long-term goals), prior knowledge of exercise, having social support from family and friends, as well as lack of support from health care providers). The overall findings suggest that how well participants exercise after surgery is a complex issue. In order to improve exercise adherence, we need to have a better understanding of the individual factors that may influence adherence.

Abstract

Total knee arthroplasty (TKA) places a large burden on the Canadian Health care system with over 700 million dollars spent on this procedure annually. Exercise has been shown to be effective in improving pain, physical function, mobility and quality of life post-operatively. There is very limited research on adherence to rehabilitation and exercise after TKA. The aim of this thesis was to increase understanding of exercise adherence in this population.

The first manuscript in this thesis was a scoping review that evaluated exercise adherence and the quality of reporting of exercise interventions within post-operative TKA rehabilitation trials. A systematic search of scientific databases was conducted for randomized controlled trials (RCT) with an exercise intervention for post-operative TKA. In total, 112 articles were included in this review. This study found that the vast majority of articles (85%) were of poor quality having either high/unclear risk of bias. The majority of RCTs (63%, N=71) on post-operative TKA rehabilitation did not adequately report exercise adherence (e.g., definition, outcome measure used and results), while only 23% (N=15) provided a definition of adherence in the context of their study. Overall reporting of the exercise intervention was poor, with 15 items (of 19) of the Consensus on Exercise Reporting Template (CERT) reported less than 60% of the time. Inadequate reporting of exercise interventions and adherence to exercises leads to decreased reproducibility and translation into clinical practice. Proper reporting of rehabilitation exercises after TKA will ensure standardization for future studies and clinical replication.

The second manuscript in this thesis was a qualitative study that aimed to understand the patient-related barriers and facilitators to exercise adherence in patients immediately after undergoing

TKA. Using an interpretive description approach, semi-structured qualitative interviews were conducted. Seven participants were interviewed at 8-weeks post-operatively in order to better capture physical, psychological, social and contextual factors linked to exercise adherence. Interview questions explored participants' experience with physical activity and exercise, motivation to perform physical activity, beliefs that exercise will reduce pain, the factors that limit their ability to engage in exercise, and the importance of using self-regulation to improve exercise adherence. Emergent themes were mapped onto the domains of the WHO adherence framework. This study identified 4 themes that fit within the WHO adherence framework: patient-related factors, condition-related factors, health care system, and social support. In particular, self-regulation, previous knowledge of exercise, post-operative complications, comorbidities, social support, and lack of guidance from health care providers were identified as personal and environmental characteristics that affect exercise adherence. The overall findings of this study suggest exercise adherence is a multifaceted construct with interconnected concepts.

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Declaration of Academic Achievement

For all the manuscripts, Nora Bakaa developed the research questions, designed the studies, collected and analyzed the data, and wrote the initial drafts.

Chapters 2 & 3

Dr. Macedo helped to refine and guide the research questions, data collection, extraction, and analysis.

Dr. Lisa Carlesso, Dr. Julie Richardson, and Dr. Luciana Macedo helped with revision/editing and provided feedback for the manuscripts.

Table of Contents

List of Tables

List of Figures

List of Appendices

List of Abbreviations

TKA - Total knee arthroplasty

OA - Osteoarthritis

WHO - World Health Organization

CAD - Canadian

ACL - Anterior Cruciate Ligament

PCL - Posterior Cruciate Ligament

MCL - Medial Cruciate Ligament

LCL - Lateral Cruciate Ligament

OARSI - Osteoarthritis Research Society International

VRS/NRS - Visual/Numerical Rating Scale

KOOS - Knee injury and Osteoarthritis Outcome Score

PF - Physical Function

EQ-5D - EuroQol 5-domain instrument

SF-12 - Short Form 12 Health Survey

CTS - 30-s Chair-Stand Test

FPWT - 40-m Fast-Paced Walk Test

SCT - Stair-Climb Test

TUG - Timed Up-and-Go Test

6MWT - 6-min Walk Test

HRERS - Hopkins Rehabilitation Engagement Rating Scale

PRPS - Pittsburgh Rehabilitation Participation Scale

SIRAS - Sport Injury Rehabilitation Adherence Scale

AESOP - Adherence to Exercise Scale for Older Patients

CHAMPS - Community Healthy Activities Model Program for Seniors Activities Questionnaire for Older Adults

RAQ-M - Modified Rehabilitation Adherence Questionnaire

ROAQ - Rehabilitation Overadherence Questionnaire

BMI - Body Mass Index

SMD - Standard Mean Difference

RCT - Randomized Controlled Trial

CERT - Consensus on Exercise Reporting Template

ROB - Risk of Bias

TiDER - Template for Intervention Description and Replication

Chapter 1: Introduction

1.1 Definition of Osteoarthritis

Osteoarthritis (OA) is a progressive disease of the total joint that represents failed repair of joint damage.[1] These degenerative processes can occur in any part of the joint including the cartilage, ligaments, menisci, and surrounding nerves or muscles.[1] Ultimately, these changes lead to a breakdown of bone and cartilage within the joint that may lead to symptoms of pain, stiffness and swelling, and resulting in functional disability.[1] Primary OA is often described as the development of OA without a clear underlying abnormality, whereas *secondary OA is* the development OA due to trauma or an underlying anatomical abnormality.[2] While OA can occur in any synovial joint of the human body, it is more common and more severe in the knee joint.[3]

1.2 Prevalence and Burden of Knee OA

According to the World Health Organization (WHO), OA is one of the leading causes of disability worldwide, affecting approximately 10 percent of individuals over 65 years.[4] It is expected that over 130 million individuals will be affected by OA by the year 2050 worldwide, due to the increase in obesity and the aging population.[5] In Canada, over 4.4 million people are affected by OA, with an estimated 10 million persons to be diagnosed by the year 2040.[6] It is also estimated that knee OA accounts for approximately 80% of the total burden (i.e. years lived with disability) of OA,[7] with a lifetime prevalence of 45%.[3]

OA places a significant burden on society with countries such as Canada, the United States, Britain, Australia, and France spending over 1-2.5% of *total national product.*[8] In 2002, the average annual health care expenditure for a single Canadian with OA was approximately $16 000 CAD, which does not take into account the indirect costs of OA.[8] Thus, the true burden of

OA is often underestimated, and in fact, may be up to eight times greater than the average annual expenditure. In Canada, the total economic burden attributed to OA is estimated to be as high as $1.45 trillion by 2040.[6]

Direct costs associated with OA include hospital visits, surgery, medication, visits to any health care provider, adverse effects of treatment, long-term care, and diagnostic tests.[8] Indirect costs are attributed to time lost from work, lost work productivity when working in a decreased capacity, and early retirement. Other individual burdens accompanying the development of OA include pain and disability, fatigue, decreased social productivity and overall quality of life.[8]

1.3 Diagnosis of Knee OA

The diagnosis of knee OA was first proposed by the American College of Rheumatology in 1986.[9] This commonly used classification consists of a clinical component including history and physical examination (e.g. knee pain, stiffness, etc.) and a radiographic component (e.g. osteophytes, loss of joint space, etc.) (*Table 1*). More recent guidelines for the diagnosis of knee OA, however, consist of only a clinical component (*Table 2*).[10] Radiographic imaging is no longer required to make a diagnosis of OA, as it does not reliability correlate with symptoms.[10] When patients do not respond to typical conservative management of OA or if a surgical intervention is being considered, then radiological investigation is recommended.[10]

1.4 Pathoanatomical Changes in Knee OA

The knee is comprised of a complex synovial joint and is considered the largest joint in the human body, which makes it highly susceptible to injury and disease.[11, 12] The major joints of the knee include the tibiofemoral joint, the patellofibular joint, and the superior tibiofibular joint

(Figure1).[11] The articular surfaces of each bone is enclosed in a layer of avascular hyaline cartilage providing a frictionless surface, which when combined with the synovial fluid that provides lubrication, allows for smooth gliding of the knee joint.[13] The hyaline cartilage is comprised of an extracellular matrix, produced by chondrocytes, which consists of collagen, proteoglycans and water molecules.[14] These extracellular components maintain the tensile strength and compressive forces of cartilage. The ligaments include the anterior cruciate ligament (ACL), the posterior cruciate ligament (PCL), and the medial and lateral collateral ligaments (MCL, LCL), which are important in providing joint stability and limiting excessive translation of the knee.[11] The medial and lateral menisci, comprised of fibrocartilage, are also important in joint stabilization, as well as limiting tensile, sheer and compressive forces to the joint.[15]

Alterations of the knee's anatomy in OA include inflammation of the synovial membrane, degeneration of the hyaline cartilage, thickening of bone and osteophyte formation, degeneration of the surrounding ligaments and menisci, thickening of the joint capsule, and molecular changes to the nerves.[14] These structural changes occur due to a complex cyclical process between the cartilage, bone and synovial tissues in knee OA. For instance, as a result of some stressor (e.g. primary OA due to aging, or secondary OA due to injury, obesity, etc.),[16] the chondrocytes within the cartilage produce what is called a matrix degrading enzyme as well as inflammatory cytokines (e.g. TNF-alpha) that lead to degradation of the chondrocytes causing inflammation.[14, 17] In an attempt to repair the cartilage, chondrocytes then produce an immature type of collagen that is not compatible with the extracellular matrix of adult cells. With the degradation of cartilage, the boney surfaces of the joint become exposed. Again, to repair the bone damage and add to joint stability, the body will produce osteophytes (boney growths along the joint surface).

Osteophyte formation along with bone marrow necrosis or fibrosis cause a hostile environment within the joint leading to pain and inflammation.[14, 18]

It is unclear how the structural joint damage in knee OA leads to pain. The articular cartilage itself is avascular with no innervation and is not considered the primary source of pain.[19] In fact, structural damage of the knee joint on a radiograph is often not correlated with clinical manifestation of pain.[19] Studies have shown that bone marrow lesions, inflammation of the synovial lining and joint effusion are more associated with pain than cartilage damage.[19] The structural deterioration of cartilage, due to increased compressive load, plays a secondary role in the experience of pain due to the exposure of subchondral bone, development of bone marrow lesions, joint effusion, and the subsequent innervation of the normally avascular cartilage tissue.[20] The collagen matrix found in cartilage undergoes little-to-no turnover with age, suggesting OA results from mechanical failure or biochemical breakdown of the joint rather than imbalances in collagen production.[21] Increased inflammation within the joint triggers a cascade of chemical mediators such as proteases, prostaglandins, neuropeptides and cytokines.[19] Based on research from animal studies, these inflammatory factors generate pain by stimulating the joint nociceptors.[19] The joint nociceptor is highly sensitive to mechanical load as such increased mechanical load results in neovascularization of cartilage and menisci, leading to further stimulation of the joint nociceptors.[19] With prolonged pain, there is increased activity of the nociceptive input of the neurons innervating the affected joint.[22] Increased inflammatory mediators and factors associated with tissue damage lead to a reduction in the excitation threshold.[19] As a result, the joint nociceptors will be activated in response to both to noxious and innocuous stimuli. This is a localized phenomenon leading to increased sensation and spreading

of pain in the affected joint known as *peripheral sensitization*.[22] When patients with OA experience referred pain in other areas of the body that are not affected by pathology, *central sensitization* occurs.[22] This process leads to heightened pain sensitivity due to increased activation and reduced excitability threshold of the neurons in the central nervous system, as well as an increased in the receptive field area that elicits neuronal activation.[19] Central sensitization in OA leads to widespread pain with increased intensity and duration.[19]

1.5 Etiology and Risk Factors Associated with Knee OA

The etiology of knee OA is complex and multifactorial.[2] There are many risk factors, both non-modifiable and modifiable, that play a role in the development of knee OA.[5, 23, 24] Non-modifiable risk factors include genetics,[2] age,[23, 25] sex,[26] and the anatomical structure of the knee joint. [27] Modifiable risk factors include obesity,[23] injury to the knee joint (e.g. meniscal injury),[5, 24] diet (e.g. vitamin D insufficiency),[25] increased physical load (e.g. increased kneeling or squatting),[25] and decreased muscle strength.[28]

1.5.1 Non-Modifiable Risk Factors

1.5.1.1 Genetics

Studies have shown that approximately 39-78% of OA can be attributed to genetic factors.[2] Several studies have shown an increased risk of knee OA, as seen by radiographic imaging, among siblings and first-degree relatives compared to the general population.[29] Previous studies have shown that heritability ranges from 39% to 71% in twins with radiographic knee OA. [30, 31] Additionally, the sibling *recurrence risk*, which refers to the probability that a disease will recur within a family[32], was estimated to be 2.08-2.31 for radiographic knee OA.[33] There are many

genes involved in function and repair of bones, tendons, ligaments, cartilage or the menisci that have been implicated in the development of OA.[2] The main genes that have been identified as potential causes of OA include insulin-like growth factor genes, cartilage oligomeric protein genes, the vitamin D receptor genes (affecting bone density and type II collagen), and the HLA region.[34] More specifically, it has been shown that the presence of the C allele of rs3815148 on chromosome 7q22 increased the prevalence by 1.14-fold, and increased the progression of knee OA by 30%.[35]

1.5.1.2 Age

OA is commonly thought of as a disease of aging, and is the most significant factor in the development/progression of OA.[23, 25] While not all older adults develop OA, there is an increased risk with exposure to modifiable risk factors and biological/anatomical changes within the joint.[25] Normal changes that occur during aging have been associated with increased susceptibility to OA.[36] For instance, the chronic production of reactive oxygen species (ROS) causes a state of oxidative stress within the chondrocytes where the amount of ROS exceeds the antioxidant capacity of the cell, playing a significant role in the process of aging. Many conditions, including OA, that have been associated with aging have been attributed to a lack of capability of cells and tissue to maintain homeostasis when under stress. There is also increased production of enzymes (e.g. matelloproteinases (MPPs), aggrecanases, and other proteases) by chondrocytes that result in degradation of the cartilage matrix. Similarly, with ageing there appears to be thinning of the cartilage surrounding the knee joint. Studies have shown that accumulation of advanced glycation end-products (AGEs) in the cartilage is associated with the development of knee OA.

1.5.1.3 Sex

In a meta-analysis comparing the prevalence and incidence of OA between sexes, the incidence and prevalence is higher in females compared to males, Incidence Rate Ratio (IRR) of 0.55, Standard Mean Difference (SMD) of 0.20 respectively.[26] Females have been found to be 1.84 times more likely to develop knee OA compared to males,[23] and males have a 0.63 risk reduction to the development of OA.[26] The increase of prevalence and severity in females has led to the hypothesis of hormonal differences as a potential cause. In animal models, estrogen helps to maintain the integrity of articular cartilage and subchondral bone, which suggests decreased levels of estrogen may increases risk to development of OA.[37] In observational and clinical trials, however, no clear associations have been found regarding the role of estrogen in OA indicating the need for further research in this area.[26, 38, 39] Additionally, researchers have also hypothesized that generally females have a greater amount of total body fat which may account for these sex differences.[40] Studies have suggested that both sex and gender difference are evident in the knee OA;[41] however, it is unclear if these terms are used interchangeably or as separate constructs, where sex refers to the biological affiliation, and gender refers to the socially derived constructs.[42]

1.5.1.4 Anatomical Structure

There is conflicting evidence within the literature regarding the association of anatomical knee structure and OA. Abnormal alignment of the knee joint has been associated with increased bone marrow lesion/necrosis and degradation of cartilage.[27] In pre-existing OA, a varus knee alignment increased the risk of medial compartment OA fourfold[43] with an odds ratio of 2.06,[44] while valgus knee alignment increased the risk of lateral compartment OA fivefold[43] with an

odds ratio of 1.54.[44] Additionally, these structural abnormalities led to more severe radiographic progression of OA compared to individuals with 'normal' alignment.[43] The Framingham Study, however, did not support these findings, suggesting no association between knee alignment and OA.[45]

1.5.2 Modifiable Risk Factors

1.5.2.1 Obesity and BMI

Obesity increases the risk of OA 2.63 times.[23] One study reported that 69% of all total knee replacement surgeries have been associated with obesity.[46] The Framingham Study provided evidence that a 5kg weight loss, among females, led to a 50% risk reduction in the development of clinical and radiographic knee OA.[24] It has been hypothesized that the leptin production by chondroblasts may be associated with OA and obesity,[40] as well as overloading of the knee joint.[34] Additionally, increased low-grade systemic inflammation is observed in obese individuals, and has been associated with cartilage breakdown and stimulating apoptosis in cartilage cells, thereby increasing susceptibility to OA.[47]

1.5.2.2 Injury

Injuries to the knee joint lead to alterations in the biomechanics of the knee, which can predispose individuals to developing OA.[5, 24] Studies have shown that a history of knee trauma can increase the risk associated with the development of OA by 3.86 times.[23] Common injuries include patellar instability, tear of one, or a combination of, the ligaments surrounding the knee joint, or menisci injury.[48] Similarly, studies have shown surgical repair (e.g. meniscectomy) increases the risk of developing knee OA.[34]

1.5.2.3 Diet

There has been conflicting evidence on the role of dietary intake in the development of knee OA.[25] Specific diets have been linked with decreased risk of developing knee OA, including high dietary fiber intake,[49, 50] soy milk intake,[51] and a Mediterranean diet.[52] The Framingham Study also reported that decreased Vitamin D intake was associated with an increased risk of progression of knee OA; however, it was not associated with new incidence of knee OA.[53] A recent randomized controlled trial provided evidence that Vitamin D3 supplementation did not decrease progression of joint space narrowing or reduce pain an function in individuals with knee OA.[54] Another recent clinical trial, however, found that sufficient Vitamin D supplementation resulted in significantly reduced loss of cartilage and physical function, as well as a reduction in effusion-synovitis in individuals with knee OA.[55] While this study provided statistically significant evidence that supports the use of vitamin D supplementation, the effects were small and did not report any clinically meaningful results. Additionally, it was a post-hoc analysis indicating the need for more prospective clinical trials.

1.5.2.4 Physical load

Occupational and exercise-related stressors predispose individuals to the development of OA due to significant repetitive loading of the knee joint.[25] Occupations that require squatting or kneeling significantly have been linked to an increased risk of knee OA by 1.10 times compared to jobs that do not require those movements.[56] Similarly, studies have shown that repetitive joint impact as seen in competitive sports such as soccer, directly increases the risk of knee OA by 5.2 times.[56] The Framingham Study also provided evidence that increased levels of physical activity in older adults can also increase the risk of knee OA by 1.2 times.[57] Long distance runners that

exhibit increased peak compressive forces on the knee joint, however; have a decreased risk of developing OA.[20] In runners, two hypothesis exist to explain why joint loading in running does not increase risk of knee OA. The first explanation suggests that the peak cartilage stress on the knee joint are not high in runners.[20] More specifically, the peak load per stride may be less important than the total accumulated load over a prolonged period. As such, an individual could possibly accumulate more strain in the knee by standing for 30 minutes than by running. The second hypothesis suggests that runners are able to withstand these stressors in the knee joint without initiating joint degradation.[20] That is, OA may not be caused by excessive load but rather unusual loads on the joint. An unusual load is one that places increased stress that the joint is not normally accustomed to. For example, a sudden change in gait biomechanics due to injury may place unusual stress on the joint that could lead to the development of OA.

1.5.2.5 Muscle Strength

In the elderly, sarcopenia and muscle atrophy are very common, which causes decreased joint stability.[28] Quadriceps muscle weakness has been associated with increased risk of knee OA both in clinical symptoms and structural degeneration.[25] Studies have shown that increased thigh muscle cross-sectional area and muscle-to-fat ratio reduce the risk of developing knee OA.[58] In contrast, increased extensor and vastus medialis cross-sectional area,[59] as well as increased extensor strength[60] has been associated with increased risk of knee OA.

1.6 Knee OA Outcome Assessments

The most commonly assessed patient-related outcomes in individuals with knee OA include physical function, pain, and quality of life in patients with knee OA. There are several core

methods of assessment that include self-reported questionnaires[61] and performance-based measures *(Table 3).*[62] The Osteoarthritis Research Society International (OARSI) recommends 5 physical performance-based measures when assessing knee function including 1) 30-s chair-stand test, 2) 40-m fast-paced walk test, 3) a stair-climb test, 4) timed up-and-go test, and 5) 6-min walk.[62] Only the first three tests are considered part of the 'core' performance-based measures for knee OA. Although, recent studies report that the core measures have evidence for reliability, however, there is evidence of poor validity and responsiveness when assessing constructs for walking, sit-to-stand motion, and stair climbing ability in individuals with OA.[63] As such, application to clinical practice remains controversial.

The international consortium for self-reported physical function measures for knee OA recommends the use of the Knee injury and Osteoarthritis Outcome Score-Physical Function (KOOS-PS).[61] The visual or numerical analog scale (VRS/NRS) has been recommended by the international consortium for use alongside the KOOS-PS as a measure of pain.[61] Lastly, knee OA has a significant negative effect on health-related quality of life.[64] As such, it is recommended that clinicians use the EuroQol 5-domain instrument (EQ-5D) or Short Form 12 Health Survey (SF-12) to assess quality of life.[61]

1.7 Non-surgical Management of Knee OA

The recent Osteoarthritis Research Society International (OARSI) guidelines recommends the use of exercise, education and self-management, and weight management as the primary non-surgical approaches to management of knee OA (*Figure 2*).[65] Other interventions include pharmaceuticals, balneotherapy, assisted devices, etc.

1.7.1 Education and Self-Management

Self-management refers to a patient's ability to manage their symptoms, treatment and psychological stresses of a medical condition.[66] In a 2014 systematic review, there was low-to-moderate evidence for the effectiveness of self-management in individuals with OA as compared with other interventions (e.g. usual care, information alone, etc.). Self-management leads to small, but clinically irrelevant change in pain (SMD -0.26, 95% CI [-0.44, -0.09]), and no significant changes in function (SMD -0.19, 95% CI [-0.5, 0.1]) as compared to minimal interventions.[66] While the effect size of self-management on pain and function is relatively small, it remains a first line recommendation as there are no adverse effects.

1.7.2 Weight Management

In a 2007 meta-analysis examining weight loss in patients with knee OA, a 5% reduction in weight within a 20-week period was associated with a significant improvement in function (Effect size = 0.23).[67] Similarly, in obese, older adults with knee OA, a greater amount of weight loss after a 6-month program (including physical activity, diet management, education, and supervised exercises) was associated with better physical function.[68] A significant dose-response correlation between weight loss and changes in pain and function has also been found in individuals with knee OA.[69] Therefore, weight management is an effective method in managing pain and improving functions in individuals with knee OA.

1.7.3 Exercise

The benefits of exercise therapy, particularly for knee OA, is evident in the scientific literature.[70] Recent systematic reviews and meta-analysis have all shown positive effects for pain management and increasing physical function in individuals with knee OA (see *Table 4).*

Regardless of the type of exercise given, the mode of delivery and duration, there are small-to-moderate effects in pain and function. Exercise therapy has been identified as one of the first line of treatment for knee OA in several clinical practice guidelines.[65, 71]

1.7.4 Pharmaceuticals

Pharmaceuticals are also a primary intervention used for management of OA, despite clinical guidelines recommendations.[65] Acetaminophen has been associated with low-level effects for pain management (SMD 0.18, 95% CI [0.11, 0.25]), and is recommended for individuals with knee OA without co-morbidities.[65] However, individuals should be cautious when using acetaminophen for pain management as there is a risk of GI complications and multi-organ failure. Intra-articular corticosteroid injections have also been recommended for short-term pain management in knee OA (no effect size reported).[65] Nonsteroidal anti-inflammatory drugs (NSAIDS) are more effective (SMD 0.37, 95% CI [0.26, 0.49]) in relieving symptoms of OA as compared to acetaminophen, but have significantly increased risk of adverse events, and therefore, are not first line recommendations.[65]

1.8 Surgical Management of Knee OA

1.8.1 Total Knee Arthroplasty

Total Knee Arthroplasty (TKA) is most commonly recommended in individuals with primary, end-stage, tri-compartmental knee OA, often after conservative management has failed.[72] There are several techniques used for TKA. Generally, an orthopedic surgeon encloses the ends of the femur and tibia with metal or plastic components that form a functional prosthetic knee joint. Post-surgically, TKA results in a significant decrease in self-reported pain and increased

functional capability, mobility, and quality of life.[73] The expected lifespan of a TKA is between 15-20 years.[72]

1.8.2 Prevalence and Burden of TKA

From 2017-18, there were more than 70 000 TKA's performed in Canada, accounting for a 17% increase over the last five years.[6, 74] The average cost of one TKA is approximately $10 000 CAD (not including physician compensation and rehabilitation costs), representing over $700 million dollars spent annually.[74] TKA's place a significant burden on the health care system (e.g. costs), the individual (e.g. rehabilitation), and the society (e.g. lost work productivity).[5]

1.8.3 Post-Surgical Complications

In Canada, 6.9% of TKA surgeries are for knee replacement revision. The most common causes of revision surgery include infection, mechanical loosening, and implant failure/breakage.[75] The cost of a joint revision surgery is 80% higher than that of a primary joint surgery, costing up to $17 000 CAD.

While TKA is considered optimal management for end-stage OA, studies have shown that up to 1 in 5 patients are not satisfied with the outcome.[76] Increased age, knee stiffness/swelling at least once per week, and use of an analgesic for pain management were associated with dissatisfaction with TKA outcomes.[77] Additionally, dissatisfied patients also had difficulty with activities of daily living, as well as other lower limb function activities such as stretching, leg strengthening exercises, turning/pivoting, lateral motion, dancing, gardening, and squatting.

Post-surgically, many patients continue to have long-term physical disability, pain, and reduced health-related quality of life.[78-80] After surgery, 14-36% of patients do not improve or have worsened outcomes,[81] while 10-34% experience long-term self-reported pain.[82] In a recent study of patients with moderate-to-severe knee OA, only 50% of individuals had meaningful improvements in physical function 16 months post-surgically.[83] While pain is often cited as a limiting factor of physical activity pre-surgery, studies have reported very little to no change in physical activity levels post-surgery, despite significant improvements in self-reported pain.[73, 84]

1.8.4 Predictors of Post-Operative Outcomes

Researchers have identified several factors including pain, previous levels of physical activity, self-efficacy, social support, comorbidities, body mass index (BMI), depression, and fear of movement as predictors of functional outcome and physical activity in individuals after TKA.[78, 85-87] These predictors demonstrate that baseline self-reported symptoms, BMI and psychosocial factors are the primary predictors of outcomes post TKA. Therefore, in addition to the biological aspects of knee OA (e.g. structural changes), it is important to address the psychosocial factors that may affect long-term patient outcomes.

1.8.5 Post-Operative Exercise

Studies have shown that post-operative exercise interventions (for 8-12 weeks) compared to usual care, education and other exercise programs, are effective for improving pain, physical activity, function, mobility and quality of life.[88, 89] Recent systematic reviews and meta-analyses provide evidence of moderate improvements in patient outcomes with exercise therapy (see *Table 5*).

1.8.6 Best Practice Guidelines

Generally, post-operative exercise for TKA is considered important for achieving optimal patient outcomes. While various studies have shown improvement in pain and function with short-term exercise interventions, there is little information on long-term rehabilitation.[90] Additionally, there is heterogeneity among studies regarding duration, delivery, and dosage of exercises. There are no clinical guidelines for post-operative rehabilitation after joint replacement surgeries. A recent Delphi Study conducted in Canada and the United States provided an expert consensus on best practices of rehabilitation after total hip and knee arthroplasty that is outlined in *Table 6*.

1.9 Exercise Adherence

1.9.1 Definition

Adherence is described by the WHO as "the extent to which a person's behaviour – taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider."[91] This definition was not developed for use in musculoskeletal conditions or adherence to exercise.[92] When assessing adherence very few studies define adherence, and often use the terms "compliance" and "adherence" interchangeably. The WHO uses the term "adherence" to reflect patient autonomy in their proposed treatment.[91] A recent systematic review of the validity, reliability, and acceptability of exercise adherence measures provided an extension to the WHO definition: "The extent to which individuals undertake prescribed behaviour accurately and at the agreed frequency, intensity and duration."[93] It is clear, however, that there is no agreed upon definition of exercise adherence and the most commonly used definition by the WHO lacks specific concepts (e.g. adherence cut-offs, frequency, intensity, etc.), which are important in adherence to exercise.[92]

1.9.2 WHO Adherence Framework

The World Health Organization adherence framework has identified five dimensions that may influence adherence to health interventions, including: 1) Socioeconomic factors, 2) Heath care team and system-related factors, 3) Condition-related factors, 4) Therapy-related factors, and 5) Patient related factors (*Figure 3*).

1.9.3 Self-Regulation and Exercise Adherence

Self-regulation has been identified as a recurrent construct in the majority of theories on understanding adherence to health interventions, including, the health belief model, the theory of planned behaviour and self-efficacy, the theory of reasoned action, and the transtheoretical model.[94] While each approach has its advantages and disadvantages in understanding exercise adherence, there is no single approach that paints a complete picture.[95] Studies have shown that initially exercise adherence is influenced by factors such as obligation to the clinician, a desire to help the researcher and avoid medication, as well as a positive attitude towards physical therapy. Long-term exercise adherence, however, is affected by pragmatic factors that include allocating time to exercise.[96]

Exercise adherence in individuals with musculoskeletal pain is a perfect example of a situation that involves self-regulation. Studies have shown that rehabilitation programs provide the best long-term outcomes post-operatively, including physical function, self-efficacy, and pain management.[97] Failure to self-regulate and adhere to exercise in this instance, often results in decreased health outcomes. Application of self-regulatory theories in exercise adherence have generally focused on altering beliefs, motives, intentions and expectations.[98] These approaches to

health management such as action planning, require significant planning in order to achieve the desired outcome of exercise. Compliance to long-term exercises in patients with knee OA involves "a willingness and ability to accommodate exercise within everyday life."[96] Addressing exercise adherence may be crucial in determining post-operative outcomes.

1.9.4 Adherence Outcome Measures

Self-reported exercise diaries are currently the most commonly utilized measure of exercise adherence in musculoskeletal rehabilitation.[99] Exercise diaries have been used in rehabilitation where patients record the number exercises they have completed per day.[100] Other self-reported measures commonly used in musculoskeletal rehabilitation are summarized in *Table 7*. None of these reported measures of adherence have been validated in post-operative TKA.

1.9.5 Adherence to Exercise Post-TKA

Rehabilitation is considered a crucial process in achieving optimal outcomes post-operatively.[90] Without exercise, patients can often develop complications that include pain, stiffness, and muscle weakness.[101] There is very little evidence whether patients adhere to exercise recommendations post-operatively.[90] Within clinical trials, adherence to post-operative TKA exercise interventions ranges between 60 to 84%.[85, 102] Long-term studies of adherence, however, have shown that nearly half of adults one-year after TKA do not adhere to exercise recommendations.[103] Exercise adherence is a particularly complex issue that encompasses a wide variety of health determinates (as per the WHO framework).

1.9.6 Predictors of Exercise Adherence

Poor adherence to therapeutic exercise is often associated with low levels of baseline physical activity, self-efficacy and self-regulation, higher levels of depression, anxiety and helplessness, poor social support/activity, a greater number of perceived barriers to exercise therapy, and increased pain levels during exercise in individuals with MSK conditions.[104] To our knowledge, there are no studies that have evaluated the factors that influence exercise adherence in individuals after TKA. Understanding the predictors of exercise adherence post-operatively may provide insight into improving patient outcomes as well as long-term improvements in physical activity through the development of targeted interventions (e.g. action planning to improve self-regulation).

1.10 Aims and Objectives

The overall aim of this thesis is to understand the factors that influence exercise adherence in patients undergoing total-knee arthroplasty.

1.10.1 Study One

Study one is a scoping review that aims to evaluate the quality of reporting and characteristics of exercise interventions delivered as part of clinical trials of post-operative TKA rehabilitation, as well as qualitatively assess exercise adherence reporting.

1.10.2 Study Two

Study two consists of qualitative semi-structured interviews to understand participants experience/beliefs regarding exercise, and which factors they view as important to exercise adherence post TKA.

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Table 0-1: The diagnostic criteria for OA as developed by the American College of Rheumatology.[9]

Using History and Physical Exam	**Using History, Physical Exam and Radiographic Findings**	**Using History, Physical Exam and Laboratory Findings**
Pain in the knee + 3 of the following:	*Pain in the knee + 1 of the following:*	*Pain in the knee + 5 of the following:*
• Over the age of 50 • < 30 mins of morning stiffness • Crepitus on active motion • Bony tenderness • Bony enlargement • No palpable warmth of the synovium	• Over the age of 50 • < 30 mins of morning stiffness • Crepitus on active motion • Presence of radiographic osteophytes	• Over the age of 50 • < 30 mins of morning stiffness • Crepitus on active motion • Bony tenderness • Bony enlargement • No palpable warmth of the synovium • ESR < 40mm/hr • Rheumatoid Factor (RF) < 1:40 • Synovial fluid (SF) signs of OA

Table 0-2: The OA diagnosis tool adapted from the Arthritis Alliance of Canada.[10]

History		
1) Pain in the knee joint 2) Morning stiffness that lasts less than 30 minutes 3) Joint pain generally related to activity		
Early OA	*Moderate OA*	*Advanced OA*
4) Description of pain experience:		
Pain is characterized by occasional predictable sharp or other pain, usually brought on by a trigger (activity, repetition, sport) that eventually limited high impact or excessive activities but has relatively little impact on daily activities.	Predictable pain is increasingly associated with unpredictable locking or buckling (knees) or other joint symptoms. The pain becomes more constant, and begins to affect daily activities, such as walking and climbing stairs.	Constant dull/aching pain is punctuated by short episodes of often unpredictable intense pain. This pattern of intermittent, intense and often unpredictable hip or knee pain results in significant avoidance of activities, including social and recreational activities.
Physical Examination		
1) **Knee Alignment:** Normal, valgus, varus 2) **Gait:** Walking with a limp after 5 minutes, pain with walking 3) **Leg length discrepancy**		
Early OA	*Moderate OA*	*Advanced OA*
4) **Knee Swelling (Bulge Test):** Palpate joint line for tenderness while checking for swelling		
Minimal amount of fluid on joint	Noticeable fluid wave with bulge test	Fluid fullness is felt in compartment and does not easily move
5) **Function and Strength:** Sit to Stand Test		
Able to complete greater than 15 repetitions in 30 seconds	Able to complete one to three repetitions in 30 seconds	Unable to complete one repetition where neurological and cardiac function are normal
6) **Knee Flexion:** Knee flexion can be assessed sitting, standing or laying. Patella joint pain is best assessed in the standing quarter flexion		
> 115 degrees	> 90-115 degrees	< 90 degrees

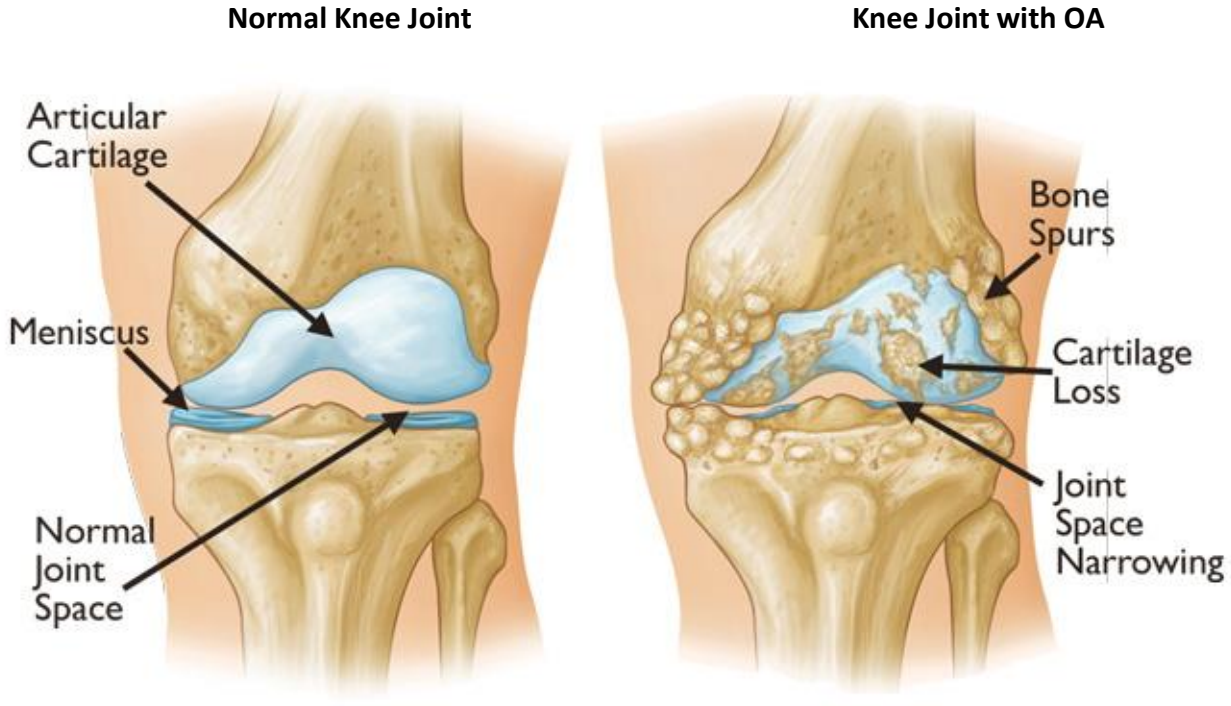

Figure 0-1: Anatomy of a normal knee joint and the structural damage that occurs with knee OA.[105]

Table 0-3: Measuring physical function, pain, and quality of life in individuals with knee OA.

Assessment Questionnaire	Scale	Psychometric Properties
Physical Function		
Knee Injury and Osteoarthritis Outcome Score-Physical Function (KOOS-PF)	The KOOS-PF is a 7-item measure of knee-specific physical function. Each item is scored on a 5-point Likert scale ranging from 0 (no problems) to 4 (extreme problems).[106] The final score is calculated as the sum of all items then transformed to a range from 0-100, where 0 indicates severe knee problems and 100 indicating no knee problems.	The KOOS has be shown have excellent internal consistency with Cronbach's alpha = 0.89, and good construct validity, $r = 0.90$ and $r = 0.85$.[106]
30-s Chair-Stand Test (CST)	The CST measures an individual's ability to rise and sit from a chair. It is measured as the number of repetitions that can be completed within 30 seconds, with a greater number indicating better performance.[62]	Excellent intra-rater reliability with ICC=0.93-0.98 (0.87,0.99).[107]
40-m Fast-Paced Walk Test (FPWT)	The FPWT measures an individual's ability to walking 40 meters. It is measured as time in seconds, where a shorter time indicates better performance.[62]	Excellent test-retest reliability with ICC=0.91 (0.81, 0.97).[107]
Stair-Climb Test (SCT)	The SCT assesses an individual's ability to climb a flight of stairs. It is measured as time in seconds, where a shorter time indicates better performance.[62]	Excellent test-retest reliability with ICC=0.90 (0.79, 0.96).[107]
Timed Up-and-Go Test (TUG)	The TUG assesses the ability of an individual to rise from a chair, walk 3-meters, and return to chair to sit back down. It is measured as time in seconds, where a shorter time indicates better performance.[62]	Excellent intra-rater reliability with ICC = 0.95 (0.72, 0.98), inter-rater reliability with ICC 0.98 (0.94, 0.99), and test-retest reliability ICC=0.75 (0.51, 0.89).[107]
6-min Walk Test (6MWT)	The 6MWT assesses an individual's ability/endurance to walk. It is measured as distance walked (meters) in a duration of 6-minutes, where longer distance indicates better performance.[62]	Excellent test-retest reliability with ICC=0.94 (0.88, 0.98).[107]
Pain		
Visual or Numerical Analog Scale	The visual/numerical analog scale is the most commonly used scale for assessing general pain in all various conditions including OA.[86] It is a scale that ranges from 0 to 10, where 0 is "no pain", and 10 is the "worst pain).	The NRS has been shown to have good test-rest reliability (r=0.67-0.96) and convergent validity (r = 0.79 to 0.95).[108]
Quality of Life		

EuroQol 5-domain instrument (EQ-5D)	The EQ-5D is a 5-item questionnaire that contains five questions relating to: mobility, self-care, usual activities, pain/discomfort and anxiety/depression.[109] Each item is rated on a scale ranging from 0 (no problem) to 5 (unable to perform). Lower scores indicate better quality of life.	The EQ-5D has be shown have excellent internal consistency with Cronbach's alpha = 0.86, and good construct validity, r = -0.688 and r = -0.782.[109]
Short Form 12 health survey (SF-12)	The SF-12 is a 12-item questionnaire that measure quality of life on several domains: physical function, pain, general health, vitality, social function, emotional health, and mental health.[110] The scale is scored by addition responses from each question to get a number ranging from 1-100, where a higher score indicates better health.	The SF-12 has excellent internal consistency with Cronbach's α = 0.82 and 0.75, for SF-12 PCS scale and MCS scale, respectively.[110] Test–retest reliability was excellent with r = 0.89 for PCS and r = 0.76 for MCS.[110]

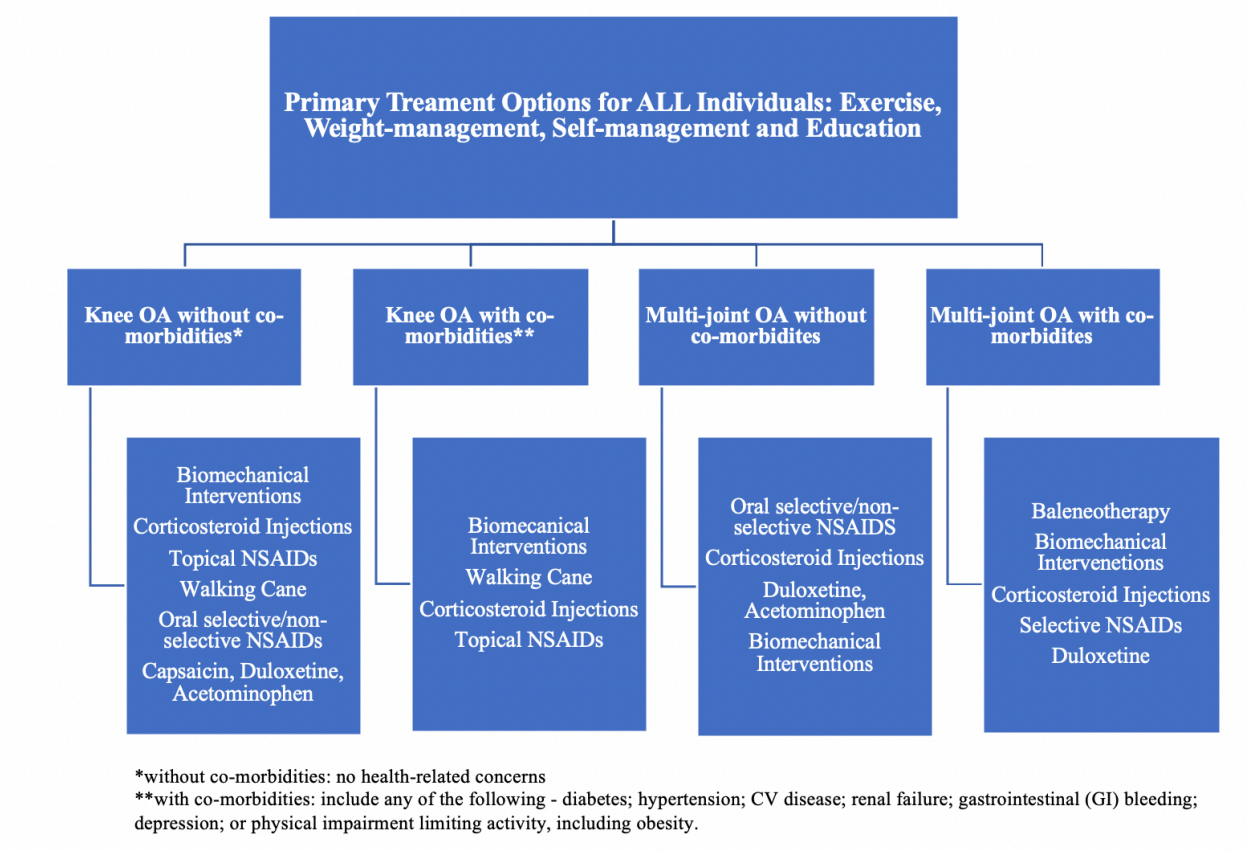

Figure 0-2: The OARSI treatment guidelines for the non-surgical management of knee OA.[65]

Table 0-4: Summary of research studies utilizing exercise therapy for the management of knee OA.

Reference	# of RCTs	Type of Exercise	Outcome
Jansen et al. (2011)[111]	12	Exercise therapy (e.g. strength training, active range of motion, aerobic)	**Pain:** Effect size 0.69, 95% CI [0.42, 0.96] **Physical Function:** Effect size 0.25, 95% CI [0.03, 0.48]
		Strength training	**Pain:** Effect size 0.38, 95% CI [0.23, 0.54] **Physical Function:** Effect size 0.41, 95% CI [0.17, 0.66]
Fransen et al. (2015)[112]	44	Mixed exercises (e.g. aerobic, strength training, flexibility)	**Pain:** SMD -0.49, 95% CI [-0.39, -0.59] **Physical Function:** SMD -0.52, 95% CI [-0.39, -0.64]
Bannuru et al. (2012)[113]	6	Tai Chi mind-body therapy	Pooled effect size of -0.72, 95% CI [-0.97, -0.47] favoring Tai Chi
Juhl et al. (2014)[114]	48	Aerobic exercise	**Pain:** SMD 0.67, 95% CI [0.39, 0.94] **Physical Function:** SMD 0.56, 95% CI [0.24, 0.87]
		Resistance training	**Pain:** SMD 0.62, 95% CI [0.45, 0.79] **Physical Function:** SMD 0.60, 95% CI [0.37, 0.83]
		Performance	**Pain:** SMD 0.48, 95% CI [0.11, 0.85] **Physical Function:** SMD 0.56, 95% CI [0.14, 0.98]

*SMD = standard mean difference, CI = confidence interval

Table 0-5: Summary of research studies utilizing exercise therapy for post-operative management of TKA.

Reference	# of RCTs	Type of Exercise	Outcome
Artz et al. (2015)[115]	18	Physiotherapy exercise (e.g. strength training, functional training, walking skills, cycling)	**Pain:** SMD -0.45, 95% CI [-0.85, -0.06] **Physical Function:** SMD -0.37, 95% CI [-0.62, -0.12]
Umehara & Tanaka (2017)[89]	27	Mixed exercises (e.g. aerobic, strength training, range of motion)	**Pain:** SMD −0.65, 95% CI [−1.22, −0.08] **Physical Function:** SMD −0.40, 95% CI [−0.74, −0.07]
Lowe et al. (2007)[88]	5	Physiotherapy (e.g. functional exercises)	**Physical Function:** Effect size 0.33, 95% CI [0.07, 0.58] **Range of motion:** Effect size 2.9, 95% CI [0.61, 5.2] **Quality of life:** Effect size 1.66, 95% CI [-1, 4.3]

*SMD = standard mean difference, CI = confidence intervals

Table 0-6: Key recommendations from the 2014 Delphi Study for post-acute joint replacement rehabilitation.[90]

Post-operative joint replacement expert panel recommendations for rehabilitation:
• Patients be offered a structured rehabilitation program • Identification of personal and environmental factors that may affect rehabilitation • Distinguish between early and late phase post-operative rehabilitation • Consider patient-specific needs and preferences • Rehabilitation should be provided by clinicians with knowledge and experience in post-operative joint rehabilitation • Provided standardized training to health care professionals in rehabilitation • Activity and participation outcomes assessed regularly • Appropriate methods to measure functional outcomes • Patients should have access to follow-up appointments in the initial 2-years post-surgically

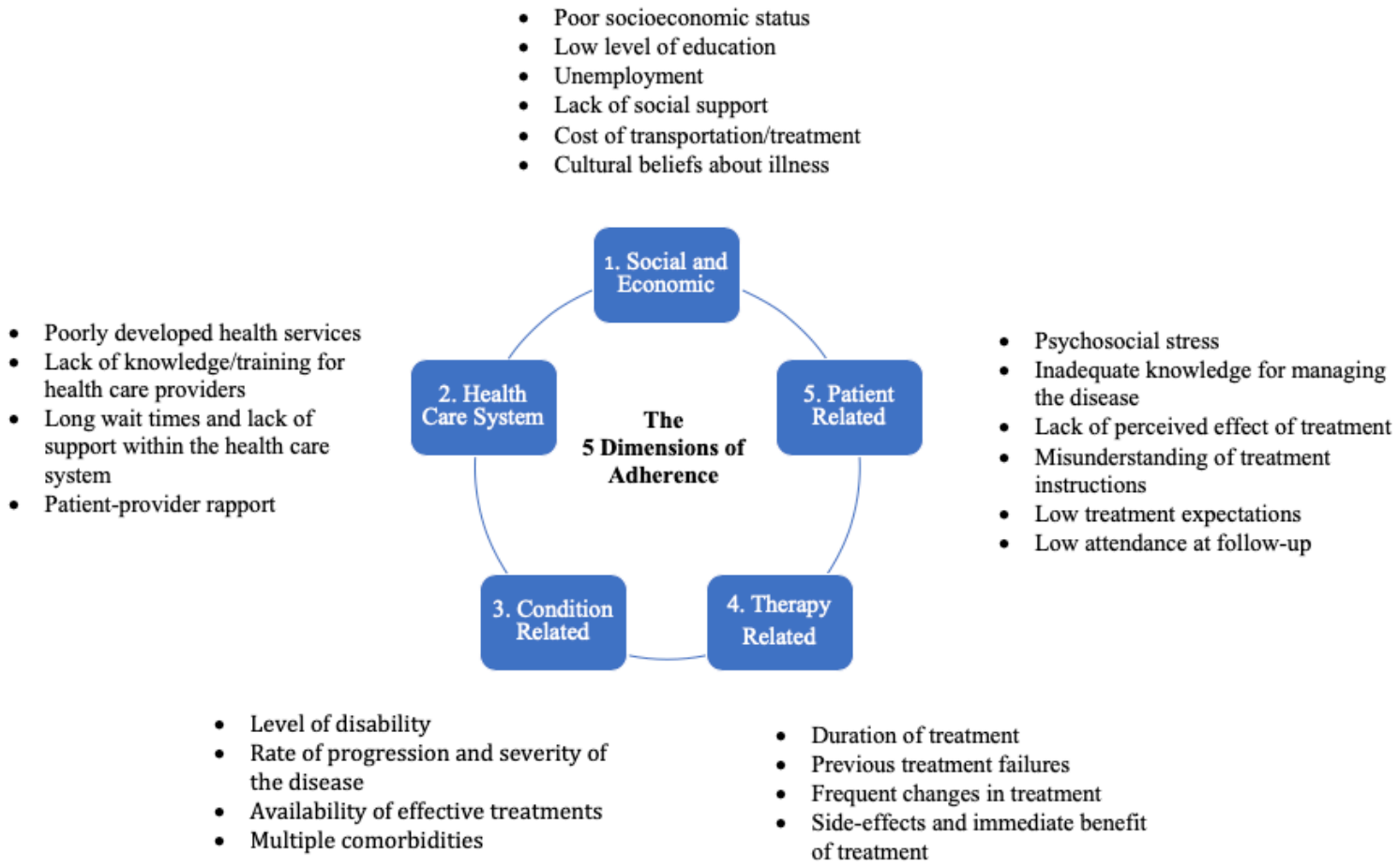

Figure 0-3: The 5 Dimensions of Adherence from the WHO adherence framework.[91]

Table 0-7: Summary of self-reported measures of exercise adherence (adapted from McLean et al. (2017)).[116]

Assessment Questionnaire	Scale	Psychometric Properties
Hopkins Rehabilitation Engagement Rating Scale (HRERS)	The HRERS is a five-item questionnaire that assesses a clinician's perception of a patient's response to rehabilitation.	An acceptable level for internal consistency (Cronbach's a = 0.91), and inter-rater agreement (ICC=0.73) was reported.
Pittsburgh Rehabilitation Participation Scale (PRPS)	The PRPS is a single item questionnaire used to rate exercise adherence during each treatment session.	There are high values of inter-rater reliability (range of ICC = 0.91-0.96). Correlations between the PRPS and the FIM-motor (range r = 0.38), with change in FIM-motor (r = 0.32), and length of stay (r = 0.13) were small.
Sport Injury Rehabilitation Adherence Scale (SIRAS)	The SIRAS is a three-item clinician driven questionnaire to rate the degree to which patients exert themselves, follow the clinician's instructions, and are receptive to changes in the rehabilitation program.	Acceptable levels of internal consistency have been shown (Cronbach's a range 0.82-0.80). Poor to high levels of inter-rater agreement (ICC range = 0.57-0.77), and acceptable test-retest reliability (range=0.63-0.77) have been shown.
Adherence to Exercise Scale for Older Patients (AESOP)	The AESOP is a 42-item interview-administered questionnaire for exercise adherence in older adults. It measures three domains: self-efficacy expectations (15 items), outcome expectations (16 items) and outcome expectancies (11 items).	Acceptable test-retest reliability was reported for self-efficacy expectations (ICC = 0.80) and outcome expectations (ICC = 0.77), and low levels was reported for outcome expectancies (ICC=0.33).
Community Healthy Activities Model Program for Seniors Activities Questionnaire for Older Adults (CHAMPS)	The CHAMPS questionnaire is a 41-item patient-reported or interview-administered questionnaire that measures physical activity over the past 4 weeks. The information can be used to calculate frequency of activities, including the number of minutes of physical activity per week and the calories expended per week.	Moderate levels of test-retest reliability were reported across the different CHAMP scores (range=0.58 to 0.67); there is also moderate levels of responsiveness.
Modified Rehabilitation Adherence Questionnaire (RAQ-M)	The RAQ-M is a 25-item questionnaire developed to assess exercise adherence in injured athletes. The RAQ-M includes six domains of adherence: perceived exertion (three items), pain tolerance during exercise (five items), self-motivation (five items), support from significant others (five items), scheduling (four	Internal consistency reliability of the six domains ranged from 0.66 to 0.87. Test-retest reliability values were acceptable ranging from 0.64 to 0.81.

	items) and environmental conditions (three items).	
Rehabilitation Overadherence Questionnaire (ROAQ)	The ROAQ is a 10-item questionnaire that measures the tendency for an athlete to be overly adherent to exercise, even if it means ignoring the practitioner recommendations and attempt an expedited rehabilitation and return to sport.	Acceptable levels of internal consistency reliability (a >0.70). There is limited evidence of the construct validity.

Chapter 2: Reporting of Post-Operative Rehabilitation Interventions and Adherence for Total Knee Arthroplasty: A Scoping Review

Reporting of Post-Operative Rehabilitation Interventions and Adherence for Total Knee Arthroplasty: A Scoping Review

Journal:
Knee Surgery, Sports Traumatology, Arthroscopy

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1.1 Abstract

Introduction: Studies that have assessed rehabilitation after TKA often lack detailed descriptions of exercise adherence and the intervention (e.g. dosage, frequency, intensity, duration, etc.).

Objective: The aim of this study was to conduct a scoping review to evaluate exercise adherence and quality of reporting of exercise interventions delivered as part of clinical trials of post-operative TKA rehabilitation.

Methods: A systematic search of scientific databases was conducted for RCTs with an exercise intervention for post-operative TKA. The definition, type of measurement used and outcome for exercise adherence were collected. Exercise interventions were assessed using the Consensus for Exercise Reporting Tool (CERT), and the Cochrane Risk of Bias Tool.

Results: The majority of RCTs (63%, N=71) on post-operative TKA rehabilitation did not adequately report exercise adherence (e.g., definition, outcome measure used and results). Of studies that had mentioned exercise adherence, only 23% (N=15) provided a definition of adherence in the context of their study. In general, RCTs were of poor quality, with 85% (N=95) of studies having high or unclear risk of bias. Overall reporting of the exercise intervention was poor, with only 4 items (of 19) (21%) of the CERT that were adequately reported within the RCTs (88-99%). All the other items included in the CERT were not fulfilled on at least 60% of the RCTs. There were no RCTs that had fulfilled all the criteria for the CERT.

Conclusion: Overall, RCTs inadequately report exercise adherence, as well as the overall exercise intervention in post-operative TKA rehabilitation. Future RCTs in post-operative TKA should use valid and reliable measures of adherence and use a proper tool for reporting of exercise interventions (e.g. CERT or TiDER).

1.2 Background

Rehabilitation, specifically therapeutic exercise, is one of the most recommended interventions for improving health outcomes after total knee arthroplasty (TKA).[1] A recent meta-analysis of 27 studies provided low-to-moderate quality evidence that exercise interventions (e.g. aerobic exercises, strength training, etc.) improved patient outcomes after TKA.[2] There was low quality evidence for pain reduction (SMD −0.65, 95% CI [−1.22, −0.08]), and moderate quality evidence for improved physical function (SMD −0.40, 95% CI [−0.74, −0.07) at 8-weeks follow-up.[2] While the benefits of exercise have been highlighted within the literature, studies that have assessed rehabilitation after TKA often lack detailed descriptions of the intervention (e.g. dosage, frequency, intensity, duration, etc.), thereby limiting translation to clinical practice.[3, 4]

There are no established clinical guidelines for post-operative TKA rehabilitation and little information on the optimal form of exercise from clinical trials. After TKA, rehabilitation is considered a crucial process in achieving optimal outcomes.[1] Despite the importance of rehabilitation, there is little evidence surrounding patient adherence to exercise recommendations immediately post TKA.[1] Lack of exercise after TKA may lead to poor post-operative outcomes, including increased pain and functional disability. Exercise adherence can be defined as: "the extent to which individuals undertake prescribed behaviour accurately and at the agreed frequency, intensity and duration."[5] Despite the importance of adherence to exercise interventions, there are no studies that focus on adherence to therapeutic exercise after TKA. Some studies that have assessed effectiveness of exercise after TKA have reported adherence to exercise interventions, however, it is unclear how adherence is defined or measured within a randomized controlled trial.[4]

Therefore, the aim of this study was to evaluate the quality of reporting and characteristics of exercise interventions delivered as part of clinical trials of post-operative TKA rehabilitation. We also aimed to qualitatively assess exercise adherence reporting to those interventions. More specifically a scoping review was conducted to answer the following questions:

1) How is exercise adherence measured and reported in post-operative TKA rehabilitation programs?
2) How is exercise adherence defined in post-operative TKA research?
3) What is the quality of reporting of exercise interventions (e.g. frequency, intensity, etc.) in post-operative TKA rehabilitation?

1.3 Methods

This scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines for scoping reviews. We also used Arksey & O'Malley's[6] methodological framework, modified by Levac et al.,[7] to guide this scoping review. This framework included the following stages: 1) Identifying the research question; 2) Identifying relevant studies; 3) Selecting studies; 4) Charting the data, collating, and summarizing; and 5) Reporting the results. This protocol was pre-registered with OSF: https://osf.io/9ku8a/.

1.3.1 Inclusion Criteria for This Review

Type of Participants*:* Studies with adults (>18 years old), that underwent bilateral or unilateral TKA, were included in this review.

Type of Studies: All randomized controlled trials (RCT) that examined post-operative exercise-based interventions were eligible for inclusion. An exercise-based intervention was defined as:

"an intervention that involved participants completing more than one session of physical exercises such as strengthening, flexibility, and/or aerobic activities."[8] If a study was multifactorial (e.g. exercise and education), then the study was included if the primary intervention was exercise. Exercise was considered a primary intervention, if exercise was a major component through the description of the intervention as well as if the outcome measures assessed exercise-related outcomes (e.g. pain, function, patient satisfaction with exercise, etc.). If a study contained an exercise intervention for both hip and knee arthroplasty, it was included. No language restrictions were applied.

Gray literature studies (e.g. abstracts, conferences, commentaries, editorials), systematic reviews, case studies, psychometric studies, studies where patients with total knee replacement were identified retrospectively were excluded. Studies that included passive forms of exercise (e.g. continuous passive motion) in the primary intervention were excluded.

Type of Outcomes: The primary outcome measures were 1) reporting of the exercise interventions through the Consensus on Exercise Reporting Template (CERT),[9] and 2) exercise adherence. Studies' outcomes included reporting of the exercise interventions (e.g. dosage, frequency, type of exercise, etc.), frequency of studies that reported exercise adherence outcomes, assessment tools used for reporting of exercise adherence (e.g. self-reported patient outcomes, accelerometer, clinical-reported measures, etc.), exercise adherence results, and any definitions of exercise adherence.

1.3.2 Search Strategy for Identifying Relevant Studies

A McMaster University Health Sciences librarian was consulted during the process of building the search strategy. A literature search was conducted (April 29, 2020) in PubMed, EMBASE, AMED, CINAHL, SPORTDiscus and Cochrane Library using terms that capture exercise, physical therapy, physiotherapy, rehabilitation, adherence, and total knee arthroplasty (Appendix A). A limiter for randomized controlled trials was placed. There was no limiter for date or language. A hand search of references that cited the included full text articles was conducted (June 22, 2020).

1.4 Data Collection

1.4.1 Selection of Studies

Initially, eligible studies were uploaded to the referencing software EndNote, and any duplicates were removed. The final list was then uploaded to Covidence, an online screening and data extraction tool. Each screening step (title/abstract and full text) was performed by two independent reviewers (NB, LC) (Appendix B). If there were any discrepancies between reviewers a third reviewer was consulted (LM). Prior to each screening step, a pilot screening occurred on the first 3 studies to ensure standardization for selection criteria between each reviewer. Any discrepancy between reviewers in the pilot screening was discussed to identify any concerns and improve reliability.

1.4.2 Data Extraction and Management

One pair of investigators independently extracted data from the remaining studies that fit the inclusion criteria. Data was exported into a data extraction sheet on Microsoft Excel. The data

extraction table included study design, sample size, descriptive statistics (e.g. age, sex, etc.), exercise intervention type, duration (e.g. 6 weeks, 12 weeks, etc.), outcome (e.g. pain, disability, etc.), and risk of bias as per the Cochrane Risk of Bias Assessment Tool.[10]. To assess completeness of exercise reporting we used the Consensus on Exercise Reporting Template (CERT).[9] The CERT is a 16 item questionnaire that contains specific items related to reporting of exercise interventions.[11] See Appendix C for a detailed description and explanation of the CERT items. The final score for the CERT is calculated as a total score out of 19. The CERT has been shown to have good inter-rater agreement in trials that included a wide variety of musculoskeletal conditions (e.g. back & neck pain, hip & knee OA).[12] We assessed the number of items that were reported in each RCT. We considered the reporting to be incomplete if 1 or more items were not reported. To assess exercise adherence, we extracted any definitions of exercise adherence, exercise adherence measurements and their outcomes. Any discrepancies between reviewers were assessed by a third-party investigator.

1.5 Data Analysis

1.5.1 Exercise Adherence

Studies were screened electronically for keywords that relate to exercise adherence. Studies were categorized as either reporting exercise adherence or not reporting and presented as a percentage. Studies that reported exercise adherence were assessed for measurement tools used for reporting of exercise adherence (e.g. self-reported patient/practitioner outcomes, accelerometer, etc.), exercise adherence results, and any definitions of exercise adherence. Data was presented qualitatively using summary tables.

1.5.2 Intervention Reporting Quality

Quality of intervention reporting was measured as a percentage of intervention completeness, assessing the number of items in each checklist that was included within the study. We reported the median and interquartile range to describe the number of reported items within each RCT. A total score for the CERT was calculated and reported as mean and standard deviation. Additionally, a description of each item that was not met from the CERT for all exercise interventions in each study was provided in the text analysis. Differences between the number of items met on the CERT between the intervention and control groups were assessed using a paired t-test, with a significance level of 0.05. Of the studies that contained two intervention groups and one control,[13-19] an average of the CERT total score for the intervention was used to conduct the paired t-test. STATA IC 15 was used to perform the statistical analysis (t-test), at an alpha level of 0.05.

1.6 Results

1.6.1 Study Selection

A total of 7858 studies were identified through database searches and a total of 374 through a hand search of reference lists (Figure 1). Thus, a total of 5513 titles and abstracts were screened after removal of duplicates. Of these studies, 243 citations were considered potentially relevant and were kept for full-text review. A total of 131 citations were excluded because they did not fulfil the inclusion criteria (See Appendix D for full list of excluded studies with reasons for exclusion). Reasons for exclusion included: 1) Abstract/Title only, 2) Duplications, 3) Continuous Passive Motion, 4) Study not yet published, 5) Study terminated, 6) Wrong

intervention, study design, or patient population, and 7) Unable to locate/translate study. Finally, 112 RCTs were included in this review.[13-124]

1.6.2 General Characteristics

The 112 RCTs consisted of a total of 120 intervention groups (more than one treatment arm in some studies) and 112 control groups. These RCTs were conducted in 28 different countries. The top countries included the United States of America (18.8%, n=21), Australia (8.9%, n=10), the United Kingdom (8%, n=9), and Canada/China/Italy/Germany (6.3% respectively, n=7 each).

1.6.3 Adherence

There were 64 (57%) studies that had mentioned exercise adherence within their study.[13, 14, 17-19, 21, 23, 25, 27, 28, 30-32, 36-41, 44, 47, 48, 52, 53, 57, 59-63, 67, 68, 72, 73, 76-78, 80, 84-87, 90-94, 96-98, 101-103, 105, 106, 108, 111, 112, 115, 117, 120, 121, 123, 125] Of these studies only 41 (65%) reported adequate information (e.g. measurement used and outcome) for adherence.[14, 17, 25, 27, 28, 30, 32, 36-39, 47, 52, 60-62, 68, 72, 73, 76, 77, 80, 84-87, 90-92, 96-98, 101-103, 106, 108, 111, 117, 120, 121] There were 15 studies that had a pre-defined cut-off for exercise adherence such as: "Satisfactory compliance was defined as an average of >75% of walking protocol."[40] Full definitions for each study is available on Table 1.[13, 14, 17, 39, 41, 52, 60, 68, 72, 73, 76, 92, 97, 117, 123] There were 6 studies that stated participants would be excluded or discharged from the study, and thus the analysis, if they failed to meet the adherence cut-offs, which is not in line with the recommended intention-to-treatment analysis.[13, 14, 32, 68, 117, 123] There was one study that evaluated adherence as the primary outcome, but did not provide any conceptual framework around the concept of adherence.[85] When evaluating the definitions used withing the

included studies, it was clear that some studies used the term compliance when describing adherence, which is problematic.

Of the 69 reported outcome measures to assess adherence, the number of attended sessions and session details (e.g. duration) (43%, N=30/69), and patient diary (41%, N=28/69) were the most commonly used. Less commonly used measures of adherence included self-reported patient and clinician questionnaires, activity monitors, computer aided systems (e.g. telehealth app), and duration/intensity of the exercise session. Adherence was primarily measured during the period of the intervention, which varied from study to study (2-3 day to 8-week intervention periods). On average, adherence to attended number of sessions was 87% (16.6%) in the intervention group (N=19),[17, 25, 27, 52, 61, 68, 73, 76, 77, 80, 86, 90-92, 96, 101, 102, 120] with number of attended sessions ranging between 47 to 100%. When the number of sessions was reported for the control group (N=10),[17, 27, 68, 73, 77, 80, 92, 101, 102] the adherence rate was 95% (6.5%), range: 83-100%. Adherence to the assigned exercise sessions as measured using a patient diary was 78% (15.9%), range: 61-110%, in the intervention group (N=9)[17, 25, 47, 102, 103, 106, 117, 121] and 76% (9.21%), range: 65.4-85%, in the control group (N=5).[17, 25, 102, 103, 106] In one study, the authors recommended exercises sessions to be completed 2x/day, and the intervention group completed more exercises than the recommended dose.[106] Only one study reported on the long term adherence to exercises after the intervention phase was completed (49% in the intervention group, and 34% in the control after 12 months).[121]

1.6.4 Quality of Reporting

There were no RCTs that fulfilled all the 16 items (total score of 19) of the CERT (See Appendix E for the completion of the CERT for each included study). There were 18 RCTs that reported at least 14 (74%) items intervention group,[14, 17, 25, 32, 39, 52, 68, 71, 72, 76, 80, 84, 91, 101, 111, 117, 121] and 9 RCTs in the control group.[14, 17, 25, 32, 39, 68, 72, 102, 111] There were 10 RCTs that reported 4 items or less (<21%) in the intervention group,[16, 51, 78, 98, 100, 104, 107, 109, 116, 122] and 17 RCTs in the control group.[33, 34, 40, 47, 50-52, 61, 62, 78, 98, 103, 107, 109, 113, 116, 122] Frequency and percentage of adequately reported CERT items are presented in Table 2. The mean (standard deviation) of adequately reported items in the intervention group was 9.4 (3.5), which was significantly higher as compared to the control group, 8.0 (3.7), $T_{107} = 5.56$, $p < 0.0001$.

The most commonly reported items in the CERT, in both the intervention and control groups, included mode of delivery (Item 2: Group or individual; Item 3: Supervised or unsupervised), setting (Item 12), and if the intervention was tailored or not (Item 14a), ranging from 80-99%. All the other items included in the CERT were not fulfilled on at least 60% of the RCTs.

The first item of the CERT refers to the description of exercise equipment used during the intervention,[11] which was poorly reported in both the intervention (I:58%) and control (C: 31%) groups. The provider description (Item 2), defined as the qualifications, teaching/supervising experience, and or training of the provider,[11] was one of the most poorly reported items (I: 8% and C: 6%). While the majority of studies listed the professional group of persons delivering the intervention (e.g. physiotherapist), they failed to include the specific qualification of the provider (e.g. expertise, training received, etc.). Authors often failed to provide a detailed description (Item 8) of each exercise (e.g. photographs), rather more generalized information was included

(e.g. strengthening and stretching). Similarly, the description of the rehabilitation program (Item 13) was also poorly reported (I: 58% and C: 42%). More specifically, sets (I: 43%, C: 38%), repetitions (I: 42%, C: 35%), and intensity (I:40%, C: 27%) were less adequately reported as compared to duration of each session (minutes) (I: 65%, C: 53%). Determining when to progress each exercise (e.g. after completion of a pre-specified amount of repetitions/sets) was also poorly reported (Item 7a; I: 53%, C: 35%). Similarly, how each exercise was progressed (e.g. gradual increase in intensity or frequency of exercise) was also insufficiently reported (Item 7b; I: 41%, C: 28%).While information about whether the study was generic or tailored was provided, studies that did tailor their intervention failed to provide a proper description of how the exercise was tailored (Item 14b). There were very few studies that mentioned any motivational strategies (Item 6) to engage participants in the exercise intervention (I: 33%, C: 22%). Nearly 50% of studies did not mention a home exercise program (Item 9) or non-exercise component (Item 10) of their intervention in both the control and intervention groups. When a home exercise program was specified, few details were provided, unless it was the same as the intervention. Authors also failed to adequately report any adverse events (Item 11) related to the exercise intervention (I & C: 45%). The planning versus actual implementation of the intervention was assessed as fidelity (Items 18 & 19), referring to training of therapists and standardization of the treatment intervention, and as the intent that the intervention was delivered as proposed.[11] Fidelity (I & C: 21%) and planned delivery (I: 33%, C: 27%) were poorly reported.

1.6.5 Cochrane Risk of Bias Assessment

The majority of RCTs included in this review were of poor quality with 16 studies with low risk of bias, 72 with high risk of bias, and 24 with unclear risk of bias. See Appendix F for detailed risk of bias assessment.

1.7 Discussion

The RCTs included in this study poorly reported exercise adherence, as well as description of the post-operative TKA rehabilitation intervention. The majority of RCTs on post-operative TKA rehabilitation did not adequately report exercise adherence (e.g., definition, outcome measure used and results). Of the studies that mentioned exercise adherence, very few provided a definition of adherence in the context of their study. Adherence was commonly measured as the number of supervised exercise sessions and self-reported exercise diary. These methods, however, have been reported to have poor validity and reliability.[5] Adherence was rarely the focus of any RCTs and often mentioned as a secondary outcome measure. There were no studies that identified a conceptual framework of exercise adherence. The use of a conceptual framework would allow researchers to systematically examine the effects of exercise adherence in any population. These findings are consistent with previous literature that suggests lack of reporting of adherence in exercise interventions.[126]

In general, RCTs were of poor quality, with the majority of studies having high or unclear risk of bias. Similarly, the overall reporting of the CERT items was very poor within the RCTs. While neither intervention was adequately reported, the control group was more likely to be underreported as compared to the intervention group, despite both containing exercise components. These findings are fairly consistent with recent literature which suggests less than

one fifth of studies adequately report exercise interventions in other musculoskeletal conditions[127] as well as educational interventions.[128]

One interesting, but not surprising, finding of this review is that the terms adherence and compliance were used interchangeably. Compliance and adherence, however, are inherently different constructs. Compliance refers to "the extent to which the patient's behaviour matches the prescriber's recommendations,"[129] while adherence refers to "the extent to which a person's behaviour, taking medication, following a diet, and/or executing lifestyle changes, corresponds with agreed recommendations from a health care provider".[129] In this case, adherence refers to a process in which the agreed upon treatment is discussed with the patient. In this way, the patient is not the only person responsible for non-adherence but places an onus on the clinician as well. A compounding problem is that some studies included pre-defined cut-offs for adherence,[13, 14, 32, 68, 117, 123] in which participants would be excluded from the study and analysis if they did not meet them. These cut-offs were different in each study and were not based on any scientific rationale for assessing adherence. As such, intent-to-treat analysis was not used, which may overestimate effectiveness of the intervention. Authors should treat adherence as a continuous measure and use of statistical procedures to address the issue of nonadherence.
Outcome measures used to assess adherence varied between studies including subjective (e.g. diary, self-reported patient/practitioner questionnaire) and objective measures (e.g. accelerometers, number of attended sessions). The inconsistency in measurements used to assess adherence limits the ability to draw conclusions regarding accuracy and compare between studies.[11] Lack of proper reporting of adherence may lead to underestimation of treatment effects, in that, participants may not be improving after an exercise intervention due to lack of

adherence, rather than an ineffective intervention, and will limit clinical application and proper understanding of the burden of the intervention on the patient.

There were very few studies that mentioned any motivational strategies to engage participants in the exercise intervention. In post-operative TKA, physical activity and exercise levels are very similar to pre-operative levels despite improvements in pain and function.[130] Adherence to exercise can, in part, be attributed to poor motivation.[131] Motivation strategies (e.g. goal setting, etc.) have been found to be effective in changing exercise behavior to foster both short and long-term adherence.[132] Additionally, only one study reported adherence to the exercises in the long-term after the intervention period. The study documented high initial adherence during the intervention (I: 72%), which then dropped significantly 12 months after the intervention (I: 49%).[121] Further, high rates of adherence reported as part of clinical trials may be higher than those in clinical practice due to the Hawthorne effect, as well as to the usual short-to-moderate follow-up times reported. Future studies should clearly define motivational strategies that foster exercise adherence during the intervention as well as in the long-term and in clinical practice.

Poor reporting for post-operative TKA exercise interventions is particularly concerning as it limits reproducibility of research, but more importantly, it limits translation into clinical practice. The majority of RCTs included in this study failed to report more than 70% of the CERT items in both the intervention and control group. This is consistent with recent literature that assessed reporting interventions for LBP.[127] In particular, description of the exercises, dosage, progression of exercise, adverse events, content of home program/non-exercise components, and fidelity were not well reported. Conversely, inadequate reporting of specific rehabilitation

procedures may lead to improper clinical application, leading to potential harm.[127] These items are particularly important in intervention reporting to reduce bias in implementation, as well as standardization for future studies or clinical replications. Poor reporting can be, in part, attributed to the complexity of rehabilitation interventions[133] leading to difficulty of standardization.[134]

1.7.1 Limitations and Strengths

This study had several limitations. First, we only assessed rehabilitation intervention for individuals who underwent a total knee replacement, excluding unicompartmental knee replacements and revision surgeries. Additionally, the RCTs included in this study were not limited by year, which may alter the results as reporting of interventions has improved over time.[127] Publication bias may influence adherence results as studies that have poor adherence are generally less likely to be published.[135] Since the purpose of this scoping review was to assess the reporting quality of interventions, there was no considerations of effectiveness of each intervention. The strengths of this study relate to the performance of a comprehensive systematic scoping review in multiple databases to assess quality of reporting in post-op TKA rehabilitation. Additionally, this study looked at both the control and intervention groups separately using a validated reporting tool as well as the validated Cochrane Risk of Bias assessment tool.

1.7.2 Key Recommendations

1) Authors should use valid and reliable outcome measures of exercise adherence. This tool should be consistent in all exercise interventions.

2) Authors should clearly define exercise adherence and use a continuous measure (rather than a cut-off) to avoid reporting bias.
3) In addition to using an RCT reporting guideline, authors should include an exercise reporting tool (e.g. TiDER or CERT).
4) Authors should adequately report exercise interventions even if it is an adjunct to the main intervention (e.g. electrotherapy plus exercise, control group, etc.).

1.8 Conclusion

This study found poor reporting of exercise adherence, as well as the overall exercise intervention in post-operative TKA rehabilitation. Adherence is primarily reported for the intervention with little information on home exercises or adherence to exercise following discharge from care. Future studies should aim to identify accurate and reliable measures of adherence, and authors should include an exercise reporting tool when planning/implementing exercise interventions. Proper reporting will allow for smoother translation of research into clinical practice as well as better quality and reproducibility of research.

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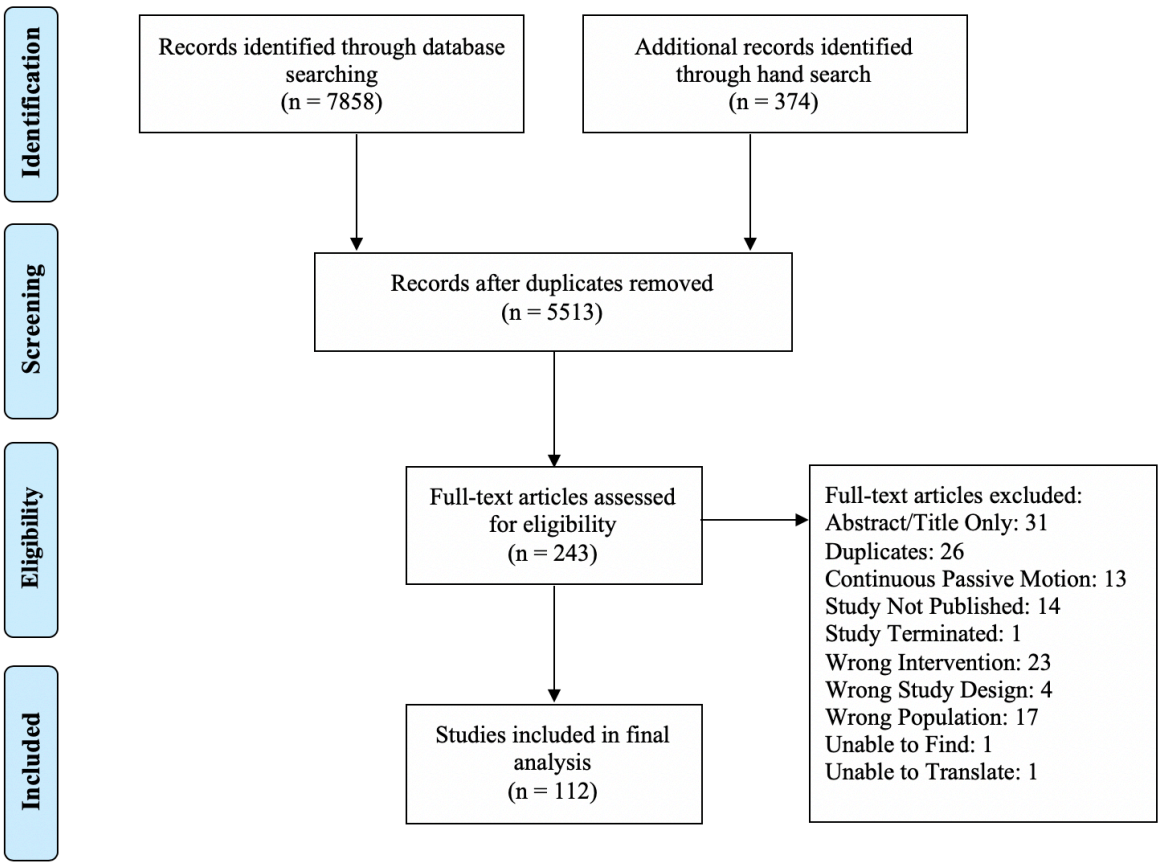

Figure 0-1: Flow diagram of study selection process.

Table 0-1: Definitions of exercise adherence.

Study	Definition of Adherence/Compliance
Akbaba et al. (2016)	"The patients were excluded if they had not completed at least 75% of the exercise programme."
Buhaglar et al. (2017)	"Adherence for both groups was defined as attendance at no less than 2 and no more than 4 outpatient sessions. Adherence for the inpatient rehabilitation group was further defined as having had a minimum 7 days of inpatient rehabilitation."
Christiansen et al. (2020)	"We classified adherence as "achieved" for participants who had ≥80% of the weekly steps/day goal recorded by the physical therapist and "not achieved" for those with <80% of the weekly steps/day goals recorded, which is consistent with the definition of adherence from a pharmacologic perspective."
Debbi et al. (2019)	"Satisfactory compliance was defined as an average of >75% of walking protocol."
Fransen et al. (2017)	"Attended the full program of 16 classes."
Harmer et al. (2009)	"Attending 8 or more sessions ."
Johnson et al. (2010)	"Subjects were required to complete at least 10 of 12 scheduled therapy sessions. Subjects were allowed to miss up to two sessions, but not in the same week, before being discharged from the study."
Kelly et al. (2016)	"Goal of 2 sessions per week."
Kramer et al. (2003)	"Compliance was defined as completion of the home exercises at least 90% of the time."
Lenguerrand et al. (2019)	"Adherence to the intervention was predefined as attendance at ≥4 sessions."
Moffet et al. (2015)	"Subjects who participated in all evaluations and attended at least 75% of the intervention sessions."
Naylor et al. (2013)	"Intervention group attended > 9 sessions; the control attended 2 sessions."
Paxton et al. (2018)	"The adherence rate (in the physical activity feedback group) cutoff of greater than 90% was assessed as the ratio of the number of weeks that the Fitbit wearable sensor and tablet application were used over the total number of weeks. Use of the Fitbit sensor was assessed by noting daily wear time (≥ 12 hr representing a valid day). Dose goal cutoff of 80% was assessed as the ratio of the total number of participants achieving their goals over the total number of participants, for each week of the intervention."
Trudelle-Jackson et al. (2020)	"Participants were considered 100% compliant if they exercised 3 to 4 times per week for 8 weeks (intervention group only). A minimum requirement of 50% compliance with the high-velocity exercise training program was necessary to remain in the study."
Yousefian et al. (2017)	"Patients not attending 100% of their therapeutic sessions were also excluded from the study."

Table 0-2: Frequency and percentage of adequately reported CERT items in the intervention and control groups.

CERT Item	Intervention (N=120)	Control (N=112)
	Frequency (%)	Frequency (%)
Item 1: Exercise Equipment	69 (58%)	32 (31%)
Item 2: Provider Qualifications	10 (8%)	7 (6%)
Item 3: Individual/Group Delivery	114 (95%)	95 (87%)
Item 4: Supervised/Unsupervised	119 (99%)	101(93%)
Item 5: Exercise Adherence	43 (35%)	29 (27%)
Item 6: Motivation	39 (33%)	24 (22%)
Item 7a: Exercise Progression Decision	63 (53%)	38 (35%)
Item 7b: Exercise Progression Description	49 (41%)	29 (28%)
Item 8: Description of Exercise	69 (58%)	46 (43%)
Item 9: Home Program Component	62 (52%)	50 (46%)
Item 10: Non-Exercise Component	63 (52%)	53 (49%)
Item 11: Adverse Events	54 (45%)	49 (45%)
Item 12: Setting of Intervention	110 (92%)	96 (89%)
Item 13: Dosage Total	45 (38%)	32 (30%)
Sets	52 (43%)	41 (38%)
Reps	50 (42%)	37 (35%)
Duration	79 (65%)	57 (53%)
Intensity	48 (40%)	29 (27%)
Item 14a: Tailored/Generic	106 (88%)	87 (81%)
Item 14b: Description of Tailoring	9 (23%)	5 (16%)
Item 15: Starting Level of Intervention	50 (42%)	35 (33%)
Item 16a: Intervention Delivered as Planned	40 (33%)	29 (27%)
Item 16b: Fidelity	25 (21%)	23 (21%)

1.10 Appendix A – Search Strategy

EMBASE

1. exp exercise/
2. exp physiotherapy/
3. exp rehabilitation/
4. exp rehabilitation care/
5. exp kinesiotherapy/
6. exercise*.ab,ti,kw.
7. physiotherap*.ab,ti,kw.
8. physical therap*.ab,ti,kw.
9. rehabilitation.ab,ti,kw.
10. rh.fs.
11. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10
12. exp knee/
13. knee.ab,ti,kw.
14. 12 or 13
15. exp arthroplasty/
16. exp total knee arthroplasty/
17. exp knee replacement/
18. 14 and 15
19. exp knee osteoarthritis/su [Surgery]
20. knee replacement*.ab,ti,kw.
21. knee arthroplast*.ab,ti,kw.
22. (knee adj3 (replacement* or arthroplast*)).ti,ab,kw.
23. exp postoperative care/
24. 14 and 23
25. 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 24
26. exp clinical trial/
27. exp controlled study/
28. controlled trial*.ti,ab,kw.
29. clinical trial*.ti,ab,kw.
30. single blind*.ti,ab,kw.
31. double blind*.ti,ab,kw.
32. rct.ti,ab,kw.
33. randomi?ed controlled trial*.ti,ab,kw.
34. random.ti,ab,kw.
35. 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34
36. 11 and 25 and 35

MEDLINE

1. exp Exercise/
2. exp Rehabilitation/

3. exp Physical Therapy Modalities/
4. exp Physical Therapy Specialty/
5. exp Exercise Therapy/
6. exercise.mp.
7. rehabilitation.mp.
8. physical therap*.mp.
9. physiotherap*.mp.
10. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9
11. exp Knee/
12. exp Knee Joint/
13. knee.mp.
14. 11 or 12 or 13
15. exp Arthroplasty/
16. exp Arthroplasty, Replacement, Knee/
17. exp Knee Prosthesis/
18. knee replacement.mp.
19. knee arthroplast*.mp.
20. exp Osteoarthritis, Knee/su [Surgery]
21. exp Clinical Trial/
22. exp Randomized Controlled Trial/
23. randomized controlled trial*.mp.
24. clinical trial.mp.
25. 21 or 22 or 23 or 24
26. 14 and 15
27. 16 or 17 or 18 or 19 or 20 or 26
28. 10 and 25 and 27

AMED

1. exp Exercise/
2. exp Exercise therapy/
3. exp Rehabilitation/
4. exp physical therapy speciality/
5. exercise.mp.
6. rehabilitation.mp.
7. physical therapy.mp.
8. physiotherapy.mp.
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. exp Knee/
11. knee.mp.
12. exp Knee joint/
13. 10 or 11 or 12
14. exp Arthroplasty/
15. 13 and 14
16. exp Arthroplasty replacement knee/
17. exp Knee prosthesis/

18. knee replacement.mp.
19. knee arthroplast*.mp.
20. 15 or 16 or 17 or 18 or 19
21. exp Clinical trials/
22. exp Randomized controlled trials/
23. clinical trial*.mp.
24. rct.mp.
25. random.mp.
26. double blind*.mp.
27. single blind*.mp.
28. randomi?ed controlled trial*.mp.
29. 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28
30. 9 and 20 and 29

CINAHL

1. Exercise (MH+)
2. Rehabilitation (MH+)
3. Therapeutic Exercise (MH+)
4. Physical therapy (MH+)
5. Exercise (TI or AB)
6. Exercise therapy (TI or AB)
7. Rehabilitation (TI or AB)
8. Physical therap# (TI or AB)
9. Physiotherap# (TI or AB)
10. #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10
11. Knee (MM)
12. Knee joint (MH+)
13. Knee (TI or AB)
14. S11 OR S12 OR S13
15. Arthroplasty (MH+)
16. Arthroplast# (TI or AB)
17. #15 OR #16
18. #14 AND 17
19. Arthroplasty, Replacement, Knee (MH+)
20. Knee replacement (TI or AB)
21. Knee arthroplast# (TI or AB)
22. #18 OR #19 OR #S20 OR #21
23. Randomized controlled trials (MH+)
24. Clinical trials (MH+)
25. Randomi?ed controlled trial* (TI or AB)
26. Clinical trial*# (TI or AB)
27. Clinical study (TI or AB)
28. Rct (TI or AB)
29. Random (TI or AB)
30. #23 OR #24 OR #25 #26
31. #10 AND #22 AND #27

SPORTDiscus

1. Exercise (DE explode)
2. Exercise therapy (DE explode)
3. Physical therapy (DE explode)
4. Rehabilitation (DE explode)
5. Exercise
6. Exercise therap* (TI or AB)
7. Physical therap* (TI or AB)
8. Rehabilitation (TI or AB)
9. Physiotherap* (TI or AB)
10. S1 or S2 or S3 or S4 or S5 or S6 or S7 or S8 or S9
11. Knee (DE explode)
12. Knee (TI or AB)
13. S11 or S12
14. Arthroplasty (DE explode)
15. Arthroplast* (TI or AB)
16. S14 or S5
17. S13 and S16
18. Total knee replacement (DE explode)
19. Total knee replacement (TI or AB)
20. Total knee arthroplast* (TI or AB)
21. TKR (TI or AB)
22. TKA (TI or AB)
23. Knee Replacement (TI or AB)
24. Knee joint replacement (TI or AB)
25. 17 or 18 or 19 or 20 or 21 or 22 or 23 or S24
26. Randomized controlled trial* (DE)
27. Clinical trial* (DE)
28. Randomi?ed controlled trial* (TI or AB)
29. Randomi?ed control trial* (TI or AB)
30. Randomi?ed clinical trial* (TI or AB)
31. Clinical trial* (TI or AB)
32. Random (TI or AB)
33. RCT (TI or AB)
34. S26 or S27 or S28 R S29 OR S30 R S31 OR S32 OR S33
35. S10 and S25 and S34

COCHRANE LIBRARY

1. Exercise (MESH EXP)
2. Rehabilitation (MESH EXP)
3. Physical Therapy Modalities (MESH EXP)
4. Exercise therapy (MESH EXP)
5. Exercise (TI, AB, KEY)
6. Rehabilitation (TI, AB, KEY)

7. Physical therap* (TI, AB, KEY)
8. Physiotherap* (TI, AB, KEY)
9. exercise therap* (TI, AB, KEY)
10. #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9
11. Knee (MESH EXP)
12. Knee joint (MESH EXP)
13. Knee (TI, AB, KEY)
14. #11 or #12 or #13
15. Arthroplasty, replacement, knee (MESH EXP)
16. Knee replacement (TI, AB, KEY)
17. Knee replacement arthroplast* (TI, AB, KEY)
18. Total knee replacement (TI, AB, KEY)
19. Knee arthroplasty* (TI, AB, KEY)
20. Arthroplasty (MESH EXP)
21. Arthroplast* (TI, AB, KEY)
22. #20 OR # 21
23. #22 AND #14
24. #15 OR #16 or #17 #18 #19 #23
25. Clinical trial (MESH EXP)
26. Randomized controlled trial* (MESH EXP)
27. Clinical trial* (TI, AB, KEY)
28. Randomi?ed controlled trial* (TI, AB, KEY)
29. Randomi?ed control trial* (TI, AB, KEY)
30. Random (TI, AB, KEY)
31. RCT (TI, AB, KEY)
32. #25 OR #26 OR #27 OR #28 OR 29 OR 30 OR 31
33. #10 AND #24 AND #32

1.11 Appendix B – Inclusion Criteria Table

Table 1. Inclusion criteria for title, abstract and full-text screening	
Reviewer: **First author:** **Year:**	
Participants: Adults (18 years or older)	
Type of Study: Randomized Control Trial	
Language: Any	
Intervention: Exercise-based intervention (Adult population (18 years or older) that includes more than one session of physical exercises such as strengthening, flexibility, and/or aerobic activities.	

1.12 Appendix C – CERT Items and Explanations[11]

Item Number	Explanation
Item 1: Detailed description of the type of exercise equipment (e.g., weights, exercise equipment such as machines, treadmill, bicycle ergometer, etc.).	• Type and brand of exercise machines, type of weights (e.g., handheld dumbbells, cuff weights, olympic bar), elastic bands. • Specific instructions regarding the setup of exercise equipment (e.g., saddle height of an ergometer, placement of elastic resistance bands).
Item 2: Detailed description of the qualifications, teaching/ supervising expertise and/or training undertaken by the exercise instructor.	• Specify who provides and/or teaches and/or supervises the exercise programme. • Considerations: the number of instructors, their professional or disciplinary background (physiotherapist, exercise physiologist, personal trainer, gym instructor, etc.); duration of experience with exercise instruction/ supervision; verification of skills; provision of any programme-specific training; usual practice or per specific recruitment.
Item 3: Describe whether exercises are performed individually or in a group.	• One person at a time ('one-on-one'), or to a group (the group's size). • If this delivery was face-to-face or by distance (telerehabilitation, DVD, booklet, etc.) • Key delivery features: e.g. amount of supervisory 'intensity', 'group effects', the number of staff or type of facility required, possible psychosocial benefits, social interaction, etc.
Item 4: Describe whether exercises are supervised or unsupervised and how they are delivered.	• Instructor that observes exercise performance, corrects exercise technique, ensures the participant has the correct movement pattern (exercise 'form'), provides guidance, provides motivation and feedback and/or modifies exercises as appropriate/required or whether exercise is undertaken in an environment where the participant has no guidance or feedback. • Explain mode of supervision (e.g., face-to-face, follow-up phone calls, telemedicine, electronic prompts and devices such as email or SMS).
Item 5: Detailed description of how adherence to exercise is measured and reported.	• A valid and reliable assessment of exercise performance
Item 6: Detailed description of motivation strategies.	• Includes: goal setting, goal achievement, engagement in shared decision-making, acknowledgement of success, graphic, visual or verbal cues and/or feed- back, motivational interviewing, preferred environments and problem-solving advice.

Item 7(a): Detailed description of the decision rule(s) for determining exercise progression. **Item 7(b):** Detailed description of how the exercise programme is progressed (e.g., numbers of repetitions, resistance, load, speed, etc.).	• How the authors determined progression of exercises • Description of progressive gradual increase in volume (repetitions multiplied by resistance), intensity (percentage of maximum capacity), frequency or time.
Item 8: Detailed description of each exercise to enable replication (e.g., photographs, illustrations, video, Smartphone app, website, protocol paper, etc.).	• Explicit information about each exercise (e.g. starting position, that is, lying, sitting, standing; targeted muscle groups; position in which the exercise is performed; and range of movement).
Item 9: Detailed description of any home programme component (e.g., other exercises, stretching, functional tasks, etc.).	• Explicit description of the content of the home program and a measure of adherence such as self-report by the participant.
Item 10: Describe whether there are any non-exercise components (e.g., training or information materials, education, cognitive–behavioural therapy, massage, etc.).	• A description of the non-exercise component (e.g. written instructions, education materials or training manuals)
Item 11: Describe the type and number of adverse events that occur during exercise.	• Exercise-specific adverse events (e.g. whether it is advisable to exercise into pain; which pain aggravations are acceptable; how much pain is acceptable; what is regarded as 'normal' muscle soreness after exercise; how to manage post exercise muscle soreness; decision rules for when to modify or cease exercise due to symptom aggravation or pain).
Item 12: Describe the setting in which the exercises are performed.	• A description of the setting in which an exercise programme occurred.
Item 13: Detailed description of the exercise intervention including, but not limited to, number of exercise repetitions/ sets/sessions, session duration, programme duration, etc.	• The dosage should include: the exercise mode, the resistance or load, the muscle contraction mode, the relative time in each contraction type (concentric, isometric and eccentric phases), rest intervals (between repetitions or sets), exercise speed and sequence, the number of exercises, repetitions and sets of each exercise, session duration, sessions per day and per week, the duration of an evaluated programme, and the number of sessions if applicable.
Item 14(a): Describe whether the exercises are generic (one size fits all) or tailored **Item 14(b):** Detailed description of how exercises are tailored to the individual.	• Exercise programmes may be a predetermined and standardised set of exercises or tailored to the individual for any reason. • A rationale, description and guide or system of decision rules for the tailoring, as well as implementation time points, should be provided. This will facilitate those planning to use the programme to know exactly how to

	administer it (e.g. the 'intensity of the exercises was adapted to patient's pain level).
Item 15: Describe the decision rule for determining the starting level at which people start an exercise programme (e.g., beginner, intermediate, advanced, etc.).	• Decision rules for determining the level at which participants start an exercise programme so that they are neither underexercised or overexercised.
Item 16(a): Describe how adherence or fidelity to the exercise intervention is assessed/measured.	• Fidelity refers to the extent to which the exercise intervention occurred as the investigators intended it. • A description should be given of who delivered the intervention and how it was delivered. • Any strategies employed to improve or guarantee fidelity should also be reported, such as training, standardised therapist treatment notes or direct observation by a researcher to document adherence to the protocol.
Item 16(b): Describe the extent to which the intervention was delivered as planned.	• Report reasons why the intervention did not occur as planned. • Provide an explanation for the effect or lack of effect of an intervention

1.13 Appendix D – List of Excluded Studies

Reference	Reason for Exclusion
1. Actrn. The effect of group work-circuit and individualised physiotherapy treatments for orthopaedic patients: a randomised control trial. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=ACTRN12613001196730. 2013.	Duplicate
2. Actrn. The STEP study: a Pragmatic, randomized, controlled trial comparing two post operative management pathways in knee or hip replacement surgery. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=ACTRN12616000696493. 2016.	Study not published yet
3. Actrn. A pedaling-based three exercise protocol compared to a non-pedaling ten exercise protocol for immediate post-operative rehabilitation after total knee replacement in a randomized controlled trial. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=ACTRN12617000647336. 2017.	Study not published yet
4. Actrn. Face-to-face physiotherapy compared to a supported home exercise program for the management of musculoskeletal conditions: the REFORM trial. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=ACTRN12619000065190. 2019.	Study not published yet
5. Alnahdi AH, Zeni JA, Snyder-Mackler L. The effect of progressive strengthening programs on function and gait mechanics after unilateral total knee arthroplasty: a randomized clinical trial. Osteoarthritis and Cartilage. 2012;20:S104-S5.	Abstract/Title Only
6. Alobaidi A, Mahmood A. Effect of continuous passive motion (CPM) exercises on post total knee arthroplasty (TKA) rehabilitation. Osteoporosis International. 2018;29 (1 Supplement 1):S162-S3.	Abstract/Title Only
7. Andersen HH. Technological assisted rehabilitation following total knee joint replacement. a randomised controlled non-inferiority trial. Annals of the Rheumatic Diseases. 2018;77:1823-4.	Abstract/Title Only
8. Atabaki S, Farahani MA, Haghani S. Effect of rehabilitation education on pain, knee stiffness and performance difficulty in patients undergoing knee replacement surgery: a randomized clinical trial. Journal of Acute Disease. 2019;8(6):233-8.	Wrong Intervention
9. Bade MJ, Christensen JC, Zeni JA, Christiansen CL, Dayton MR, Forster JE, et al. Movement pattern biofeedback training after total knee arthroplasty: Randomized clinical trial protocol. Contemporary Clinical Trials. 2020;91 (no pagination).	Wrong Study Design
10. Bandholm T, Kehlet H. Physiotherapy Exercise After Fast-Track Total Hip and Knee Arthroplasty: Time for Reconsideration?...Liebs TR, Herzberg W, Ruther W, Haasters J, Russlies M, Hassenpflug J. Multicenter randomized controlled trial comparing early versus late aquatic therapy after total hip or	Wrong Study Design

knee arthroplasty. Arch Phys Med Rehabil 2012;93:192-9. Archives of Physical Medicine & Rehabilitation. 2012;93(7):1292-4.	
11. Beaupre L, Davies D, Jones C, Cinats J. Exercise combined with continuous passive motion or slider board therapy compared with exercise only: a randomized controlled trial of patients following total knee arthroplasty. Physical therapy. 2001;81(4):1029-37.	Includes Passive Motion
12. Bellelli G, Buccino G, Garrah M, Padovani A, Trabucchi M. Action observation treatment in the rehabilitation of post-surgical orthopaedic patients: a randomised controlled trial. European Journal of Neurology. 2009;16(S3):308-.	Abstract/Title Only
13. Bethge M, Bartel S, Streibelt M, Lassahn C, Thren K. Improved outcome quality following total knee and hip arthroplasty in an integrated care setting: results of a controlled study]. Rehabilitation. 2011;50(2):86-93.	Wrong Intervention
14. Bettger J, Green CL, Holmes DN, Chokshi A, Mather RC, III, Hoch BT, et al. Effects of Virtual Exercise Rehabilitation In-Home Therapy Compared with Traditional Care After Total Knee Arthroplasty VERITAS, a Randomized Controlled Trial. Journal of Bone and Joint Surgery-American Volume. 2020;102(2):101-9.	Duplicate
15. Boissy P, Tousignant M, Moffet H, Nadeau S, Briere S, Merette C, et al. Conditions of Use, Reliability, and Quality of Audio/Video-Mediated Communications During In-Home Rehabilitation Teletreatment for Postknee Arthroplasty. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2016;22(8):637-49.	Wrong Study Design
16. Borgwardt L, Zerahn B, Bliddal H, Christiansen C, Sylvest J, Borgwardt A. Similar clinical outcome after unicompartmental knee arthroplasty using a conventional or accelerated care program: a randomized, controlled study of 40 patients. Acta Orthopaedica. 2009;80(3):334-7.	Wrong Intervention
17. Buhagiar MA, Naylor JM, Harris IA, Xuan W, Kohler F, Wright R, et al. Effect of Inpatient Rehabilitation vs a Monitored Home-Based Program on Mobility in Patients With Total Knee Arthroplasty The HIHO Randomized Clinical Trial. Jama-Journal of the American Medical Association. 2017;317(10):1037-46.	Duplicate
18. Cawthorne D, March L, Parker D, Coolican M, Negus J. TKR-power-patient outcomes using wii enhanced rehabilitation after a total knee replacement. Physiotherapy (united kingdom). 2015;101:eS204-eS5.	Abstract/Title Only
19. Chen G, Gu RX, Xu DD. The application of electroacupuncture to postoperative rehabilitation of total knee replacement. Zhongguo zhen jiu [Chinese acupuncture & moxibustion]. 2012;32(4):309-12.	Includes Passive Motion
20. Chi CI. Effects of joint mobilization techniques in primary total knee arthroplasty: a single-blind randomized controlled trial. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=ChiCTR-IOR-16009192. 2016.	Wrong Study Design
21. Chow TPY, Ng GYF. Active, passive and proprioceptive neuromuscular facilitation stretching are comparable in improving the knee flexion range in people with total knee replacement: a randomized controlled trial. Clinical rehabilitation. 2010;24(10):911-8.	Includes Passive Motion

22. Christiansen M, Thoma L, Master H, Mathews D, Schmitt L, Ziegler M, et al. 1-year outcomes from a novel physical therapist-administered physical activity intervention after total knee replacement: a pilot study. Arthritis and Rheumatology. 2018;70:439-40.	Abstract/Title Only
23. Christiansen MB, Thoma LM, Master H, Mathews D, Schmitt LA, White DK. Preliminary findings of a novel physical therapist administered physical activity intervention after total knee replacement. Osteoarthritis and Cartilage. 2018;26 (Supplement 1):S334.	Abstract/Title Only
24. Christiansen MB, Thoma LM, Master H, Voinier D, Schmitt LA, Ziegler ML, et al. The feasibility and preliminary outcomes of a physical therapist-administered physical activity intervention after total knee replacement. Arthritis care & research. 2019.	Abstract/Title Only
25. Chughtai M, Newman JM, Sultan AA, Khlopas A, Navarro SM, Bhave A, et al. The Role of Virtual Rehabilitation in Total Knee and Hip Arthroplasty. Surgical technology international. 2018;32:299-305.	Wrong Study Design
26. Codine P, Dellemme Y, Denis-Laroque F, Herisson C. The use of low velocity submaximal eccentric contractions of the hamstring for recovery of full extension after total knee replacement: a randomized controlled study. Isokinetics & Exercise Science. 2004;12(3):215-8.	Includes Passive Motion
27. Ctri. EFFECTIVENESS OF TELEPHONICALLY REINFORCED HOME EXERCISE PROGRAM FOLLOWING TOTAL KNEE REPLACEMENT: - AN ASSESSOR BLINDED RANDOMIZED CONTROLLED TRIAL. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=CTRI/2018/09/015578. 2018.	Study not published yet
28. Dan M, Boca I-C. BENEFICIILE KINETOTERAPIEI ÎN PROGRAMUL DE RECUPERARE FUNCŢIONALĂ DUPĂ ARTROPLASTIA TOTALĂ DE GENUNCHI. Romanian Journal of Physical Therapy / Revista Romana de Kinetoterapie. 2013;19(31):23-8.	Unable to Find
29. Debbi EM, Bernfeld B, Soudry M, Salai M, Laufer Y, Herman A, et al. A biomechanical therapy program for patients after total knee arthroplasty - A randomized controlled trial (preliminary results). Osteoarthritis and Cartilage. 2014;22:S82.	Abstract/Title Only
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36. Fung V, Ho A, Shaffer J, Gomez M. Poster 106: The Utilization of Nintendo Wii Fit in the Rehabilitation of Outpatients Following Total Knee Replacements: Preliminary Results of a Randomized Controlled Trial. Archives of Physical Medicine & Rehabilitation. 2010;91(10):e37-e.	Abstract/Title Only
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45. Hershko E, Tauber C, Carmeli E. Biofeedback versus physiotherapy in patients with partial weight-bearing. American journal of orthopedics (Belle Mead, NJ). 2008;37(5):E92-6.	Wrong Patient Population
46. Hsu WH, Hsu WB, Shen WJ, Lin ZR, Chang SH, Hsu RWW. Twenty-four-week hospital-based progressive resistance training on functional recovery in female patients post total knee arthroplasty. Knee. 2019;26(3):729-36.	Wrong Study Design
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50. Isrctn. Comparison of post-discharge physiotherapy versus usual care following total knee replacement: a randomised clinical trial. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=ISRCTN07624314. 2004.	Duplicate
51. Isrctn. Activity orientated rehabilitation following knee arthroplasty: feasibility study. http://wwwwhoint/trialsearch/Trial2aspx?TrialID=ISRCTN13579789. 2016.	Study not published yet
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54. Jayabalan P, Almeida GJ, Wan H, Sowa GA, Piva SR. THE INVESTIGATION OF CANDIDATE BIOMARKERS TO ASSESS THE EFFICACY OF A NOVEL REHABILITATION REGIMEN FOLLOWING TOTAL KNEE ARTHROPLASTY: A PILOT STUDY. American journal of physical medicine & rehabilitation. 2014:a72-a3.	Abstract/Title Only
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A single-blind, randomised controlled trial. Arthritis and Rheumatism. 2011;63(12):4043-.	
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59. Kuiken TA, Amir H, Scheidt RA. Computerized biofeedback knee goniometer: Acceptance and effect on exercise behavior in post-total knee arthroplasty rehabilitation. Archives of Physical Medicine and Rehabilitation. 2004;85(6):1026-30.	Wrong Study Design
60. Labraca NS, Castro-Sánchez AM, Matántilde, rdn-Penarrocha GA, Arroyo-Morales M, Moreno-Lorenzo C. Starting Rehabilitation within 24 Hours After Total Knee Arthroplasty Was Better Than Delaying to within 48 to 72 Hours. Journal of Bone & Joint Surgery, American Volume. 2012;94(4):366-.	Abstract/Title Only
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65. Liao CD, Tsauo JY, Chiu YS, Ku JW, Huang SW, Liou TH. Effects of elastic resistance exercise after total knee replacement on muscle mass and physical function in elderly women with osteoarthritis: a randomized controlled trial. American journal of physical medicine & rehabilitation. 2019.	Duplicate
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67. Liu PL, Li L, Zhang YK, Li M, Kane K, Wang YH, et al. A comparison of two rehabilitation protocols after simultaneous bilateral total knee arthroplasty: a controlled, randomized study. Journal of International Medical Research. 2009;37(3):746-56.	Includes Passive Motion

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74. Nct. Early Progressive Strength Training to Patients With Unicompartmental Knee Replacement. https://clinicaltrialsgov/show/NCT01345825. 2011.	Study not published yet
75. Nct. The Difference Between Rehabilitation With or Without Strength Training After Total Knee Replacement. https://clinicaltrialsgov/show/NCT01351831. 2011.	Duplicate
76. Nct. The Utilization of Nintendo Wii™ in Outpatient Rehabilitation Following Total Knee Replacement. https://clinicaltrialsgov/show/NCT01548664. 2012.	Duplicate
77. Nct. The HIHO Study: hospital Inpatient vs Home Rehabilitation After Total Knee Replacement. https://clinicaltrialsgov/show/NCT01583153. 2012.	Duplicate
78. Nct. Independent Exercise Compared With Formal Rehabilitation Following Primary Total Knee Replacement. https://clinicaltrialsgov/show/NCT01826305. 2013.	Study not published yet
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80. Nct. Comparison of Treatments Following Total Knee Replacement. https://clinicaltrialsgov/show/NCT02237911. 2014.	Study not published yet
81. Nct. Virtual vs. Traditional Physical Therapy Following Total Knee Replacement. https://clinicaltrialsgov/show/NCT02914210. 2016.	Study not published yet
82. Nct. Rehabilitation for Total Knee Replacement: a Novel Biofeedback System Versus Conventional Home-based Rehabilitation. https://clinicaltrialsgov/show/NCT03047252. 2017.	Duplicate
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86. Nct. Effects of Exercise and Education in Patients With Chronic Pain After Total Knee Replacement. https://clinicaltrialsgov/show/NCT03886259. 2019.	Duplicate
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1.14 Appendix E – CERT Analysis

Author	Intervention	Equipment	Qualifications	Individual or Group	Supervised or Unsupervised	Adherence Measurements	Motivation	Decision for Progression	Description of Progression	Exercise Description	Home Component	Non-exercise	Adverse Event	Setting	Dosage	Generic or Tailored	Description of Tailoring	Start Decision	Planned Delivery	Adherence/Fidelity
Akbaba et al. (2016)	Less Supervision	+	?	+	+	?	+	+	+	+	+	+	+	+	?	+	?	?	?	?
	Healthy Control	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Physical Therapy	+	?	+	+	?	+	+	+	+	+	+	+	+	+	+	?	?	?	?
Alghadir et al. (2016)	Pre-and-Post Exercise	?	?	+	+	?	?	?	?	?	+	+	?	+	?	+	N/A	?	?	?
	Post-Exercise Only	?	?	+	+	?	?	?	?	?	+	+	?	+	?	+	N/A	?	?	?
Anneli et al. (2017)	Exercise Group	+	?	+	+	?	+	+	+	+	+	+	+	+	+	+	N/A	?	?	+
	Control	?	?	+	+	?	+	+		?	+	+	?	+	?	+	N/A	?	?	+
Aprile et al. (2011)	Individual followed by Group Exercise	?	?	+	+	?	?	?	?	?	?	?	?	+	?	+	N/A	+	?	?
	Group followed by Individual Exercise	?	?	+	+	?	?	?	?	?	?	?	?	+	?	+	N/A	+	?	?
Artz et al. (2017)	Physiotherapy intervention	?	?	+	+	?	?	?	?	?	+	+	?	+	?	+	N/A	?	?	?
	Usual Care	?	?	+	+	?	?	?	?	?	+	+	?	+	?	+	N/A	?	?	?
Avramidis et al. (2011)	Electric Muscle Stimulation	?	+	+	+	?	?	?	?	+	?	+	?	+	+	+	N/A	+	?	+
	Usual Care	?	?	+	+	?	?	?	?	+	?	?	?	+	?	+	N/A	+	?	+
Bade et al. (2017)	High-Intensity Exercise	?	?	+	+	+	+	+	+	+	+	+	+	+	+	+	N/A	+	+	+
	Low-Intensity Exeercise	+	+	+	+	+	?	+	+	+	+	+	+	+	+	+	N/A	+	+	+
Bellelli et al. (2010)	Standard + Video with motor exercises	?	?	+	+	?	?	+	+	+	?	?	?	+	?	+	N/A	+	?	?
	Standard + Video without motor	?	?	+	+	?	?	+	+	+	?	+	?	+	?	+	N/A	+	?	?
	Leg-Press	+	?	+	+	+	?	+	?	+	?	?	+	+	+	+	N/A	?	+	?

Bily et al. (2016)	Functional Physiotherapy	+	?	+	+	+	?	+	?	+	?	+	+	+	+	+	?	+	+	?
Bini et al. (2017)	Asynchronous Video	?	?	+	+	+	?	+	+	?	+	+	?	+	+	+	?	+	?	+
	Standard Care	?	?	+	+	?	?	?	?	?	+	?	?	+	?	?	?	+	?	+
Bohl et al. (2019)	PT 0-Day Post-op	?	?	+	+	?	?	+	?	?	?	?	?	+	?	+	+	+	?	?
	PT 1-Day Post Op		?	+	+	?	?	?	?	?	?	?	?	+	?	+	+	+	?	?
Brandes et al. (2018)	Standard Care + Activity Counselling	?	+	+	+	+	+	+	?	?	?	+	?	?	+	+	+	+	+	+
	Standard Care	?	??	+	+	+	?	?	?	?	?	+	?	+	+	+	+	+	+	+
Bruun-Olsen et al. (2013)	Walking Skill	+	?	+	+	?	+	+	?	+	?	?	?	+	?	+	?	+	?	?
	Standard Care	?	?	+	+	?	?	?	?	?	?	?	?	+	?	+	?	+	?	?
Bugbee et al. (2016)	AlterG	+	+	+	+	?	?	+	?	+	+	+	+	+	+	+	+	+	?	+
	Land-Based	+	+	+	+	?	?	+	?	?	+	+	+	+	+	+	+	+	?	+
Buhaglar et al. (2017)	Inpatient with Home Program	+	?	+	+	+	+	+	?	+	+	?	+	+	?	+	N/A	+	+	?
	Home Program	+	?	+	+	+	+	+	?	+	+	?	+	+	+	+	N/A	+	+	?
	Observational Group	+	?	+	+	+	+	+	?	+	+	?	+	+	+	+	N/A	+	+	?
Bulthuis et al. (2007)	Intensive Exercise	?	?	+	+	?	?	+	+	?	?	+	?	+	?	+	+	+	?	?
	Standard Care	?	?	?	?	?	?	?	?	?	?	+	?	+	?	?	?	?	?	?
Cai et al. (2017)	Cognitive Behavioural Intervention	?	?	+	+	?	?	+	+	+	?	+	+	+	+	+	?	+	?	+
	Control	?	+	+	+	?	?	+	+	+	?	+	+	+	+	+	?	+	?	+
Cai et al. (2018)	Cognitive Behavioural Intervention	?	?	+	+	?	?	+	+	?	?	+	?	+	?	+	?	+	?	?
	Standard Care	?	?	+	+	?	?	?	?	?	?	+	?	?	?	+	N/A	?	?	?
Campbell et al. (2019)	SMS bot	?	?	+	+	+	+	?	?	?	+	+	+	+	?	+	N/A	?	+	?
	Traditional Education	?	?	+	+	+	+	?	?	?	+	+	+	+	?	+	N/A	?	+	?
Chen et al. (2017)	EMG Biofeedback	+	?	+	+	?	?	+	+	+	?	?	?	+	?	+	?	+	?	?
	Standard Care	?	?	+	+	?	?	+	+	+	?	?	?	+	+	+	N/A	?	?	?
	Joint Rehabilitation	+	?	+	+	?	?	+	+	+	?	?	?	+	?	+	N/A	+	?	?
Chen et al. (2016)	Telephone Call + Exercise	?	+	+	+	+	+	+	?	?	+	?	?	+	?	+	N/A	+	+	+
	Exercise Only	?	+	+	+	+	+	+	?	?	+	?	?	+	?	+	N/A	+	+	+
Christiansen et al. (2015)	Weight-Bearing Biofeedback	+	?	+	+	+	+	+	+	?	+	+	?	+	?	+	?	+	+	?
	Standard Care	+	?	+	+	+	+	+	+	?	+	+	?	+	?	+	?	+	+	?

Christiansen et al. (2020)	Fitbit/Step Goals	+	?	+	+	+	+	+	+	+	+	+	+	+	?	+	N/A	?	+	+
	Standard Care	+	?	+	+	+	+	+	+	+	+	+	+	+	?	+	N/A	?	+	+
De Fine et al. (2017)	High-flexion group	?	?	+	+	?	?	?	?	?	?	+	+	+	?	?	?	?	?	?
	Mid-flexion group	?	?	+	?	?	?	?	?	?	?	+	+	+	?	?	?	?	?	?
Debbi et al. (2019)	Biomechanical device	+	?	+	+	?	?	+	+	?	+	?	+	+	?	?	?	+	+	?
	Sham Device	+	?	+	+	?	?	+	+	?	+	?	+	+	?	?	?	+	+	?
Demircioglu et al. (2015)	NMES	?	?	+	+	?	?	?	?	?	+	+	+	+	?	+	N/A	+	?	?
	Exercise Group	?	?	+	+	?	?	?	?	?	+	+	+	+	?	+	N/A	+	?	?
den Hertog et al. (2012)	Fast-Track	?	?	+	+	?	+	?	?	?	?	?	+	+	?	+	N/A	+	?	?
	Standard Care	?	?	+	+	?	?	+	+	?	?	+	+	+	?	+	?	+	?	?
Doerfler et al. (2016)	High-Velocity Exercise	+	?	+	+	?	+	+	+	+	+	+	?	+	?	+	N/A	+	?	?
	Slow-Velocity Exercise	+	?	+	+	?	+	+	+	+	+	+	?	+	+	+	N/A	+	?	?
Donec & Krisciunas (2014)	Standard Care + KTape	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?
	Standard Care	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?
Ebert et al. (2013)	Manual Lymphatic Drainage	?	?	+	+	?	?	?	?	+	?	+	?	+	?	+	N/A	+	?	?
	Control	?	?	+	+	?	?	?	?	+	?	+	?	+	?	+	N/A	+	?	?
Eichler et al. (2019)	Telerehab	?	?	+	+	+	+	?	?	?	+	?	?	+	?	+	?	?	+	+
	Standard Care	?	?	?	+	?	?	?	?	?	?	?	?	+	?	?	?	?	?	+
Eisermann et al. (2004)	Computer-aided Training	+	?	+	+	?	+	?	?	?	?	+	+	+	?	+	+	?	?	?
	Standard Care	+	?	+	+	?	?	?	?	?	?	+	+	+	?	+	N/A	?	?	?
Evgeniadis et al. (2008)	Pre-op Only	+	?	+	+	?	?	+	+	?	+	?	?	+	?	+	?	+	?	?
	No Treatment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Post-op only	+	?	+	+	?	?	+	?	?	+	?	?	+	?	+	?	+	?	?
Ficklscherer et al. (2016)	Standard Care + Nintendo Wii	+	?	+	+	?	+	?	?	?	?	+	?	+	?	?	?	?	?	?
	Standard Care	?	?	?	?	?	?	?	?	?	?	+	?	?	?	?	?	?	?	?
Fleischman et al. (2019)	Web-based PT	?	?	+	+	?	?	+	?	?	+	?	+	+	?	+	N/A	+	?	?
	Outpatient PT	?	?	?	+	?	?	?	?	?	+	?	+	+	?	?	?	?	?	?
	Home Exercise	?	?	+	+	?	?	+	?	?	+	?	+	+	?	+	N/A	+	?	?
Fortuno Godes et al. (2010)	PT + Physiologic Life Rhythm	?	?	?	?	?	?	?	?	+	?	+	?	?	?	?	?	?	?	?

	Physical Therapy	?	?	?	?	?	?	?	?	+	?	?	+	?	?	?	?	?	?	?
Fransen et al. (2017)	Group Exercise	+	?	+	+	+	?	+	+	+	+	?	+	+	+	+	N/A	+	+	+
	Standard Care	+	?	?	?	?	?	?	?	?	?	?	+	+	?	?	?	?	?	+
Frost et al. (2002)	Functional Training	+	?	+	+	?	?	+	+	+	+	+	?	+	?	+	N/A	?	?	?
	Standard Care	+	?	+	+	?	?	?	?	+	+	?	?	+	?	+	N/A	?	?	?
Fung et al. (2012)	Wii Fit Gaming	+	?	+	+	?	?	+	?	+	?	?	?	+	?	+	N/A	+	?	?
	Lower Extremity Exercise		?	?	+	?	?	+	+	+	?	?	?	+	?	+	N/A	?	?	?
Gianola et al. (2020)	Virtual Reality	+	?	+	+	?	?	?	?	+	?	?	?	+	+	+	N/A	?	?	?
	Standard Care	+	?	+	+	?	?	?	?	+	?	?	?	+	?	+	N/A	?	?	?
Giaquinto et al. (2010)	Hydrotherapy	?	?	?	+	?	?	?	?	?	?	+	+	+	?	+	N/A	?	?	?
	Land-Based	+	?	?	+	?	?	?	?	?	?	+	+	+	?	+	N/A	?	?	?
Han et al. (2015)	Home Exercise	+	?	+	+	?	+	+	+	?	+	+	+	+	?	+	N/A	+	?	?
	Standard Care	?	?	+	+	?	?	?	?	?	?	?	+	+	?	?	?	+	?	?
Hardt et al. (2018)	Standard Care + App-Based Feedback	?	?	+	+	?	?	?	?	+	?	+	?	+	?	+	?	+	?	?
	Standard Care	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?
Harikesavan et al. (2017)	Standard Care + Hip Strengthening	+	?	+	+	?	+	+	+	+	+	+	?	+	+	+	N/A	?	?	?
	Standard Care	+	?	+	+	?	+	+	+	+	+	+	?	+	+	+	N/A	?	?	?
Harmer et al. (2009)	Water-Based	?	?	+	+	+	+	?	?	?	+	?	+	+	?	+	N/A	?	+	?
	Land-Based	+	?	+	+	+	+	?	?	?	+	?	+	+	?	+	N/A	?	+	?
Hepperger et al. (2017)	Guided Hiking	+	?	+	+	+	?	+	+	+	?	?	?	+	?	+	N/A	?	+	?
	Continue with ADL's	?	N/A	+	+	?	?	N/A	N/A	?	+	?	?	+	?	?	?	N/A	?	?
Hoorntje et al. (2020)	Goal Attainment Scaling	?	?	+	+	+	?	?	?	+	?	?	?	?	?	+	?	?	+	?
	Standard Care	?	?	?	+	0	?	?	?	?	?	?	?	+	?	+	N/A	?	+	?
Husby et al. (2018)	Maximal Strength Training	+	?	+	+	?	?	+	+	+	?	+	?	+	+	+	N/A	?	?	?
	Standard Care	?	?	+	+	?	+	?	?	?	+	+	?	+	?	?	N/A	?	?	?
Iwakiri et al. (2020)	ROM Day 1	?	?	+	+	?	?	?	?	?	?	?	+	+	?	+	N/A	?	?	?
	ROM Day 7	?	?	+	+	?	?	?	?	?	?	?	+	+	?	+	N/A	?	?	?
Jakobsen et al. (2014)	Physical Strength Training	+	+	+	+	?	?	+	+	+	+	+	+	+	+	+	N/A	?	?	?
	Standard Care	+	+	+	+	?	?	+	+	+	+	+	+	+	+	+	N/A	?	?	?
Jin et al. (2018)	Virtual Reality	+	?	+	+	?	+	?	?	?	?	+	?	+	?	+	N/A	?	?	?

	Standard Care	?	?	+	+	?	?	?	?	?	?	+	?	+	+	+	N/A	?	?	?
Jogi et al. (2015)	Standard Care + Balance	+	?	+	+	?	?	+	?	+	+	+	?	+	+	+	N/A	+	+	?
	Standard Care	+	?	+	+	?	?	+	?	+	+	+	?	+	?	+	N/A	+	+	?
Johnson et al. (2010)	Whole Body Vibration	+	?	+	+	+	?	+	+	+	+	+	+	+	+	+	N/A	+	+	?
	Progressive Resistance Training	+	?	+	+	+	?	+	+	+	+	+	+	+	+	+	N/A	+	+	?
Ju et al. (2019)	Strength Training + Moxibustion Therapy	?	?	?	+	?	?	?	?	+	?	+	+	?	+	+	N/A	?	?	?
	Strength Training	?	?	?	+	?	?	?	?	+	?	?	+	?	+	+	N/A	?	?	?
Karaman et al. (2017)	Pilates	+	?	+	+	?	+	?	?	+	+	+	?	+	?	+	N/A	?	?	?
	Standard Care	?	?	+	+	?	+	+	+	+	+	+	?	+	+	+	N/A	?	?	?
Kauppila et al. (2010)	Multidisciplinary Rehab	+	?	+	+	?	+	+	+	+	+	+	+	+	?	+	N/A	+	?	+
	Standard Care	?	?	?	+	?	?	?	?	+	+	+	?	+	?	+	?	?	?	+
Kelly et al. (2016)	High Velocity	+	?	+	+	+	?	+	+	+	+	+	+	+	+	+	N/A	+	+	?
	Low Velocity	+	?	+	+	+	?	+	+	+	+	+	+	+	+	+	N/A	+	+	?
Kramer et al. (2003)	Clinic-Based	?	?	+	+	+	?	?	+	?	+	+	?	+	+	+	N/A	+	+	?
	Home Based	?	?	+	+	+	+	?	?	?	+	+	?	+	?	+	N/A	+	+	?
Lee et al. (2020)	Dynamic Exercise Visual Feedback	?	?	+	+	?	?	+	+	+	?	?	?	+	+	+	N/A	?	?	?
	Dynamic Exercise	?	?	+	+	?	?	+	+	+	?	?	?	+	+	+	N/A	?	?	?
Lenguerrand et al. (2019)	Physical Therapy	+	?	+	+	+	+	+	+	+	+	?	+	+	+	+	+	?	+	+
	Standard Care	?	?	+	+	?	?	?	?	?	?	?	+	+	?	?	?	?	?	+
Lenssen et al. (2006)	2 PT Sessions/day	?	?	+	+	+	?	?	?	+	?	?	?	+	?	+	N/A	?	?	?
	1 PT Session/day	?	?	+	+	+	?	?	?	+	?	?	?	+	?	+	N/A	?	?	?
Levine et al. (2013)	Physical Therapy	?	?	+	+	?	?	?	?	?	?	?	?	?	?	+	N/A	?	?	?
	NMES	?	?	+	+	?	?	?	?	?	?	+	?	?	?	+	N/A	?	?	?
Li et al. (2019)	Tai Chi Chuan	?	+	+	+	?	?	?	?	+	?	?	+	?	?	+	N/A	+	?	+
	Standard Care	?	?	+	+	?	?	?	?	+	?	?	+	?	?	+	N/A	?	?	+
Liao et al. (2013)	Functional Training + Balance	+	?	+	+	?	?	?	?	+	?	?	?	+	+	+	N/A	?	?	?
	Functional Training	?	?	+	+	?	?	?	?	+	?	?	?	+	+	+	N/A	?	?	?
Liao et al. (2020)	Elastic Resistance Exercise	+	?	+	+	+	?	+	+	+	+	?	+	+	+	+	N/A	?	+	+
	Standard Care	?	?	+	+	+	?	?	?	?	?	?	+	+	?	+	N/A	?	+	+

Liebs et al. (2010)	Ergometric Cycling	+	?	+	+	?	?	?	?	+	?	+	+	?	?	+	N/A	?	?	+
	Standard Care	?	?	+	+	?	?	?	?	?	?	+	+	?	?	+	N/A	?	?	+
Liebs et al. (2012)	Early Aquatics	+	?	?	+	?	?	?	?	?	?	+	+	+	?	?	?	?	?	?
	14 Day Post-Op Aquatics	+	?	?	+	?	?	?	?	?	?	+	+	+	?	?	?	?	?	?
Lin et al. (2018)	Lower Extremity Muscle Strength Training	+	+	+	+	?	+	?	?	+	?	+	+	+	+	+	N/A	?	?	+
	Standard Care		?	+	+	?	+	?	?	?	+	?	+	+	?	+	N/A	?	?	+
Lowe et al. (2012)	Home Visit	+	?	+	+	+	?	+	+	+	+	+	+	+	?	+	N/A	+	+	?
	Physiotherapy		?	+	+	?	+	+	+	+	+	+	+	+	?	+	N/A	+	?	?
Lysack et al. (2005)	Standard Care + 1 App Based Exercise	?	?	+	+	+	?	?	?	?	?	?	?	+	?	+	N/A	?	+	?
	Standard Care	?	?	+	+	+	?	?	?	?	?	?	?	+	?	+	N/A	?	+	?
Madsen et al. (2013)	Group Based Exercise	+	?	+	+	+	+	+	+	+	+	?	?	+	+	+	N/A	?	+	?
	Home Based Exercise	?	?	+	+	+	?	?	?	?	+	?	?	+	?	+	N/A	?	+	?
Mahomed et al. (2008)	Inpatient Rehab	?	?	+	+	+	?	+	?	+	?	+	?	+	?	+	N/A	?	+	?
	Home Based Exercise	?	?	+	+	+	?	+	+	+	?	+	+	+	?	+	N/A	+	+	?
McAvoy (2009)	Land Physical therapy	+	?	+	+	?	?	?	?	+	?	+	?	+	+	+	N/A	?	?	?
	Integrated Physical Therapy	?	?	+	+	?	?	?	?	+	?	+	?	+	+	+	N/A	?	?	?
Mitchell et al. (2005)	Usual Hospital Physiotherapy	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?
	Home Based Exercise	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?
Mockford et al. (2008)	Outpatient Physiotherapy	?	?	+	+	+	?	?	?	+	+	?	?	?	?	+	N/A	?	?	?
	Standard Care	?	?	+	+	?	?	?	?	+	+	?	?	?	?	+	N/A	?	?	?
Moffet et al. (2004)	Intensive Functional Rehab	+	?	+	+	+	?	+	?	+	+	+	+	+	+	+	+	+	+	+
	Standard Care	?	?	+	+	?	?	?	?	+	+	+	+	+	?	+	N/A	?	?	+
Moffet et al. (2015)	Telerehab	?	?	+	+	+	?	+	?	?	+	+	+	+	?	+	?	?	+	?
	Face-to-Face	?	?	+	+	+	?	+	?	?	+	+	+	+	?	+	?	?	+	?
Monticone et al. (2013)	Functional Training	+	?	+	+	?	+	?	?	+	+	+	+	+	?	+	N/A	?	?	?
	Standard Care	+	?	+	+	?	+	?	?	+	+	+	+	+	?	+	N/A	?	?	?

Moutzouri et al. (2018)	Focal Sensorimotor Exercise Training	+	?	+	+	?	?	+	+	+	+	?	?	+	+	+	?	?	?	?
	Functional Training	+	?	+	+	?	?	+	+	+	+	?	+	+	+	+	?	?	?	?
Munin et al. (1998)	3-days post-op	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?
	7-days post-op	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?
Ko et al. (2013)	One-on-One Exercises	?	?	+	+	+	?	+	+	?	+	+	+	+	?	?	?	?	+	+
	Group Based	+	?	+	+	+	?	+	+	+	+	?	+	+	+	+	N/A	?	+	+
	Monitored Home Exercise	+	?	+	+	+	?	+	+	+	+	+	+	+	+	?	?	?	+	+
Paravlic et al. (2019)	Motor Imagery	+	?	+	+	+	+	?	?	+	+	+	+	+	?	+	+	?	+	?
	Standard Care		?	+	+	+	+	?	?	+	+	?	+	+	?	+	+	?	+	?
Paxton et al. (2018)	Physical Activity Feedback	?	?	+	+	+	+	+	+	?	?	+	?	+	?	+	N/A	+	+	?
	Standard Care	?	?	+	+	?	+	?	?	?	?	?	?	+	?	+	N/A	+	?	?
Peiris et al. (2012)	OT + PT 6 days	?	?	+	+	+	?	?	?	?	?	?	?	+	?	?	?	?	?	?
	OT + PT 5 days	?	?	+	+	+	?	?	?	?	?	?	?	+	?	?	?	?	?	?
Petterson et al. (2009)	Exercise + NMES	+	?	+	+	?	?	?	?	+	?	+	+	+	+	+	N/A	?	?	?
	Exercise Only	+	?	+	+	?	?	?	?	+	?	+	+	+	+	+	N/A	?	?	?
Piqueras et al. (2013)	Telerehab	?	?	+	+	?	?	?	?	?	+	?	?	+	?	?	?	?	?	?
	Standard Care	?	?	+	+	?	?	?	?	?	+	?	+	+	?	?	?	?	?	?
Piva et al. (2019)	Physical Therapy	?	?	+	+	?	?	+	+	+	+	?	?	+	?	+	?	+	?	?
	Community Care	?	?	+	+	?	?	?	?	?	?	?	+	+	?	+	N/A	+	?	?
	No Treatment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Piva et al. (2017)	Cognitive Behavioural Intervention	+	?	+	+	+	+	+	+	+	+	+	?	+	+	+	N/A	+	+	?
	Standard Care	+	?	+	+	+	?	+	+	+	+	?	+	+	+	+	N/A	?	+	?
Piva et al. (2010)	Functional Training + Balance	+	?	+	+	+	+	+	+	+	+	?	?	+	+	+	N/A	?	+	?
	Functional Training	+	?	+	+	+	+	+	+	+	+	?	+	+	+	+	N/A	?	+	?
Prvu Bettger et al. (2020)	Telerehab	+	?	+	+	+	+	+	?	?	+	?	+	+	?	+	?	?	+	?
	Standard Care	?	?	?	?	+	?	?	?	?	?	?	?	?	?	+	N/A	?	+	?
Rahmann et al. (2009)	Ward Exercise	+	+	+	+	?	?	+	+	+	?	?	+	+	+	+	N/A	+	?	+
	Aquatic Physio	+	+	+	+	?	?	+	+	+	?	?	+	+	+	+	N/A	+	?	+
	Water Exercises	+	+	+	+	?	?	+	+	+	?	?	+	+	+	+	N/A	+	?	+
Rajan et al. (2004)	Outpatient/Inpatient PT	?	?	?	+	?	?	?	?	?	+	?	?	+	?	?	?	+	?	?
	Inpatient Only	?	?	+	+	?	?	?	?	?	+	?	?	+	?	?	?	+	?	?

Roig-Casasus et al. (2018)	Balance Training + Functional	+	?	+	+	?	?	?	?	+	?	?	+	+	+	+	N/A	+	?	?
	Functional Training	?	?	+	+	?	?	?	?	+	?	?	+	+	+	+	N/A	+	?	?
Russell et al. (2011)	Telerehab	+	?	+	+	+	+	?	?	?	+	?	?	+	?	+	N/A	?	+	?
	Face-to-Face	?	?	+	+	+	+	?	?	?	+	?	?	+	?	+	N/A	?	+	?
Russo et al. (2017)	Videoinsight group	?	?	+	+	?	+	?	?	?	+	?	?	?	?	?	?	?	?	?
	Control	?	?	+	+	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Sattler et al. (2019)	Multi-exercise group	+	?	+	+	+	?	?	?	+	+	+	+	+	+	+	N/A	?	+	?
	Pedaling-Based Group	+	?	+	+	+	+	?	?	+	+	+	+	+	+	+	N/A	?	+	?
Shabbir et al. (2017)	Functional Training	?	?	+	+	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
	Strengthening Training	?	?	+	+	?	?	?	?	?	+	?	?	?	?	?	?	?	?	?
Shanb et al. (2014)	Exercise + EMG	+	?	+	+	?	?	+	+	+	?	+	?	+	+	+	N/A	?	?	?
	Exercise Only	?	?	+	+	?	+	+	+	+	?	+	?	+	+	+	N/A	?	?	?
Smith et al. (2019)	Fitness Tracker Group	+	?	+	+	+	+	+	+	+	+	?	?	+	+	+	+	+	+	?
	Exercise Only	+	?	+	+	+	+	+	+	+	+	?	?	+	+	+	+	+	+	?
Stevens-Lapsley et al. (2012)	Standard + NMES	+	?	+	+	?	?	+	+	+	+	+	+	+	+	+	N/A	?	?	+
	Standard Care	+	?	+	+	?	?	+	+	+	+	+	+	+	+	+	N/A	?	?	+
Tanaka et al. (2020)	Standard + Intensive Functional Rehab	+	?	+	+	?	?	?	?	+	?	?	?	+	?	+	N/A	?	?	?
	Standard Care	?	?	?	?	?	?	?	?	?	?	?	?	?	?	+	N/A	?	?	?
Tanaka et al. (2017)	Standard + Hybrid Assistive Limb	+	+	+	+	?	?	?	?	?	?	?	?	+	?	+	N/A	?	?	+
	Standard Care	?	+	+	+	?	?	?	?	?	?	?	?	+	?	+	N/A	?	?	+
Timmers et al. (2019)	Day-to-Day App Feedback	+	?	+	+	?	+	?	?	?	+	+	?	+	?	+	N/A	?	?	+
	2x/week App Feedback	+	?	+	+	?	+	?	?	?	?	+	?	+	?	+	N/A	?	?	+
Tousignant et al. (2011)	Telehealth	+	?	+	+	?	?	?	?	?	?	?	?	+	?	?	N/A	?	?	?
	Home Visit	?	?	+	+	?	?	?	?	?	?	?	+	+	?	?	N/A	?	?	?
Trudelle-Jackson et al. (2020)	Exercises + Step-Monitoring	+	?	+	+	+	+	+	+	+	+	?	?	+	+	+	N/A	+	+	?
	Step-Monitoring	+	?	+	+	?	+	+	+	?	+	?	?	+	+	+	N/A	+	?	?
Unver et al. (2016)	Weighted Exercises	+	?	+	+	?	?	+	+	?	+	?	+	+	+	+	N/A	+	?	?
	Non-weighted group		?	+	+	?	?	+	+	?	+	?	+	+	+	+	N/A	+	?	?
	Weighted Exercises	?	?	+	+	?	?	?	?	+	+	+	+	+	?	+	N/A	?	?	?

Valdes et al. (2010)	Standard care	?	?	+	+	?	?	?	?	+	+	?	+	+	?	+	N/A	?	?	?
Valtonen et al. (2010)	Aquatic Resistance Group	+	?	+	+	+	+	?	+	?	?	?	+	+	+	+	N/A	?	+	?
	No Treatment	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vuorenmaa et al. (2014)	Monitored Home Exercise	+	?	+	+	+	+	+	+	+	+	+	+	+	+	+	N/A	+	+	?
	Standard Care	?	?	+	+	+	?	+	?	?	+	+	?	+	?	+	N/A	+	+	?
Wozniak et al. (2017)	Standard Care + KTape	?	?	+	+	?	?	?	?	?	?	+	?	+	?	?	?	?	?	?
	Standard Care	?	?	+	+	?	?	?	?	?	?	?	?	+	?	?	?	?	?	?
Yousefian et al. (2017)	Experimental	+	?	+	+	?	?	+	+	+	?	?	+	+	+	+	N/A	?	?	?
	Control	?	?	+	+	?	?	+	+	+	?	?	+	+	+	+	N/A	?	?	?
Zietek et al. (2015)	Intensive Fast-Track	+	?	+	+	?	?	?	?	+	?	+	?	+	?	+	N/A	?	?	?
	Standard Track	?	?	+	+	?	?	?	?	?	?	+	?	+	?	+	N/A	?	?	?

1.15 Appendix F – Cochrane Risk of Bias Assessment

Author	Randomization	Allocation Concealment	Blinding	Incomplete Data	Selective Reporting	Other Sources of Bias	Evaluation of Risk of Bias
Akbaba et al. (2016)	+	-	+	?	-	+	High Risk of Bias
Alghadir et al. (2016)	+	-	+	+	?	+	High Risk of Bias
Anneli et al. (2017)	+	-	+	?	?	+	High Risk of Bias
Aprile et al. (2011)	+	-	-	?	?	+	High Risk of Bias
Artz et al. (2017)	+	-	-	+	+	+	High Risk of Bias
Avramidis et al. (2011)	+	-	+	?	?	+	High Risk of Bias
Bade et al. (2017)	+	-	+	+	?	+	High Risk of Bias
Bellelli et al. (2010)	?	-	+	+	?	-	High Risk of Bias
Bily et al. (2016)	+	-	-	+	?	+	High Risk of Bias
Bini et al. (2017)	+	-	-	?	?	+	High Risk of Bias
Bohl et al. (2019)	+	-	-	+	+	+	High Risk of Bias
Brandes et al. (2018)	+	-	-	+	-	+	High Risk of Bias
Bruun-Olsen et al. (2013)	+	+	+	+	+	+	Low Risk of Bias
Bugbee et al. (2016)	?			+	?	+	High Risk of Bias
Buhaglar et al. (2017)	+	+	+	+	+	+	Low Risk of Bias
Bulthuis et al. (2007)	+	+	-	+	?	+	High Risk of Bias
Cai et al. (2017)	+	-	-	+	?	+	High Risk of Bias
Cai et al. (2018)	+	+	+	+	?	+	Unclear Risk of Bias
Campbell et al. (2019)	+	-	+	+	+	+	High Risk of Bias
Chen et al. (2016)	+	+	+	+	?	+	High Risk of Bias
Chen et al. (2017)	+	-	-	+	?	+	High Risk of Bias
Christiansen et al. (2015)	+	+	+	?	+	+	Unclear Risk of Bias
Christiansen et al. (2020)	+	+	+	?	-	+	High Risk of Bias
De Fine et al. (2017)	?	-	+	?	?	+	High Risk of Bias
Debbi et al. (2019)	+	+	+	+	?	+	Unclear Risk of Bias
Demircioglu et al. (2015)	+	-	-	+	?	+	High Risk of Bias
den Hertog et al. (2012)	+	+	-	+	?	+	High Risk of Bias
Doerfler et al. (2016)	?	+		+	?	+	Unclear Risk of Bias

Donec & Krisciunas (2014)	+	+	-	+	?	+	High Risk of Bias
Ebert et al. (2013)	+	+		+	?	+	Unclear Risk of Bias
Eichler et al. (2019)	+	-	-	+	-	+	High Risk of Bias
Eisermann et al. (2004)	?	-	-	+	?	-	High Risk of Bias
Evgeniadis et al. (2008)	+	+	+	+	?	+	Unclear Risk of Bias
Ficklscherer et al. (2016)	?			?	?	+	High Risk of Bias
Fleischman et al. (2019)	+	+	+	+	+	+	Low Risk of Bias
Fortuno Godes et al. (2010)	+	-	-	?	?	+	High Risk of Bias
Fransen et al. (2017)	+	+	+	+	-	+	High Risk of Bias
Frost et al. (2002)	+	-	+	+	?	+	High Risk of Bias
Fung et al. (2012)	+	-	+	+	+	+	High Risk of Bias
Gianola et al. (2020)	+	+	+	+	+	+	Low Risk of Bias
Giaquinto et al. (2010)	+	+	+	?	?	+	Unclear Risk of Bias
Han et al. (2015)	+	+	+	+	-	+	High Risk of Bias
Hardt et al. (2018)	+	+	+	+	?	+	Unclear Risk of Bias
Harikesavan et al. (2017)	+	-	+	?	?	+	High Risk of Bias
Harmer et al. (2009)	+	+	+	+	?	+	Unclear Risk of Bias
Hepperger et al. (2017)	+	-	-	?	?	+	High Risk of Bias
Hoorntje et al. (2020)	?	-	-	?	-	+	High Risk of Bias
Husby et al. (2018)	+	-	-	+	-	+	High Risk of Bias
Iwakiri et al. (2020)	+	+	+	+	-	+	High Risk of Bias
Jakobsen et al. (2014)	+	+	+	+	+	+	Low Risk of Bias
Jin et al. (2018)	?	-	-	?	?	-	High Risk of Bias
Jogi et al. (2015)	+	+	+	?	-	+	High Risk of Bias
Johnson et al. (2010)	+	-	-	?	?	+	High Risk of Bias
Ju et al. (2019)	+	-	-	?	?	-	High Risk of Bias
Karaman et al. (2017)	?	-	-	+	?	+	High Risk of Bias
Kauppila et al. (2010)	+	+	-	+	?	+	High Risk of Bias
Kelly et al. (2016)	+	+	+	+	-	+	High Risk of Bias
Kramer et al. (2003)	-	-	+	+	-	-	High Risk of Bias
Lee et al. (2020)	+		-	+	?	+	High Risk of Bias

Lenguerrand et al. (2019)	+	+	-	+	+	+	High Risk of Bias
Lenssen et al. (2006)	+	?		+	?	+	Unclear Risk of Bias
Levine et al. (2013)	+	-	-	+	?	+	High Risk of Bias
Li et al. (2019)	+	+	?	+	?	+	Unclear Risk of Bias
Liao et al. (2013)	+	+	+	+	?	+	Unclear Risk of Bias
Liao et al. (2020)	+	+	+	+	+	+	Low Risk of Bias
Liebs et al. (2010)	+	+	?	+	+	+	Unclear Risk of Bias
Liebs et al. (2012)	+	+	?	+	?	+	Unclear Risk of Bias
Lin et al. (2018)	+	+	-	+	?	+	High Risk of Bias
Lowe et al. (2012)	+	+	+	+	+	+	Low Risk of Bias
Lysack et al. (2005)	?	-	-	+	?	+	High Risk of Bias
Madsen et al. (2013)	?	+	+	?	+	+	Unclear Risk of Bias
Mahomed et al. (2008)	+	-	-	+	?	+	High Risk of Bias
McAvoy (2009)	+	+	+	+	?	+	Unclear Risk of Bias
Mitchell et al. (2005)	+	+	+	+	?	+	Unclear Risk of Bias
Mockford et al. (2008)	+	-	+	+	?	-	High Risk of Bias
Moffet et al. (2004)	+	+	+	+	?	-	High Risk of Bias
Moffet et al. (2015)	+	+	+	+	?	-	High Risk of Bias
Monticone et al. (2013)	+	+	+	+	?	+	Unclear Risk of Bias
Moutzouri et al. (2018)	+	+	+	+	+	+	Low Risk of Bias
Munin et al. (1998)	+	+	+	+	?	-	High Risk of Bias
Ko et al. (2013)	+	+		+	+	+	Low Risk of Bias
Paravlic et al. (2019)	+	+	-	+	+	+	High Risk of Bias
Paxton et al. (2018)	?	-	-	+	+	+	High Risk of Bias
Peiris et al. (2012)	+	+	+	+	+	+	Low Risk of Bias
Petterson et al. (2009)	?	-	+	+	?	+	High Risk of Bias
Piqueras et al. (2013)	+	-	+	+	?	+	High Risk of Bias
Piva et al. (2010)	+	?	?	+	+	+	Unclear Risk of Bias
Piva et al. (2017)	+	+	+	+	+	+	Low Risk of Bias
Piva et al. (2019)	+	+	+	+	+	+	Low Risk of Bias
Prvu Bettger et al. (2020)	+	+	-	+	+	+	High Risk of Bias
Rahmann et al. (2009)	+	+	+	+	+	+	Low Risk of Bias

Rajan et al. (2004)	+	-	+	-	?	-	High Risk of Bias
Roig-Casas√∫s et al. (2018)	+	?	+	+	?	+	Unclear Risk of Bias
Russell et al. (2011)	+	+	+	+	+	+	Low Risk of Bias
Russo et al. (2017)	+	?	+	-	?	+	High Risk of Bias
Sattler et al. (2019)	+	+	+	+	+	+	Low Risk of Bias
Shabbir et al. (2017)	+	+	+	-	?	-	High Risk of Bias
Shanb et al. (2014)	+	+	-	+	?	+	High Risk of Bias
Smith et al. (2019)	+	-	-	+	?	+	High Risk of Bias
Stevens-Lapsley et al. (2012)	+	-	-	+	?	+	High Risk of Bias
Tanaka et al. (2017)	+	-	+	+	?	+	High Risk of Bias
Tanaka et al. (2020)	+	+	+	+	+	+	Low Risk of Bias
Timmers et al. (2019)	+	+	-	+	+	+	High Risk of Bias
Tousignant et al. (2011)	+	+	-	+	-	+	High Risk of Bias
Trudelle-Jackson et al. (2020)	+	+	-	+	?	+	High Risk of Bias
Unver et al. (2016)	+	-	-	+	?	+	High Risk of Bias
Valdes et al. (2010)	-	-	-	-	?	+	High Risk of Bias
Valtonen et al. (2010)	?	+	+	+	+	+	Unclear Risk of Bias
Vuorenmaa et al. (2014)	+	?	+	+	+	+	Unclear Risk of Bias
Woźniak-Czekierda et al. (2017)	?	-	-	+	?	-	High Risk of Bias
Yousefian et al. (2017)	+	?	+	+	?	+	Unclear Risk of Bias
Zietek et al. (2015)	+	+	+	+	?	+	Unclear Risk of Bias

Chapter 3: Understanding Barriers and Facilitators of Exercise Adherence after Total-Knee Arthroplasty

Understanding Barriers and Facilitators of Exercise Adherence after Total-Knee Arthroplasty

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1.1 Abstract

Introduction: There is limited research on understanding the biopsychosocial aspects of exercise adherence after total knee arthroplasty (TKA).

Objective: The purpose of this study is to understand the perceived patient barriers and facilitators of exercise adherence in patients immediately after undergoing TKA.

Methods: Using an interpretive description approach, semi-structured qualitative interviews were conducted. Participants were interviewed at 8 weeks post-operatively in order to better capture physical, psychological, social and contextual changes post-operatively. Topics that were explored included participants experience with physical activity and exercise, motivation to perform physical activity, beliefs that exercise will reduce pain, the factors that limit their ability to engage in exercise, and the importance of using self-regulation to improve exercise adherence.

Results: This study identified 4 themes within the WHO adherence framework: patient-related factors, condition-related factors, health care system, and social support. In particular, self-regulation, knowledge of exercise, post-operative complications, comorbidities, social support, and lack of guidance from health care providers were identified as personal and environmental characteristics that affect exercise adherence.

Conclusion: Exercise adherence is a multidimensional, interconnected construct and future research should focus on understanding the factors, particularly health care system, that impact adherence.

1.2 Background

Total knee arthroplasty (TKA) is the most commonly recommended treatment option for moderate-to-severe knee osteoarthritis (KOA).[1] Post-operatively exercise is considered an essential aspect in improving post-operative outcomes such as pain and physical function.[2] Research has shown that there are little-to-no changes in physical activity from before surgery to 1 year post-operatively.[3, 4] Poor post-surgical outcomes may be related to decreased levels of physical activity and exercise, both before and after surgery. Lack of adherence to health care recommendations and rehabilitation in people post TKA have been linked to complications such as increased pain, stiffness, and muscle weakness.[5]

There are many known intrinsic and extrinsic factors that influence exercise adherence in individuals with KOA. Intrinsic factors may include knowledge of their condition, beliefs regarding exercise, previous history of physical activity, self-efficacy, pain, and allocating time to exercise.[6-9] Extrinsic factors include social support, access to exercise equipment, weather and transportation.[7, 10] Studies have shown that factors that influence exercise adherence in the short term are different to those in the long term in individuals with KOA.[6] Initially adherence to an exercise intervention in people with KOA was influenced by factors such as obligation and desire to help the researcher, avoid medications, and the perceived effectiveness of the intervention at managing symptoms.[6] Exercise adherence in the long-term was affected by pragmatic factors (e.g. allotting time to exercise, incorporating exercise into daily routine),[6] as well as condition-related factors (e.g. comorbidities, lack of trust in the new joint).[6, 11]

A previous qualitative study that assessed patients' experiences of living with KOA and their post-TKA expectations, found that health care providers rarely suggested physiotherapy as an intervention to manage symptoms of KOA prior to surgery, but patients believed physiotherapy to be an essential aspect of post-operative recovery.[12] When assessing engagement in physical activity post-TKA, researchers found that patients felt having more physiotherapy sessions post-operatively would have improved motivation for exercise, and cost of treatment session was cited as the main limitation.[11]

Although adherence to post-TKA rehabilitation is of great importance to regain function and reduce pain, studies assessing adherence immediately post-surgically are lacking.[5] There is very little research on understanding the biopsychosocial aspects of exercise adherence in this population. Therefore, the purpose of this study is to understand the perceived patient barriers and facilitators of exercise adherence in patients immediately after undergoing TKA.

1.3 Methods

The Standards for Reporting Qualitative Research (SRQR) guidelines will be followed.[13] Qualitative semi-structured interviews[14] methods were used in this study to understand beliefs, experiences, and perspectives surrounding exercise adherence in patients following TKA.

1.3.1 Ethics

Ethics approval was provided by the Hamilton Integrated Research Ethics Board (#7811).

1.3.2 Research Paradigm

Interpretive description was used to inform the understanding of exercise adherence in patients after TKA. Developed by Thorne et al. interpretive description is a method used to generate clinically relevant information for health researchers using an inductive approach.[15-17] This approach to qualitative research assumes the existence of multiple realities, that are constructed through context, experience and social interaction. Interpretive description uses a constant comparative analysis that allows for a coherent strategy to design and implement research that can be applied to the clinical setting.[17] Thus, the goal of interpretive description is not to generalize findings to the population of interest, but rather to explore and describe the human experience in the given context.

1.3.3 Setting

Participants were recruited from a prospective longitudinal (8-week) cohort study aimed at evaluating post-operative exercise adherence. Qualitative interviews were conducted at the end of the final 8-week follow-up of the quantitative study. To provide rich descriptions of the participants and further describe their pre and post-operative (8-weeks) knee function the following outcome measures were collected: demographic information (e.g. age, sex, etc.), pain intensity (average pain level from 0-10 in the last week), self-reported function (Knee Osteoarthritis Outcome Score (KOOS)), comorbidities, self-efficacy (Pain Self-efficacy Questionnaire (PSEQ)), fear of movement (Fear of Movement Scale for Osteoarthritis (FMSO)), and exercise adherence (the number of times/day they completed each of the recommended rehabilitation exercises (3x/day) during the 8-week timeframe).

Participants were recruited from orthopedic surgeons in Ontario (Hamilton, Greater Toronto area and other locations). The surgeon, administrative personnel or nurse practitioner, identified eligible patients either at the time of booking appointments or at the time of their pre-operative appointment. Participants were consented to the study by a member of the research team at their pre-operative appointment. Participants were also asked to confirm consent to the interviewers at the time of the last follow-up assessment of the quantitative study (8-weeks post-operatively).

1.3.4 Participants

All participants within the larger longitudinal cohort study were included in the qualitative interviews. Participants were included in the study if they met the following criteria: 1) Adults > 50 years, 2) Able to understand and answer study questionnaires in English and 3) undergoing unilateral and first TKA. Participants were excluded from the study if they met any of the following criteria: 1) Self-reported dementia/cognitive impairment that would limit understanding of data collection.

1.3.5 Researcher Characteristics

Interviews were conducted by NB who is a chiropractor with 2 years of clinical experience and received training in qualitative research methods through a structured workshop and has conducted focus group interviews as part of a previous research study.

1.3.6 Data Collection

Participants were interviewed at 8 weeks post-operatively in order to capture physical, psychological, social and contextual changes post-operatively impacting exercise adherence. The interview guide was developed from previous literature assessing exercise adherence in knee OA, and from the authors' prior understanding and experience. Topics that were explored

included participants experience with physical activity and exercise, motivation to perform physical activity, belief that exercise will reduce pain, the factors that limit their ability to engage in exercise, and the importance of using self-regulation to improve exercise adherence.

Qualitative semi-structured interviews[14] were conducted with each participant by phone (using Zoom), lasting between 45-90 minutes (Appendix A). Interview questions were updated for each participant based on emergent themes from previous interviews. Interviews were digitally audio-recorded and transcribed verbatim. The investigators used the qualitative software "Nvivo" to manage, store, and analyze data from the transcripts. In order to understand the factors that influenced exercise adherence, participants were asked to share their experience with post-operative rehabilitation during their recovery process. The descriptive nature of the interview allowed for the development of probes to explore examples more thoroughly.[18]

1.3.7 Methodological Rigor

Several well-established techniques to ensure methodological rigor were pursued, including; member checking (participants' comments on any emergent themes), verification (researchers converge on recognizing "identical patterns" in the data), referential adequacy (providing enough quotes to ensure the findings fit the data), and maintaining an audit trial (records of decisions made).[19]

1.4 Data Analysis

As per interpretive description, data collection and analysis proceeded concurrently, with each step informing the other. Line-by-line reading of the 7 transcripts was performed by NB and

thematic patterns were explored from each participant. Once themes and patterns were identified, each meaningful segment of text was assigned a conceptual code that reflected patient's beliefs, motivations, and perceptions regarding exercise adherence (Figure 1). When conceptual codes become saturated, NB built pattern codes where specific dimensions of patients' experiences were clustered into recurring themes (see Appendix B for all quotes used to develop the themes). New participants were asked to reflect and elaborate on these themes as they emerged. Throughout the study, the interviewer (NB), continuously reflected on emergent themes and the analysis in order to ensure a holistic understanding of the patient experience. Once the codes and themes were developed by NB, these were shared with LM who reviewed and provided feedback on the quotes and emergent themes. Together NB and LM discussed and revised themes. The themes were reviewed using the lens of a chiropractor (NB), a physiotherapist (LM), and as rehabilitation scientists (NB & LM).

1.5 Results

Participants were recruited starting January 2020 and recruitment was halted on March 2020 due to COVID-19. The sample consisted of seven (six female) participants (age: 64.1 (4.95)) that had undergone their first total knee arthroplasty (Table 1). There were 19 participants recruited for the larger mixed method study. Five participants were lost to follow-up (did not answer), 3 participants did not have time to complete the baseline questionnaires prior to surgery, 3 participants did not end up having a TKA, and 1 participant dropped out due to family circumstances. Of the seven remaining participants that completed baseline and 8 weeks post-op follow ups, all agreed to participate on this qualitative study. Considering self-reported outcomes collected at baseline and 8 weeks post-surgery, most participants (4/7) had clinically meaningful

changes in KOOS score (mean (standard deviation), KOOS baseline: 32.1 (7.0), KOOS follow-up: 25.0 (6.7)). There were two participants (P6 & P7) that had an increase/little change to KOOS scores post-operatively, which may be related to post-operative complications. Three of the seven participants exercised within the recommended amount by the World Health Organization prior to surgery (>30mins/day, 3x/week). In general, at 8 weeks post-operatively, a relatively high adherence to post-operative exercise was reported (Median 84%, range 47%-100%, N=5). One participant did not complete their diary with number of exercises per day, rather time spent exercising. Another participant did not complete the adherence diary due to post-operative complications.

There were seven identified themes including: self-regulation, knowledge and experience of exercise, post-operative complications, comorbidities, lack of exercise guidance/progression, and social support (Figure 2). Emergent themes were mapped onto the overarching domains of the WHO adherence framework.[18] The World Health Organization adherence framework has identified five dimensions that influence adherence to health interventions, including:

1) Socioeconomic factors (e.g. education, social support, unemployment, etc.),
2) Healthcare system-related factors (e.g. wait times, patient-provider rapport, knowledge and training of health care providers, etc.),
3) Condition-related factors (e.g. level of disability, comorbidities, etc.),
4) Therapy-related factors (e.g. duration of treatment, side-effects, etc.), and
5) Patient related factors (e.g. expectations, perceived benefits, psychosocial stress, etc.).

This study identified 4 WHO domains: patient-related factors, condition-related factors, healthcare system-related factors and socioeconomic factors.

1.5.1 Theme 1: Patient-Related Factors

Patient-related factors played a key role in understanding adherence to health care interventions. Under this domain, two sub-themes were identified: 1) Self-regulation and 2) Knowledge of Exercise.

1.5.2 Self-Regulation

Self-regulation has been defined as "the ability of an individual to exert control over their self."[20] This ability allows individuals to engage in goal-oriented behavior, which helps foster adherence to exercise. In order to foster goal-oriented behaviours individuals must engage in self-regulatory behaviors, which include goal setting, planning, monitoring their actions, and feedback from the environment.[21] Monitoring is an essential aspect of self-regulation, which allows individuals to reflect and modify their behaviour to reach their intended goals. In this context, several participants emphasized the importance of these intrinsic factors in promoting exercise behaviour. Prior to surgery, participants had specific goals that they wanted to reach (e.g. golfing, walking, etc.), which increased motivation to comply with post-operative exercise:

> P3: "I had a goal that if the weather was good, I was going to go out and golf in May, and I think I'm still on target for that in terms of being able to take the swing, being able to go walk […] to get myself to the point where in a matter of 10 weeks I should be in a position I should be to do the things I want to do and probably after 12-16 weeks I expect to be far stronger than I was prior to the operation. That's my goal. And I can do it. There's no question about it."

Conversely, the perceived benefits of exercise (e.g. range of motion, pain relief) were described as a reason to stop exercising, if these goals were met:

> P1: "Well, at the moment, I'm frustrated with my progress. I'd like it to be better, and there's nothing wrong with it. I'm probably still ahead of where I could be. […] I certainly haven't achieved what I need to, so until I can get there, I'll keep [exercising]. Probably when I get there, I'll quit doing it."

Planning also emerged as an important aspect of exercise adherence post-operatively through creating a routine for completing their exercises and incorporating them into their activities of daily living:

> P5: "I do it in the morning and then I do it in the afternoon. And I also try now and I'm doing it like for example he's [their physiotherapist] got me doing lunges on the stairs, so I try and do them when I go up the stairs or if I go up the stairs, to the bedroom or to the bathroom, I will do the lunges. […] I sit on the commode in front of the TV swinging my leg and then when I was out in the garden yesterday, I was doing a couple of lunges while I was pulling weeds and things like that. I'm doing them off and on. I'm doing them more than twice a day."

One participant stated that monitoring their exercise program and regularly documenting their progress played a key role in ensuring adherence to their exercise routine:

> P4: "It was documented everyday what we did. How far I could you know bend my knee, let's say one exercise would be lying on the bed, taking the bungee cord, putting it on my ankle and pulling it towards me. […] Every exercise was measured from the day I started."

Participants also found that having positive reinforcement helped to increase motivation and progression of exercise. Feedback from the environment often leads to improved self-regulatory

skills, and therefore, successful goal attainment.[21] P3 attributed seeing and feeling changes in the composition of their lower limb muscles as motivation to continue with their rehabilitation:

> "I could feel the difference now, now that I've been working out for this rehab program. It's been 9 weeks today since the operation. I could feel the difference between the atrophy in my muscles, particularly my quad muscles relative to where it was prior to the operation. […] It's not just feeling it, I can visibly see the difference in the tone of the quad muscle itself."

In contrast, participants also reported immediate negative feedback during exercise that decreased their ability to engage in the recommended exercise sessions. One participant had difficulty due to pain:

> P7: **"**[Pain] prevents me from doing the number of reps that I would want to. So, you know, at a minimum, I'm trying to do 10 reps. I'm working, you know, like I said, I've got up to 30 reps on some of them. But if the pain on the second or third time during the exercise in the day is too high, then my number of reps is less."

In a similar lens, self-discipline also served as an important tool to prioritize exercise. One participant (P1) reiterated the importance of altering their mindset prior to surgery to ensure a positive outcome: "I made up my mind before I started it that I was going to exercise as required. So even though there were times when it would have been nice to have skipped it. I never did." In regard to post-operative recovery, one participant (P5) stated that "you push yourself to get up and go. You push through the pain; you do the exercises…" Another participant also struggled with the exercises post-operatively, but continued to push themselves to reach their goal:

> P4: "You know, some days I wake up, and I'd say, oh my god, I've got to do exercises, because you're in pain afterwards. […] You're in a lot of pain. and some exercises I

actually ended up crying a couple times. But you know we [participant and their partner] did it."

Conversely, another participant highlighted that lack of self-discipline and inability to prioritize exercise lead to decreased exercise adherence:

P2: "I guess the lack of discipline is probably the biggest factor [for exercising]. […] The times that I've let my good intentions for exercise get interrupted, it's usually a family emergency or a holiday or something where I need the time I would be devoting to the exercise to do something that I thought was more important."

1.5.3 Knowledge and Experience of Exercise

Perception and knowledge of exercise played a significant role in post-operative rehabilitation. Participants understood the importance in engaging in regular exercise post-operatively, which fostered adherence. One participant describes lack of movement post-operatively as the worst possible option:

P6: "Sitting down and doing nothing is just the worst thing in the world. You can't do that. You have to get up and walk if nothing else. Some people don't like walking. Well. um, I don't know how she can fix that, because you certainly can't. Sitting down all day is the worst thing to do. You can't just turn into a complete solid rock. You must move."

Similarly, another participant emphasized the importance of early engagement in post-operative exercise:

P3: "So, what I would tell people is you know push it to what you think is the limit right off the bat. Work on the mobility and stretching cause that's the most important thing and

> you'll feel a ton better, a lot quicker than you can imagine the recovery would be. Don't even hesitate."

In addition to understanding the importance of exercise post-operatively, observing an individual who had undergone a total knee replacement prior to them was helpful in ensuring adherence to post-operative exercise:

> P3: "I know my sister went through total replacements on both knees and her first one, she felt she didn't get the physio right away. She didn't feel well, she wasn't able to exercise at first for a couple of weeks versus the second one, she got out right away and she could tell the difference in her mobility and what she's capable of doing between the two."

Having a previous history of physical activity and exercise was also helpful in understanding both the importance of exercise and how to modify the exercise to fit their individual needs.

> P1: "I kind of knew that [bridging] was a really good extension strengthening core exercise. Anyway, so if I hadn't known that beforehand, I probably would have just kept doing them on the couch."

1.5.4 Theme 2: Condition-Related Factors

There were two main themes identified under the domain of condition-related factors: 1) Post-operative complications, 2) Comorbidities.

1.5.5 Post-operative Complications

Post-operative complications emerged as a limitation to immediate post-operative exercise adherence. One participant described difficulty completing her post-operative exercise because

of limitations in the knee due to scar tissue formation. Even though she was completing her exercises regularly, she was unable increase the range of motion in her knee:

> P5: "I had to have a knee manipulation because the scar tissue had built up so bad that I was limited in what I could do with my knee. […] I felt that I couldn't push through doing some of the exercises. I was doing the ones that they had given me at the hospital but the one where you slide your knee along the bed and bring it toward you, I could only go so far. My knee would not let me bend it to bend it fully and it was because of the scar tissue."

1.5.6 Comorbidities

While engaging in regular exercise may be beneficial post-operatively, patients with multiple comorbidities may have other limitations that decrease their ability to adhere to exercise. One participant stated that while they do engage in regular exercise, they remain limited in what they are able to do because of pain in the opposite knee that requires surgical intervention:

> P6: "I actually need both knees replaced. So even with this one being. The other knee does not support me doing a lot of exercise right now. I physically cannot go up and down stairs yet. I've got 16 stairs in two flights to get down to my basement and I cannot make it. That I can go down, but I cannot make it back up without assistance. So right now, until I get both knees done that is what's preventing me from doing stuff right now."

1.5.7 Theme 3: Health Care System

Participants stated that they required more guidance for exercise therapy post-operatively. The inability to access individualized information from their trusted health care provider may affect

the patient-provider relationship. This perspective contradicts previous statements from participants regarding their knowledge and experience of exercise. Some participants felt that not all of their informational needs were met post-operatively. In particular, lack of safety knowledge regarding their exercises, which may lead to increased adverse events during and after exercise. One participant felt that their post-operative complications may have been prevented, if they had more guidance on how to properly exercise:

> P2: "I think the main point I would make is just that looking back having the people supporting me more informed about the things that could go on. Especially around the exercising, because I do think that I was not careful enough, but I didn't know not to be. I was very much encouraged to kind of push through which I think is probably the right thing to do and in any other circumstance. […] I think it would have helped me if they could modify their strategy or approach for that situation, rather than a one size fits all."

Another participant expressed lack of expectations and information on exercise progression from their health care provider regarding exercise therapy, and how to progress their exercises. Lack of proper exercise progression may affect long-term health goals leading to poorer prognoses.

> P6: "There is no rule. There's no guideline to say, okay, week one, week two, week three, like what to expect. There is no expectation at all. Other than okay so we got this little pamphlet with the exercises to do and all of that stuff. And I did it, but I mean come week six I was doing quite well. But, you know, I was working at it, I just wasn't making a point of doing it once every hour."

1.5.8 Theme 4: Socioeconomic Factors

A recurring factor was the level of support provided by family and friends for post-operative recovery, particularly surrounding exercise. A strong social network was viewed as a favourable

determinate of a successful recovery. It allowed patients to have more time to devote to exercise, as well as motivation and encouragement to continue exercising. One participant described their experience with post-operative exercise, which was encouraged by others, this way:

> P7: "I have set up a bunch of friends to give me a hard time if I'm not doing it and to constantly check up on me. I actually have my nephew here today and he is like 'have you done your exercise, just have you done your exercises'. Because I know if I don't have that I wouldn't."

Another participant stated that family was able to help them with household tasks, which then freed up time to complete their exercises:

> P1: **"**I didn't have to do anything about meals. He made them for me, and he looked after the dogs. So, it allows me to just do what I needed to do, which was, you know, move around and exercise and recover right. He would ask me if I done them or if I was doing them, he would encourage me to keep doing them."

1.6 Discussion

The overall findings of this study suggest exercise adherence post-operatively is a multifaceted construct with interconnected concepts. Self-regulation, knowledge of exercise, post-operative complications, comorbidities, social support, and lack of guidance were identified as personal and environmental characteristics that affect exercise adherence. Properly planning exercise programs by creating a routine increased engagement with exercise post-operatively. Similarly, positive reinforcement in the form of increased muscle strength, as well as working towards a particular goal promoted fidelity and adherence. Prior knowledge of the perceived benefits of exercise helped to foster competence and confidence in post-operative rehabilitation. These

factors make up the patient-related sequalae of the WHO adherence framework that influence exercise adherence. The socioeconomic determinates of exercise adherence emerged at the level of social support individuals had during their recovery. Exercise adherence was also influenced by condition-related determinants of health due to sequalae of the surgical intervention (e.g. pain, post-operative compilations). Lastly, the findings provided evidence that limitations in the health care system plays a crucial role in understanding exercise adherence.

The findings of this study can be presented as a continuum representing facilitators or barriers of exercise adherence. For example, 'pushing' through the pain to exercise was often viewed as an important aspect of their overall recovery; however, another participant felt that in their particular circumstances 'pushing' themselves to complete exercises created more harm than benefit. Similarly, while some participants were encouraged to continue exercising with the reduction of pain and increased functional capacity, another participant viewed the benefits of exercise as a reason to stop exercising in the long-term.

The emergent themes are all interconnect and must be addressed concurrently to foster exercise adherence. For instance, if an individual were to have post-operative complications or other condition related factors (e.g. comorbidities, pain/swelling), they would require an adaptable health care system that would allow for individualized treatment and potentially more rehabilitation guidance (e.g. increased number of session or follow-up). It is essential that health care providers provide adequate information on how to progress/modify exercise for individuals post-surgically. Lack of guidance from health care providers is a recurrent construct in various health conditions.[22] Prior research has also shown that more than half of therapists do not

monitor or supervise exercise in individuals with OA.[23] As such, adherence to therapeutic exercise is often viewed as the patient's responsibility, rather than a partnership between the patient-therapist. The failure of health care providers to recognize their role in facilitating behaviour change may contribute to poor exercise adherence immediately post-operatively as well as in the long-term.[24]

In a recent systematic review, Essery et al. reported self-motivation, self-efficacy, prior history of exercise-related behaviour, and social support were factors that affected home-based adherence to therapeutic exercise in individuals with OA.[25] Similarly, Jack et al. provided evidence that poor treatment adherence in individuals with musculoskeletal conditions was associated with depression, anxiety, poor social support, increased levels of pain during exercise, just to name a few.[26] The identified factors in these studies are mainly patient-related that affect adherence to exercise. Beinart et al. found moderate evidence that intervention related factors influence adherence to exercise in individuals with low back pain, for example, supervision or motivational strategies.[27] These findings were largely corroborated in our study, with the addition of condition-related and healthcare system related factors that also influenced patient adherence with exercise.

While exercise was generally viewed as a positive facilitator for recovery from surgery, it is important to address the aforementioned facilitators and barriers of adherence prior to surgery. This will ensure adequate engagement in exercise post-operatively. Additionally, fostering adherence immediately after surgery may encourage patients to engage in regular exercise in the long-term. In fact, individuals are more likely to engage in long-term exercise if they have a

prior history of exercise behaviour.[28] As such, it appears that current health interventions do not foster sustainable behavioral change in the short or long-term. This is particularly problematic given the high prevalence of knee OA, and concurrent comorbidities (e.g. diabetes, heart disease, etc.) in this population, which are often managed with exercise interventions. Long-term exercise adherence is a particularly complex issue that encompasses a wide variety of concepts (as per the WHO framework). Future studies should develop and implement pre-operative interventions that incorporate the various facilitators and address the barriers of exercise adherence. Additionally, longitudinal studies should be conducted to determine if pre-operative interventions foster long-term exercise adherence.

1.6.1 Strengths & Limitations

There are several limitations in this study, the first being small sample size as data collection was halted due to COVID-19. Given the use of descriptive analysis in this study, however, the descriptions provided by the participants (N=7) were rich and exhaustive. Another limitation of this study is that all, but one participant, were female, which may limit generalizability. The aim of this qualitative study, however, was to describe the barriers and facilitators of exercise adherence after TKA, and not to provide generalizable results.

1.7 Conclusion

Overall, this study identified 4 themes that coincide with the WHO adherence framework: patient-related factors, condition-related factors, health care system, and social support. In particular, self-regulation, knowledge of exercise, post-operative complications/limitations, comorbidities, social support, and lack of guidance from health care providers were identified as

personal and environmental characteristics that affect exercise adherence. Future studies should focus on understanding the factors related to exercise adherence and how to translate this information into clinical practice.

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Table 0-1: Participant descriptions.

Participant	Sex	# of Comorbidities	Pain*	KOOS*	PSEQ*	FMSO*	Adherence*
P1							
Baseline	Female	4	3	32.75	57	11	
8 weeks post-op			1	21.5	60	9	87%
P2							
Baseline	Female	3	6	30.25	41	14	
8 weeks post-op		N/A	N/A	N/A	N/A	N/A	N/A
P3							
Baseline	Male	1	6	31	46	11	
8 weeks post-op			1	21.25	55	10	100%
P4							
Baseline	Female	2	6	37	35	17	
8 weeks post-op			2	27.25	59	10	47%
P5							
Baseline	Female	1	7	46.25	36	14	
8 weeks post-op			0	17.5	56	8	84%
P6							
Baseline	Female	2	7	24	51	17	
8 weeks post-op			6	26.25	34	16	N/A
P7							
Baseline	Female	6	2	37.25	32	18	
8 weeks post-op			2	36.75	19	17	75%

*Pain intensity in the last week, Knee Injury and Osteoarthritis Outcome Score (KOOS), Pain Self-efficacy Questionnaire (PSEQ), Fear of Movement Scale for Osteoarthritis (FMSO), Exercise adherence using a diary (# of times exercised per day/# of recommended sessions (3x/day for 8weeks))

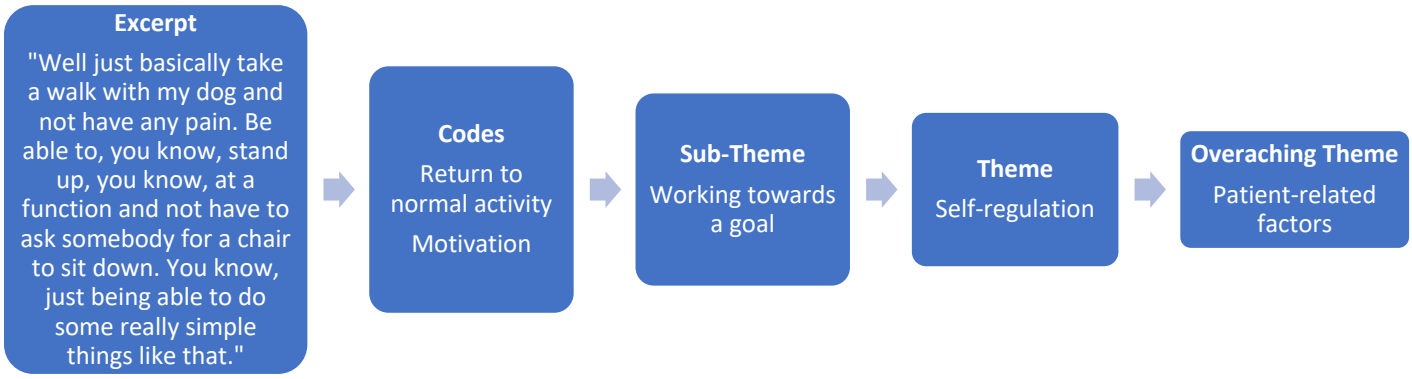

Figure 0-1: An example of theme development. An example of an interview excerpt with the codes, sub-theme, initial theme and the overarching theme applied.

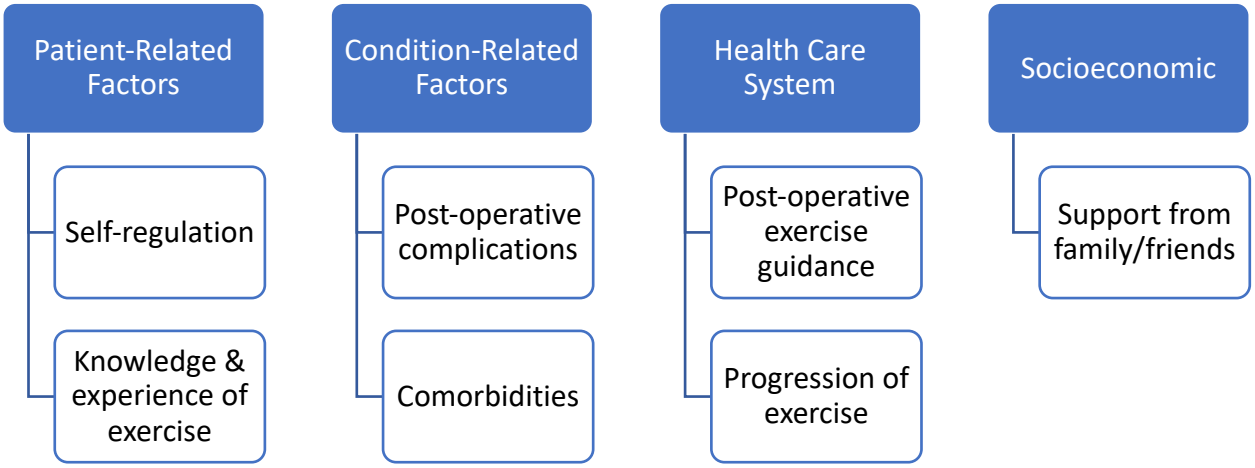

Figure 0-2: Overview of final thematic map of factors affecting exercise adherence in post-operative TKA.

1.9 Appendix A – Interview Guide

Just before we get started, I'd like to take a few moments to review the consent for this study. You have been invited to participate in a 45 to 90-minute interview. We will talk to you about your preoperative expectations and later, your post-operative experiences about your recovery process to your knee surgery. With your permission, we will be taking audio recordings of the interviews as well as handwritten notes.

Interview Content Questions

1. Looking back, tell us about your decision to use surgery as a means of treating knee OA.

2. What is the best-case scenario as an outcome of the surgery?
   *Describe what an acceptable or satisfactory outcome is to you (e.g. physical function, social, pain, work, quality of life).

3. Can you tell me about your recovery process since the surgery?

4. Did you engage in exercise regularly before surgery?

5. What are you feeling towards exercising?
   *do you enjoy exercising?

6. If not, what are the factors that limited your ability to engage in regular exercise before surgery?

7. Tell me about your motivation to perform physical activity and exercise prior to surgery?
   *what contributed to your ability exercise

8. Do you believe that regular exercise would help reduce your symptoms?
   *Advantages and disadvantages to exercises?

9. What are the recommendations that you received for exercise pre-operatively?
   *Who gave you these recommendations?
   *Were you told how to progress your exercises?
   *When did you know how to progress your exercise or physical activity level?

10. Did you engage in any structured rehabilitation post-operatively?
    *physiotherapy, etc.

11. Tell me about your motivation to perform physical activity and exercise after surgery?

12. What are the factors that limited your ability to engage in regular exercise after-surgery?

*what did you have to overcome or tell me about why the exercise was not done at home?

13. What are the main barriers that affected your post-operative rehabilitation?
    *were you afraid of injuring your knee during exercise post-operatively?

14. Do you believe that exercise will help you to maintain your functional ability in the long-term?

15. Do you think that self-control plays a role in your ability to exercise regularly in the long term?
    *did you set any goals for yourself to continue exercising?
    *did you engage in any reward system for engaging in exercise?
    *did you formally set up time each day to engage in exercise?
    *did you feel guilty at all when not exercising?

16. If you were in the position to tell an individual with arthritis to exercise who understood the importance of exercise but do not exercise, what would you recommend?
    *What do you think would help them to exercise regularly?

1.10 Appendix B – Quotes for Theme Development

Patient-Related Factors Affecting Adherence

- **Self-Regulation** refers to the ability for an individual to control their thoughts, emotions and behaviours to achieve a goal.
    - **Self-determination** refers to the feeling of feeling a sense of willingness, having a feeling of choice about what one is doing, of endorsing one's actions fully, and experiencing freedom in one's thoughts, feelings, and actions. In this context, participants have intrinsic motivations to engage in exercise post-operatively.
        - **P1:** "So, I made up my mind before I started it that I was going to exercise as required right so. Even though there were times when it would have been nice to have skipped it. I never did. So, I did exercises three times a day. […] Well, there's lots of days when I'd be happy to skip it, except that I'm I know I'm like I'm not doing anything."
        - **P2:** "You know my seemingly unlimited ability to be distracted by other things, and my disinclination to do things I don't want to do. So, I guess the lack of discipline is probably the biggest factor [for exercising]. […] The times that I've let my good intentions for exercise get interrupted, tt's usually a family emergency or a holiday or something where I need the time, I would be devoting to the exercise to do something that I thought was more important."
        - **P6:** "I would do it, if I didn't feel like it I didn't. […] I'm doing it. I gotta do it, I gotta do it, I don't have a choice. I push myself harder than most. So that's just me."
    - **Positive reinforcement:** Participants had motivations that prompted progression of exercises.
        - **P4:** "It was documented every day What we did. How far I could you know bend my knee, let's say one exercise would be lying on the bed, taking the bungee cord, putting it on my ankle and pulling it towards me. So that was measured every day how well I could do that, um. What else was being measured. Every exercise was measured from the day I started. Yeah, how many repetitions, the degree of difficulty. Yeah. Everything was charted yeah."
        - **P2:** "I'm walking around my condo. And I just started yesterday, deciding to wear a one of those little pedometers to see how many steps. I walk didn't walk that many yesterday it was maybe about 300."
        - **P7:** "So now my reward is actually doing the exercises and getting on the scale and seeing that number decrease."
        - **P4:** "But you know when you're doing those exercises like right after you are in pain. You need the ice or heat or whatever, just to get that in, but I think most of it. Like I said, it was my muscles that I haven't you know worked in a long time. I actually lost muscle on my calf because of the way I was favoring my leg right."
        - **P3:** "And I could feel the difference now, now that I've been working out for this rehab program. It's been 9 weeks today since the operation. I could feel the difference between the atrophy in my muscles, particularly

my quad muscles relative to where it was prior to the operation. It just wasn't something I was really aware of. It just shows for how long I've been favoring the one side and not putting enough weight and pressure on that right side at all. Now I can feel and tell the difference. It's not just feeling it, I can visibly see the difference in the tone of the quad muscle itself."

- **Creating a routine and incorporating exercises into ADLs**
  - **P2:** "Having kind of a regular habit of it. You know, if I fit it into my schedule in a regular spot then I'm more likely to do it. It's just that that spot sometimes gets. So, I mean it's the times that my exercising is interrupted."
  - **P4:** "You definitely need a plan in place. You can't just swing this and just say I'm going to do this today, and not going to do it tomorrow, you have to have that self-discipline and you have to have either family or friends, or somebody to help you through it. Or physio outside your home or whatever it takes, but you have to have a plan in place. And you know, if you can put a plan in place a good plan and stick to it."
  - **P1:** "I did exercises three times a day for you know what, four weeks or something. So that was part of the daily routine. Try to do morning and since I moved to twice a day, I do it after supper now."
  - **P7:** "I will do so I do one set in the morning and one set in the afternoon. And then if I'm really feeling up like I'll do another set before I go to bed."
  - **P1: "**And then, you know, like to find out something downstairs I just go up and down stairs and that sort of thing. So, try to build basic exercise into activity."
  - **P5:** "I do it in the morning and then I do it in the afternoon. And I also try now and I'm doing it like for example he's got me doing lunges on the stairs, so I try and do them when I go up the stairs or if I go up the stairs, to the bedroom or to the bathroom, I will do the lunges. He's showing me how to go up the stairs using my bad leg, going up my bad leg and how to go up the stairs or he's shown me different things to do with the commode. I didn't have a chair that was high enough that I could swing my leg underneath and he was showing me different things to do with that. So, I sit on the commode in front of the TV swinging my leg and then when I was out in the garden yesterday, I was doing a couple of lunges while I was pulling weeds and things like that. I'm doing them off and on. I'm doing them more than twice a day."
- **Pushing through discomfort to continue exercising**
  - **P5: "**You push yourself to get up and go. You push through the pain, you do the exercises because if you don't do the exercises, in my case, it would have made it a lot harder. I would be way behind. I feel like I'm way behind now, but I would have been further behind because I had no physio."
  - **M4: "**You know, some days I wake up, and I'd say, oh my god, I've got to do exercises, because you're in pain afterwards. Right you are, you're in a

lot of pain. and some exercises I actually ended up crying a couple times. But you know we did it."

- **P3:** "Make sure, let your body tell you when you're pushing it too far. I tend to be one that tends to push it a lot further because of my pain tolerance but you know I haven't done any damage. Like I said with the post-op visit, with the x-rays checking it out, they said everything was progressing extremely well. So obviously I had done the progression as they had sort of recommended without going over the top and doing any new damage to it and I could feel it. There has not been any excessive pain. It's progressively gone down and no recurrence. I've flown right by the expectations in terms of how far I can bend and how much I can bear on the knee."
- **P3:** "Just the limitations from the surgery, the fact that I could only bend the leg so far and stretch it so far and straighten it so far. But you know I worked on that on a daily basis."
- **P5:** "I felt I couldn't push myself because of the knee just wouldn't do what I wanted it to do. And it was swelling. I was out working in the garden and if I was out in the garden, I'd do an hour's work and I'd come in and my legs would be like a balloon. I felt as if my knee shouldn't have been swelling at that time. When we went to the knee class, they didn't tell you about the swelling and how it would swell up so quickly and you are at a limitation if there are scar tissue and you can't do things. You can walk but I couldn't bend my knee fully so to me that held me back. I felt it held me back."
- **P7:** "[Pain] prevents me from doing the number of reps that I would want to. So, you know, at a minimum, I'm trying to do 10 reps. I'm working, you know, like I said, I've got up to 30 reps on some of them. But if the pain on the second or third time during the exercise in the day is too high, then my number of reps is less."
- **P7:** "I think for building up the strength of a muscle, especially in the quads. The calve I'm not too sure about. The strengthening of the muscle in you know your calve and below because that's where they actually cut through and that muscle is the hardest to is the one that's causing me the most pain right now and I know that that will come back, but definitely improving the quads before you go for surgery."

- **Working towards a goal as a motivation for exercise adherence.**
  - **P1:** "And one of my big goals is, of course, to get more extension, you know, I've got five degrees more. So, my last physio appointment I was minus 10 And for flexion, I made it to 110 which she said, the goal was 120."
  - **P3:** "I had a goal that if the weather was good, I was going to go out and golf in May, and I think I'm still on target for that in terms of being able to take the swing, being able to go walk. […] to get myself to the point where in a matter of 10 weeks I should be in a position I should be to do the things I want to do and probably after 12-16 weeks I expect to be far

stronger than I was prior to the operation. That's my goal. And I can do it. There's no question about it."

- **P2:** "Well, after surgery in one way, I'm kind of highly motivated [to exercise] because I don't want to do it again. I don't want to go through the surgery again, it was pretty hellish in terms of the things that happened, and I don't want to risk that again, so I feel pretty motivated to try and make the best of this one."
- **P7:** "Well, the golf is the long, because that is something I have really, really missed. The second motivation is my job. I could lose my job if I'm not able to travel and when I do most of my work down in the US and I have not been able to walk through airports or anything like that. So, my motivation is to keep my job."
- **P4:** "Well just basically take a walk with my dog and not have any pain. Be able to, you know, stand up, you know, at a function and not have to ask somebody for a chair to sit down. You know, just being able to do some really simple things like that."
- **P2:** "I have grandchildren. I have one very, you know, a six-month grandchild and a six-year-old grandchild, and then others who are in their teens, but with the little ones, it would have been nice to be able to be more engaged with them."

- **Knowledge of Exercise**
  - **Importance of Exercise. Overall participants understood the importance of post-operative exercise for optimal recovery.**
    - **P5:** "If you don't do it, you'll lose it. And it's true. If you don't do the exercises you won't get the full use of what they've done. Of replacing the knee."
    - **P1: "**Yeah, you know, I mean, there's lots of times when you don't want to. And it would be a lot easier not to. But if they actually do make you feel better in and the icing post exercise also helps. So, you know, I think you've probably got to be prepared to do six months of exercise as I look at it now. Now, I probably would have told you before surgery, maybe three months, but for me it's goanna be longer."
    - **P3:** "So, what I would tell people is you know push it to what you think is the limit right off the bat. Work on the mobility and stretching cause that's the most important thing and you'll feel a ton better, a lot quicker than you can imagine the recovery would be. Don't even hesitate."
    - **P2:** "So many people have done [a total knee replacement] it and are thrilled with the results and I probably will be when it's all over, but I would say, you know, it isn't just a piece of cake. Even without the complications, it's a long haul. And to make it all worthwhile, you have to really be persistent about the exercises and that's not comfortable."
    - **P6:** "Um, but, sitting down and doing nothing is just the worst thing in the world. You can't do that. You have to get up and walk if nothing else. Some people don't like walking well. Um, I don't know how she can fix that. Because you certainly can't, sitting down all day is the worst thing do. You can't just turn into a complete solid rock. You must move because

the muscles are just going to atrophy. You know, like I know I can feel that for that first day I packed. I woke up. Oh, I'm hurting everywhere. Oh yeah, this is not good. So, I knew I had to walk it off and get it going. And so, you get to move. Um, but you can't not do it. You have to exercise; you can't sit have to get up. Yes. When you need somebody to get up and walk with you."

- **Prior understanding of exercise**
  - **Understanding importance of exercise from others who had experienced TKA**
    - **P5:** "Another good thing is, I had a friend who had her knee done. Mind you, she wasn't a good example because she didn't heal very well, but I think if they set you up with a buddy that has had knee surgery and has gone through it, it would be like a mentorship type of thing. You could ask and bounce questions off that person because you only go and see the doctor so many times. And if you don't have anybody you can ask the questions to, you're asking the physiotherapist. Well, they only see, they haven't experienced what a person has gone through with the knee and I think they would see different people, what they would go through."
    - **P3:** "I know my sister went through total replacements on both knees and her first one, she felt she didn't get the physio right away. She didn't feel well, she wasn't able to exercise at first for a couple of weeks vs the second one, she got out right away and she could tell the difference in her mobility and what she's capable of doing between the two."
  - **Understanding how to exercise from previous experience with physical activity**
    - **P3:** "I'm very fortunate that I'm very well balanced. I have extremely good balance. I've been fortunate with that all my life and in sports I was able to play a lot of sports at a high level because of that and now I've found that I'm getting it all back again. And even during the recovery because I had that I'm really well balanced, there was no real slips, there was no falls. I've had no falls, no slips throughout the entire rehab process."
    - **P1:** "You need a place where it works best way, and for me, some of it on the floor, but then I can actually get on the floor by sitting two steps. So, I can sit on the steps and then just go to the floor things like bridges and stuff like that. So, I just kind of set up a little gym thing near the stairs which I kind of just left there so that I have to look at it every day. So, I mean, in the beginning, I did this on the couch, but they're not as effective. Right. And like, that's too soft to do that so you just have to kind of figure out where you get the most out of it. Bridges had been part of the yoga stuff right from Monica's study, though, and the yoga that I did here, the therapeutic bridges were part of it too. So I mean, I kind of knew that that was a really good extension strengthening core

> exercise. Anyway, so if I hadn't known that beforehand. I probably would have just kept doing them on the couch. But you know, I know that they're much better. There's much more activity in the muscles being done on the floor."

Social Support

- **Support from family and friends**
  - **P1:** "Basically because, you know, I didn't have to do anything about meals. He made them for me. And he looked after the dogs. So, it allows me just to do what I needed to do, which was, you know, move around and exercise and recover right. He would ask me if I done them or if I was doing them, he would encourage me to keep doing them."
  - **P7:** "I have set up a bunch of friends to give me a hard time if I'm not doing it and to constantly check up on me and I actually have my nephew here today and he is like have you done your exercise, just have you done your exercises. Because I know if I don't have that I wouldn't."
  - **P2:** "So, my friend. She was amazing. She kind of certainly got herself into more than she bargained for. She stayed with me and I only ended up, you know, I was home Wednesday, stayed home overnight Wednesday. I had started on some exercises in the hospital. She started me on some. […] I would not have gotten to where I am, without having my family, my friends. Even my church community, who, you know, helped with food. I don't know how people do it on their own, honestly. The social support has been critical, really crucial."

Condition-Related Factors

- **Post-operative complications that limited ability to exercise post-operatively**
  - **P5:** "I had to have a knee manipulation because the scar tissue had built up so bad that I was limited in what I could do with my knee. […] I felt that I couldn't push through doing some of the exercises. I was doing the ones that they had given me at the hospital but the one where you slide your knee along the bed and bring it toward you, I could only go so far. My knee would not let me bend it to bend it fully and it was because of the scar tissue."
  - **P7:** "Recovery has been slightly different, because I did email and let you know that my leg actually broke during surgery. So, for two weeks I was bedridden. I was only allowed to put 30 pounds weight on the leg, which meant that equated to my big toe. So, and then type of exercising that I could do was severely limited because of the break in the tibia. And I saw the surgeon and after two weeks. He said, no, still no load bearing for six weeks, but I was I got myself into a wheelchair so I could be more mobile. So, for six weeks. The exercising literally that I can do was just flexing my feet up and down to get calf muscle to work. I couldn't do any strengthening exercise or any resistance exercises."
  - **P2: "**I think the main barriers [to exercise] were the complications, definitely, that I had with it. I think the complications and the fact that there wasn't a lot of

information that went with it. So, okay, I had pulmonary embolism, and I had to have blood thinners. I had no idea. If I thought about it, yeah, sure, I could figure that maybe I would be more likely to have a bleed and maybe shouldn't press myself or push myself but nobody actually said that to me and I was still post-operative so I really wasn't thinking a lot for myself. So, I think more information about the complications and how that might impact or change the way I did the exercising would have been very helpful and might have prevented the bleed."

- **Comorbidities**
    - **P6:** "I actually need both knees replaced. So even with this one being. The other knee does not support me doing a lot of exercise right now. I physically cannot go up and down stairs yet. I've got 16 stairs in two flights to get down to my basement and I cannot make it. That can go down, but I cannot make it back up without assistance. So right now, until I get both needs done that is what's preventing me from doing stuff right now."

Health Care System

- **Patients require more guidance for exercise therapy post-operatively**
    - **P2: "**I think the main point I would make is just that looking back having the people supporting me more informed about the things that could go on. Especially around the exercising, because I do think that I was not careful enough, but I didn't know not to be. I was very much encouraged to kind of push through which I think is probably the right thing to do and in any other circumstance. But I think people, maybe physiotherapists who deal with total knee replacements, if they have more awareness of what the ramifications are for someone with a pulmonary embolism and it's a 5% to 7% chance of happening with this kind of surgery. I think if they had that information in their pocket, so to speak. Yeah, I think it would have it would have helped me if they could modify their strategy or approach for that situation, rather than a one size fits all."
    - **P2: "**I've been very nervous about taking on anything new physically, because one of the things that happened is that I took on one of the things that prompted the bleed. That I was a little overly zealous using those muscles and I think part of it is that no one warned me not to, you know, I don't think it happens that often that maybe physiotherapists don't realize that hey, this is a possibility so we've got to help this person pay more attention to what's going on in their body instead of. Having some warning about what could happen. I'm not sure it would have changed things but, it did make me, one of the things that was positive about it as it did make me much more adamant about my own limitations."
    - **P6: "**There is no rule. There's no guideline to say, okay, week one week two, week three, like what to expect. There is no expectation at all. Other than okay so we got this little pamphlet with the exercises to do and all of that stuff. And I did it, but I mean come week six I was doing quite well. But, you know, I was working at it just wasn't making a point of doing it once every hour."

- **Patients require more guidance for exercise therapy pre-operatively**

- **P7: "**I didn't even know I could do physiotherapy before [surgery]. So even when I went even when I had gone to my GP because I was in so much pain. At there was never a mention of let's send you to physio so you can build up your muscles before."
- **P5: "**I guess because they all knew what I was doing, because I was walking a lot and doing the stairs, they didn't really give me much exercises to do at home. They just encouraged me to keep walking, keep moving. Dr. Levy was telling me to do the squats to strengthen the muscles in the upper part of the leg. He said it would help me in time but to me I didn't notice any difference. If anything, it was only aggravating my knee because at that time, when you did a squat my knees were really sore, and to put pressure on your knee doing a squat and then holding it, that was making it even worse."

Chapter 4: Discussion & Future Direction

Knee OA is one of the leading causes of disability worldwide.[1] TKA is often recommended in individuals with end-stage knee OA, after conservative management (e.g. exercise, manual therapy, injections, etc.) fails.[2] TKA place a large burden to the Canadian Health care system with over 700 million dollars spent on this procedure annually.[3] While TKA often leads to decreased pain and increased function, up to 1 in 5 patients are not satisfied with the outcome.[2] Studies have shown that 14-36% of patients experience no change or worsened outcomes post-operatively,[4] and 10-34% have long-term self-reported pain.[5] Exercise has been shown to be effective at improving pain, physical function, mobility and quality of life post-operatively.[6, 7] Understanding adherence to exercise post-operatively is essential in improving health outcomes.

This thesis includes two manuscripts that aimed to increase understanding of exercise adherence in this population. The first manuscript assesses limitations within reporting of exercise protocols and adherence in post-operative TKA rehabilitation trials, while the second study assessed barriers and facilitators of exercise adherence that should be incorporated into clinical trials. A summary of each manuscript, as well as future directions will be provided in this chapter.

1.1 Summary of Chapter 2

1.1.1 Reporting of Post-Operative Rehabilitation Interventions and Adherence for Total Knee Replacement: A Scoping Review

The first manuscript in this thesis was a scoping review that evaluated exercise adherence and the quality of reporting of exercise interventions within post-operative TKA rehabilitation trials. A systematic search of scientific databases was conducted for RCTs that included an exercise intervention for post-operative TKA. This study found that 63% of studies did not adequately report exercise adherence, and only 23% reported a definition of adherence. Quality of reporting of interventions was also very poor, with no studies fulfilling all the criteria of the CERT. In

general, the RCTs were of poor quality, with 85% of studies having high or unclear risk of bias. Inadequate reporting of specific rehabilitation procedures may lead to improper clinical application which could lead to potential harm.[8] The CERT criteria are particularly important in intervention reporting to reduce bias in implementation, as well as standardization for future studies or clinical replications.

1.2 Summar of Chapter 3

1.2.1 Understanding Barriers and Facilitators of Exercise Adherence after Total-Knee Arthroplasty

The second manuscript in this thesis is a qualitative study that aimed to understand the patient-related barriers and facilitators of exercise adherence in patients immediately after undergoing TKA. Using an interpretive descriptive approach, semi-structured qualitative interviews were conducted at 8-weeks post-operatively. This study identified 7 themes were identified as personal and environmental characteristics that affect exercise adherence that include: self-regulation, knowledge of exercise, post-operative complications, comorbidities, social support, and lack of guidance from health care providers (i.e. exercise guidance and progression). These themes were then mapped onto 4 overarching themes from the WHO adherence framework:[9] patient-related factors, condition-related factors, health care system, and social support. In particular, self-regulation, knowledge of exercise, post-operative complications/limitations, comorbidities, social support, and lack of guidance from health care providers were identified as personal and environmental characteristics that affect exercise adherence.

The overall findings of this study suggest exercise adherence is a multifaceted construct with interconnected concepts. It is essential that the health care practitioner provide adequate

information on how to progress/modify exercise for individuals post-surgically. Exercise was generally viewed as a positive facilitator for recovery from surgery; however, it is unclear if participants will continue to engage in regular exercise in the long term. Current health interventions, after TKA, do not foster sustainable behavioral change over the long-term.

1.3 List of Key Findings

1.3.1 Chapter 2

- The majority of RCTs on post-operative TKA rehabilitation did not adequately report exercise adherence (e.g., definition, outcome measure used and results) and very few provided a definition of adherence in the context of their study.
- When assessed, adherence was commonly measured as the number of supervised exercise sessions and self-reported exercise diary.
- Adherence was rarely the focus of any RCTs and often mentioned as a secondary outcome measure.
- RCTs were of poor quality, with the majority of studies having high/unclear risk of bias.
- The overall reporting of the CERT items was very poor with 15 out of the 19 items being reported in less than 60% of the RCTs. The most commonly reported items in the CERT included mode of delivery (Item 2: Group or individual; Item 3: Supervised or unsupervised), setting (Item 12), and if the intervention was tailored or not (Item 14a), ranging from 80-99%.
- The control group treatment protocol was more likely to be underreported compared to the intervention group, despite both containing exercise components.

1.3.1 Chapter 3

- Post-operative exercise adherence is a multifaceted construct with interconnected concepts
- Self-regulation, knowledge of exercise, post-operative complications, comorbidities, social support, and lack of guidance were identified as personal and environmental characteristics that affect exercise adherence.
- Patient-Related Determinates of Adherence
    - Creating daily routines increased engagement with exercise post-operatively.
    - Positive reinforcement in the form of increased muscle strength, as well as working towards a particular goal promoted fidelity and adherence.
    - Prior knowledge of the perceived benefits of exercise helped to foster competence and confidence in post-operative rehabilitation.
- Socioeconomic Determinates of Adherence
    - Increased social support from family and friends fostered increased exercise adherence.
- Condition-Related Determinants of Adherence
    - Health due to sequalae of the surgical intervention (e.g. pain, post-operative compilations) as well as comorbidities (e.g. pain in the opposite knee) were barriers to exercise adherence.
- Health care System Determinants of Adherence
    - Lack of adequate information regarding safety of exercise and progression presented as a barrier to exercise adherence.

1.4 Limitations

This thesis contributes to the scientific literature in assessing and understanding exercise adherence after TKA. There were several limitations, however; in the implementation of these manuscripts.

In Chapter 2, we only assessed rehabilitation interventions for individuals who underwent TKA, excluding unicompartmental knee replacements and revision surgeries, which may limit generalizability. The RCTs included in this study were not limited by year, which may alter the results as reporting of interventions has improved over time.[8] Additionally, studies that have poor adherence are generally less likely to be published, leading to publication bias, and possibly overestimation of adherence in this study. Lastly, there was no considerations of effectiveness of each intervention, as the primary focus of this study was to assess quality of reporting.

For Chapter 3, one of the main limitations was small sample size as data collection was halted due to COVID-19. The use of descriptive analysis, however, provided rich and exhaustive descriptions from participants regarding adherence. The majority of the participants in this study were female, with the exception of one, which may limit overall generalizability. The aim of this study, however, was not to provide generalizable results rather understand facilitators and barriers of adherence. Lastly, the results of this study may have been impacted by COVID-19 as participants were on lock-down when the interviews were conducted which may have provided physical and psychosocial impacts to their responses.

1.5 Knowledge Translation Recommendations

The primary goal of this research was to promote clinical change by providing a better understanding of the current interventions after TKA, and the facilitators and barriers of exercise adherence. Poor reporting of exercise interventions is particularly concerning as it limits reproducibility and translation of research into clinical practice. Inadequate information regarding adverse events, exercise description for instance, can lead to improper incorporation of research interventions in clinical practice, leading to potential increased harm. To improve quality of reporting of interventions authors should: 1) Use a tool for reporting of exercise intervention (e.g. TiDER or CERT, 2) Adequately report exercise interventions even if it is an adjunct to the main intervention (e.g. electrotherapy plus exercise, control group, etc.). Interventions should be reported either within the manuscript or as an appendix to improve reproducibility within research, as well as translation into clinical practice.

To improve quality of reporting for exercise adherence authors should use valid, reliable, and consistent outcome measures of exercise adherence, provide a clear definition of exercise adherence, and use a continuous outcome measure (rather than a cut-off) to avoid reporting bias. Patients should not be excluded from the study or analysis as a result of poor adherence as this would add significant bias and not comply with an intention-to-treat analysis. Rather, when adherence is of concern authors could consider a per-protocol analysis as an adjunct to the primary intention-to-treat analysis. Measuring adherence is essential in determining effectiveness of an intervention. Low adherence to an intervention may be related to poor implementation, inadequate delivery, increased complexity or difficulty of the intervention, or patient-related factors (e.g. complications, lack of time, etc.). Lack of information regarding exercise adherence

limits the ability to translate into clinical practice, where adherence rates are significantly poorer compared to a clinical trial. Future studies should include reporting tools that facilitate easier transition of research into clinical practice.

Additionally, there are several barriers and facilitators of exercise adherence that emerged from Chapter 3. Development and implementation of interventions that address self-regulation, knowledge of exercise, health care system, social support, either pre- or post- operatively may lead to increased exercise adherence post-operatively. More importantly, addressing these factors may also lead to behavioral change that foster long-term adherence to exercise. The failure of health care providers to recognize their role in facilitating behaviour change may contribute to poor exercise adherence.[10] Patients felt that they did not have adequate information regarding exercise post-operatively. Clinically, health care providers should review barriers and facilitators of exercise prior to surgery, provide patients with adequate information on post-operative rehabilitation (e.g. complications, progression of exercise, etc.), and provide adequate follow-up to ensure adherence. The majority of patients receive educational material and an exercise pamphlet post-operatively, then discharged from care. Clinicians should identify patients that would benefit from a structured rehabilitation program or more physiotherapy sessions. In particular, clinicians and patients should work together to create a treatment plan that increases exercise adherence and fosters long-term behavioral changes. Researchers should develop and implement pre-operative interventions that incorporate the various facilitators and address the barriers of exercise adherence. Additionally, longitudinal studies should be conducted to determine if pre-operative interventions foster long-term exercise adherence.

1.6 Conclusions

Total knee arthroplasty is a very common surgical procedure and exercise intervention are often recommended post-operatively to improve pain and function. Addressing adherence to exercise post-operatively may facilitate better long-term health outcomes. Our study provided evidence of poor quality of reporting of TKA rehabilitation interventions as well as adherence to these interventions. This limits reproducibility of exercise interventions as well as translation into clinical practice. Additionally, there are several facilitators and barriers (e.g. self-regulation, knowledge of exercise, health care system, social support, etc.) that influence exercise adherence post-operatively which are often not addressed as core content of the available RCTs. Health care providers should work collaboratively with patients to address these facilitators and barriers and provide tailored interventions to improve adherence to exercise.

1.7 References

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