A PILOT RANDOMIZED TRIAL OF A NOVEL INTERVENTION TO
PROMOTE PHYSICAL ACTIVITY IN PEOPLE WITH KNEE OSTEOARTHRITIS:
PROTOCOL AND BASELINE ANALYSIS FROM THE TRACK-OA STUDY

by

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
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Abstract

Objectives: (1) Develop a protocol for a pilot randomized controlled trial (RCT) of a novel physical activity (PA) counseling intervention to increase bout moderate-to-vigorous physical activity (MVPA) time (bout ≥ 10 minutes at ≥ 3 Metabolic Equivalents [METs]) and decrease bout sedentary time (bout > 20 minutes at ≤ 1.5 METs) for people with knee osteoarthritis (OA), and (2) conduct a secondary baseline analysis to assess the relationships between a measure of patient engagement and bouted MVPA time, as well as bouted sedentary time.

Methods: A protocol for a pilot RCT was developed and published. Feasibility objectives related to study processes, resources, management, and effectiveness were set. Inclusion criteria were a diagnosis of knee OA or having experienced four weeks of knee symptoms during the last year, no inflammatory arthritis, and no contra-indications to being active. Patient engagement was measured with the Partners in Health Scale (PIH). MVPA and sedentary time were measured with the BodyMedia SenseWear Mini (SW). Knee OA status was assessed with the Knee injury and OA Outcome Score. Bivariate and stepwise regression analyses were performed to estimate the relationship between PIH and bouted MVPA/sedentary time.

Results: Participants (female = 28, male = 6), were aged [mean (standard deviation [SD])] 55.5 (8.6) years, with a BMI of 27.2 (4.7) kg/m². The sample indicated a PIH of 24.4 (16.4), 53.9 (62.4) minutes of daily bouted MVPA, and 508.9 (178.9) minutes of bouted sedentary time. Regression analysis [b (standard error [SE]) where b indicates estimated regression coefficient] found log-transformed bouted MVPA was not associated with PIH, but was negatively associated with age, $b = -0.042 (0.018; p < 0.01)$ and BMI, $b = -0.15 (0.031; p < 0.001)$. Bouted sedentary time was not associated with PIH, but was positively associated with BMI, $b = 27.47 (4.29; p < 0.001)$ and female sex, $b = 156.01 (51.93; p < 0.001)$. 
Conclusion: Patient engagement may not be associated with objectively-measured physical activity among people living with knee OA, methodological factors and a small sample size may have contributed to the findings. Further work is needed to clarify these relationships.
Preface

This thesis contains the published TRACK-OA study protocol developed with oversight from Dr. Linda Li in collaboration with her research team (Chapter 2). The manuscript was written by the candidate, with approval from all secondary authors. Additionally, this thesis contains a study conducted by the candidate under the supervision of Dr. Linda C. Li, with the guidance of Dr. Charlie H. Goldsmith, Dr. Lynne Feehan, and Dr. William Miller. The study was a secondary analysis of the baseline data collected from TRACK-OA participants. The study design and analysis were primarily the work of the candidate.

Ethical approval for the TRACK-OA study was provided by the University of British Columbia Clinical Research Ethics Board (H14-02631).
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<td>ACL</td>
<td>Anterior Cruciate Ligament</td>
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<tr>
<td>ACR</td>
<td>American College of Rheumatology</td>
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<tr>
<td>ADL</td>
<td>Activities of Daily Living</td>
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<td>ARC</td>
<td>Arthritis Research Canada</td>
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<td>ASMP</td>
<td>Arthritis Self-Management Program</td>
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<td>BAP</td>
<td>Brief Action Planning</td>
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<td>BCT</td>
<td>Behaviour-Change Technique</td>
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<td>BMI</td>
<td>Body Mass Index</td>
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<td>Btd.</td>
<td>Bouted</td>
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<tr>
<td>CI</td>
<td>Confidence Interval</td>
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<tr>
<td>CSEP</td>
<td>Canadian Society for Exercise Physiology</td>
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<td>EULAR</td>
<td>European League Against Rheumatism</td>
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<td>KG</td>
<td>Kilogram</td>
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<td>KOOS</td>
<td>Knee Injury and Osteoarthritis Outcome Score</td>
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<td>MET</td>
<td>Metabolic Equivalent of Task</td>
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<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<tr>
<td>MVPA</td>
<td>Moderate-to-Vigorous Physical Activity</td>
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<td>NHANES</td>
<td>National Health and Nutrition Examination Survey</td>
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<tr>
<td>NSAID</td>
<td>Non-Steroidal Anti-Inflammatory Drug</td>
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<td>OA</td>
<td>Osteoarthritis</td>
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<tr>
<td>Acronym</td>
<td>Description</td>
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<td>OARSI</td>
<td>Osteoarthritis Research Society International</td>
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<td>OTC</td>
<td>Over-the-counter</td>
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<td>PA</td>
<td>Physical Activity</td>
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<td>PIH</td>
<td>Partners in Health Scale</td>
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<td>QOL</td>
<td>Quality of Life</td>
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<td>RA</td>
<td>Rheumatoid Arthritis</td>
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<td>ROA</td>
<td>Radiographic Knee Osteoarthritis</td>
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<tr>
<td>SCT</td>
<td>Social Cognitive Theory</td>
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<tr>
<td>SD</td>
<td>Standard Deviation</td>
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<td>SE</td>
<td>Standard Error</td>
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<td>Sed.</td>
<td>Sedentary</td>
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<td>SOA</td>
<td>Symptomatic Knee Osteoarthritis</td>
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<tr>
<td>SMART</td>
<td>Specific, Measurable, Attainable, Realistic, Time-bound</td>
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<tr>
<td>SMD</td>
<td>Standardized Mean Difference</td>
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<tr>
<td>SW</td>
<td>BodyMedia SenseWear Mini Armband</td>
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<tr>
<td>TKA</td>
<td>Total Knee Arthroplasty</td>
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<tr>
<td>TPB</td>
<td>Theory of Planned Behaviour</td>
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<tr>
<td>TTM</td>
<td>Transtheoretical Model</td>
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I find myself immensely grateful to many people for the roles they played in supporting me throughout this degree. I owe a great debt to my supervisor, Dr. Linda Li, from whom I have learned so much, and whose guidance, support, and commitment throughout this process has been instrumental to my success. Similarly, a great thanks is owed to my committee members Dr. Charlie Goldsmith, Dr. William Miller, and Dr. Lynne Feehan for taking time to provide mentorship and insights that shored up my understanding of how one actually goes about doing this wonderful thing we call science.

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Dedication

To Gramma and Gramps.
Chapter 1: Introduction

1.1 Thesis Overview

This thesis is divided into four chapters. Chapter 1 provides an introductory overview of knee osteoarthritis (OA), with a brief discussion of effective management strategies and a focus on appropriate self-management of the disease. Within the context of knee OA self-management, the pivotal role of the engaged patient is highlighted, and the broad benefits of physical activity (PA) participation for this population are discussed. Finally, a discussion of effective PA promotion techniques is given. Chapter-specific objectives are given within each subsequent chapter (Chapters 2 and 3). Chapter 2 leverages the discussion of PA promotion strategies in the development of the protocol for the TRACK-OA study, a pilot randomized controlled trial (RCT) that assessed the feasibility and preliminary efficacy of a new intervention designed to increase PA participation among people living with knee OA. Follow-up results for this trial are not included in this thesis, but will be published in a future manuscript. Chapter 3 outlines an exploratory cross-sectional analysis of the baseline data from the TRACK-OA study (pre-randomization) that aimed to assess the relationships between a measure of patient engagement and time spent participating in two key PA behaviours. Chapter 4 provides a discussion of the results of this analysis, as well as limitations and future work before concluding the thesis. Note that the use of the word “significant” throughout this thesis refers to statistically significant differences ($\alpha = 0.05$), and not a subjective judgment on the part of the author.

1.2 Overview of Osteoarthritis

OA is by far the most common chronic joint disease, alone affecting over four million Canadians [1]. OA is a progressive, degenerative condition that primarily affects the knees, hips,
hands, and spine. Classically, OA has been thought of as a disease of eroding cartilage, but it is now recognized as a “whole joint” disease that involves relatively early bone remodeling, cartilage degeneration, and synovial inflammation that can result in changes in the peripheral nervous system’s processing of joint nociceptive signaling. The hallmark outcomes of these processes are pain and stiffness that can result in increasing levels of functional disability as the disease progresses [2].

The burden of OA on the individual and society is substantial. OA-related joint pain, stiffness, and functional limitations can lead to decreased ability to participate in activities that are valued or necessary for daily living [3]. Symptoms of fatigue and restless sleep can further reduce quality of life [4–6]. According to the Arthritis Alliance of Canada, one in eight Canadian adults were living with OA in 2011 [1]. Due to a combination of factors such as increasing rates of obesity, greater longevity, and a sedentary lifestyle, the prevalence of OA is expected to be more than double within a generation [1]. Economic costs related to OA in Canada are also substantial. In 2010, total economic burden of the condition was estimated to be $27.5 billion, including over $10 billion in direct healthcare costs (e.g. doctor visits, surgical procedures) and over CAD $17 billion in indirect costs (e.g. work absenteeism, disability). In tandem with the projected increase in OA prevalence, direct and indirect OA-related costs are expected to increase drastically over the next 30 years, reaching as high as $1.45 trillion by 2040 [1].

1.3 Knee Osteoarthritis

The most common joint affected by OA is the knee, though prevalence varies by definition. Knee OA is most commonly classified radiographically, with x-ray-visible features
used to identify OA severity according to the Kellgren/Lawrence (K/L) scale [7]. This scale
grades radiographic knee OA (ROA) in five levels (0-4) based on the presence of osteophytes
(grade > 1), with more severe grades having successive appearances of joint space narrowing,
sclerosis, cysts, and deformities. In epidemiological studies, a cutoff of at least K/L grade 2
(definite osteophytes and possible narrowing of joint space) has typically been used to indicate
the presence of ROA [8]. For example, in the Framingham study, an American longitudinal
cohort of over 5200 men and women between the ages of 30 and 62 years beginning in the
1950’s, ROA was present in 19.2% of individuals over 44 years [9,10]. A nationally
representative American sample, the National Health and Nutrition Examination Study
(NHANES), demonstrated a higher prevalence with ROA present in 37% of participants over 60
years [11].

Clinically, OA manifests as a syndrome of chronic joint pain that can be accompanied by
varying degrees of functional disability and reduced quality of life [12]. About a quarter of
adults over 55 years live with chronic knee pain [13]. Criteria for the clinical classification of
OA were developed in 1986 by the American College of Rheumatology (ACR; then the
American Rheumatism Association) and have been shown to correlate well with cartilage
damage [14]. These criteria, however, have primarily been used to standardize reporting in
research. In 2009, the European League Against Rheumatism (EULAR) convened an expert task
force with the goal of developing evidence-based guidelines for the clinical diagnosis of knee
OA. This panel found six symptoms and signs that, when all present, yielded a 99% likelihood
of having K/L grade ≥ 2 in adults over the age of 45 years. These clinical features were
persistent knee pain, morning stiffness, reduced function, crepitus, restricted movement, and
bony enlargement [15].
While studies have indicated the relationship between chronic knee pain and subsequent development of knee OA [16,17], there is an acknowledged discordance between the existence of ROA and symptomatic presentation [18]. In 2008, Bedson and Croft conducted a systematic literature search to ascertain both the presence of ROA in people living with chronic knee pain and the presence of chronic knee pain in those with ROA. They found wide variation among studies, with 15% - 76% of those living with knee pain reporting ROA, and 15% - 81% of those with ROA reporting knee pain [19]. A more recent cross-sectional study by Muraki et al. (2015) showed knee pain to be present in about 10% of men and 15% of women with K/L grade 0 or 1, 11% of men and 20% of women with K/L grade 2, and between 42% - 49% of all individuals with K/L grade 3 or 4 [20]. These findings help to clarify the relationship between ROA and symptomatic presentation and are in line with other studies showing that severe radiographic disease is more frequently associated with deleterious knee pain [9,21]. Thus, symptomatic knee OA (SOA) is generally defined by the presence of chronic pain, stiffness, or aching in a joint that has evident ROA [7]. Unsurprisingly, reports of SOA are lower than those using radiographic evidence alone. In the Framingham study, 6.7% of people over the age of 44 years reported SOA. Similarly, in the NHANES study, 12% of people surveyed were affected by SOA [9,11]. Given that those with symptomatic disease are most likely to require medical treatment and suffer from functional disability, this is a group of importance for health intervention.

1.4 Knee Osteoarthritis Risk Factors and Comorbidities

Because of its complex etiology, a precise pathogenesis of knee OA is often difficult to identify. The condition is now recognized as a metabolically active process that can result from a variety of insults and pathologies that yield a common clinical endpoint [22]. As such, OA
may be best described as a failure to properly repair damage from stresses that may arise from any tissue within the synovial joint [23]. Such intra-articular stress may result from biomechanical [24] or biochemical causes [25], and genetic factors may further act to increase an individuals’ risk of pathological joint processes [26]. Thus, the development of knee OA can be summarized as a multifactorial process resulting from the dynamic interplay between systemic and local risk factors.

1.4.1 Systemic Risk Factors

Systemic risk factors contributing to the development of knee OA are thought to increase the vulnerability of the joint to abnormal biomechanics and subsequent pathology. While not considered a normal part of the aging process, increasing age is a major risk factor for knee OA development [9,11,27]. Using population administrative data from British Columbia, Kopec et al. (2007) showed that prevalence of OA increased markedly across the lifespan, affecting 3% of those 30-34 years, 14% of those 50-54, and 37% of those 70-74 [28]. This increasing pattern is thought to be due to cumulative exposures to other risk factors and a concurrent decrease in the robustness of the joint as aging continues [7]. Female sex is another risk factor, with women about 1.5 times more likely than men to develop knee OA and also more likely to suffer more severe symptoms [29]. Susceptibility to OA is further known to vary along ethnic lines. While studies have yet to specifically investigate knee OA, First Nations populations in Canada are known to suffer from disproportionately high rates of arthritis [30]. Moreover, prevalence of knee OA among Chinese females in the Beijing OA Study was found to be significantly higher than Caucasian women in the Framingham study [31]. Relatedly, there is an increasing recognition of the role of genetic factors in OA development. Sibling studies have suggested that
genetic predisposition to knee OA may account for half or more of cases [32,33], possibly through increasing the likelihood of presenting with other established risk factors or through increased susceptibility to more severe OA phenotypes [34].

1.4.2 Local Risk Factors

Systemic risk factors, while important to an understanding of disease pathology, may be difficult or impossible to change. Conversely, local factors that influence how load is transmitted across the knee joint may be modifiable and represent good targets for intervention. In general, local risk factors tend to adversely affect normal biomechanics of the knee. In a healthy joint, epidemiological and experimental evidence suggests that dynamic loading (through moderate PA, for example) is beneficial for the maintenance of proper cartilage homeostasis. However, in situations where the joint is compromised (e.g. by injury or excessive loading) such loading may lead to catabolic processes that contribute to OA development [35]. Several systematic reviews have found a link between knee OA and occupational duties [36–38], with occupations that involve frequent kneeling, squatting, lifting/carrying, and heavy standing work consistently being linked to the condition [39]. A 2013 cross-sectional study by Ezzat et al. compared the presence of ROA, SOA, and MRI evidence of knee OA in two population cohorts made up of individuals with varying amounts of cumulative occupational physical load. The authors found the risk of ROA of those in the highest quarter of cumulative occupational physical load was three times that of those in the lowest quarter. Moreover, the analysis discovered a dose-response relationship between risk of symptomatic and MRI knee OA and increasing cumulative occupational physical load [40].
Frequent or excessive joint loading may be particularly problematic in the context of a weak or compromised knee joint. As the quadriceps muscles absorb load and provide dynamic stabilization across the knee, weakness in these muscles is thought to play a key role in OA development [41,42]. Evidence suggests that weak quadriceps may precede the development of ROA in women [43] and are strongly associated with knee OA symptoms [41]. Muraki et al. (2015) showed the odds of having knee pain for men and women in the lowest fifth of quadriceps strength were 5.87 times and 2.78 times, respectively, that of those in the highest fifth, independent of ROA status [20]. A history of acute knee injury may also compromise the joint and drastically increase the risk of developing OA. In particular, injuries to the anterior cruciate ligament (ACL) have been strongly linked to OA [44,45], with studies of soccer players who suffered ACL injury finding roughly 80% developed evidence of ROA within 14 years and 70% exhibited functional limitations [44,46]. A 2014 systematic review found that 20% of ACL-injured knees had moderate to severe radiographic changes after 10 years, while such changes were present in 5% of the uninjured, contralateral knees [47].

An important modifiable risk factor in the development of knee OA is obesity [48,49]. Risk of OA is known to increase with increasing body mass index (BMI), and a majority of obese individuals will develop SOA in their lifetime [48,50]. In the Rotterdam study, a large population-based cohort of people 55 years and up from the Netherlands (n = 1372) were followed for a mean 6.6 years to examine the relationship between body weight and knee OA onset and progression. The odds of developing knee OA for those with a BMI over 27.5 kg/m² (overweight to obese) were 3.3 times that of those with BMI < 25 kg/m² at baseline, with similarly higher odds of OA progression for those who began the study with the disease [51]. Moreover, data from the Framingham study demonstrated a 50% decreased risk of developing
SOA for women who lost 5 kg [52]. Obesity has also been associated with increased reports of pain. In the NHANES III study, obesity was associated with 43.6% increase in the estimated prevalence of knee pain over those who were underweight [53]. Additionally, a UK study reported that asymptomatic obese individuals over 50 years old were over three times as likely as non-obese individuals to develop knee pain during a three-year follow up [54].

The role of overweight and obesity in knee OA development crosses the boundary between local and systemic risk factors. First, additional weight causes additional force loading across the knee joint which can contribute to or magnify existing mechanopathology [55,56]. A 2016 study by Harding et al. assessed tibiofemoral contact and muscle forces across the joint using three-dimensional gait analysis [57]. They found a positive association between BMI and compression and shear forces in the joint, and suggested that such increased forces may be particularly detrimental in a compromised, osteoarthritic knee [58]. Second, studies have suggested that systemic inflammatory markers related to adipose tissue may play a metabolic role in joint degradation. For example, leptin, a cytokine released by adipose tissue, has been found in the synovial fluid, cartilage, and osteophytes of OA-affected joints, but not in healthy joints. Levels of leptin in these tissues were positively correlated with BMI, and experiments with animal models found that leptin strongly activated the catabolic functions of chondrocytes [59]. The presence of other proinflammatory cytokines such as C-reactive protein, TNF-alpha, and IL-1 also positively correlate with increasing BMI and are known to mediate cartilage matrix degradation and joint inflammation [60].
1.4.3 Comorbidities

Considerable attention has been paid to the relationship between knee OA and obesity, but individuals often suffer from other chronic comorbidities that magnify their health burden and further decrease quality of life [61–64]. A cross-sectional study in the Netherlands found that 98.6% of individuals with knee and hip OA suffered at least one comorbid condition, with disease of the ear, eye, nose, and throat, cardiovascular disease, and metabolic syndrome among the most frequent [64]. Stang et al. (2006) investigated the prevalence of comorbidities in people living with arthritis and found significant associations with ulcer, chronic pain, hypertension, cardiovascular disease, respiratory disease, diabetes, and mental disorders [62]. Among mental disorders, depressed mood is known to be particularly prevalent in the knee OA population. Sale et al. (2008) examined the prevalence of comorbidity and depression in 1,227 individuals with OA who participated in a prospective cohort study. Aside from a high prevalence of hypertension (55%), heart problems (33%) and lung problems (23%), 21% of individuals were reported to have depressed mood [6]. Though the causality of the relationship remains to be determined, the presence of depressive symptoms has been found to be associated with more severe knee pain [65,66].

A particular concern is the possibility of a self-reinforcing relationship developing between knee OA and other chronic comorbidities. In a 2013 review Wluka et al. highlighted the vicious cycle that may develop between knee OA, obesity, and other conditions [49]. The cycle begins when an increase in pain associated with knee OA leads to a decrease in PA, decreasing energy expenditure. If debilitating pain and inactivity persist, decreases in muscle mass can coincide with weight gain, adding further load to an increasingly unstable, painful joint. This may result in the acceleration of OA-related structural changes and an increase in the
severity of pain that contributes to functional disability, further increasing risk of developing comorbidities that perpetuate the cycle [49]. In line with this hypothesis are findings suggesting people with OA are at an increased risk of cardiovascular disease [67], type II diabetes [68], and mortality from these conditions [69]. These studies suggest the need for interventions to mitigate the impact of knee OA and the health risks of associated comorbid conditions.

1.5 Management of Knee Osteoarthritis

OA remains a disease with no cure and no established method of halting disease progression. As such, ongoing and diligent management is required to deal with the challenges of the condition over time. In this context, management of knee OA refers to the broad array of strategies an individual may use to cope with the impact of the condition on their life and maintain their overall health and wellbeing. This encompasses the gamut of self-care activities an individual engages in (i.e. self-management), as well as the support and treatments received from caregivers (both informal and professional). As a progressive disease, management of knee OA may evolve over time. For example, not all individuals with chronic knee pain seek treatment [70], and many in early stage OA may opt to “bear with it” on their own. Over time, however, increases in pain or disability related to disease progression may prompt individuals to seek care [71,72]. For these people, various interventions may be recommended.

International bodies such as ACR, EULAR, and the Osteoarthritis Research Society International (OARSI) have developed evidence-based guidelines for the therapeutic management of knee OA. These guidelines first recommend treatment with non-invasive, conservative modalities. For example, ACR guidelines strongly recommend PA (both aerobic exercise and strength training) commensurate with ability, as well as weight loss (for people who
are overweight) as first-line management strategies. ACR guidelines also conditionally advocate further treatments such as attendance of self-management education programs (wherein individuals learn various strategies to successfully live with their condition), undergoing physical therapy, and treating pain with oral analgesics and (oral or topical) non-steroidal anti-inflammatory drugs (NSAIDs) as needed. Patients with end-stage disease who do not obtain sufficient relief from these treatments are recommended to consider opioid analgesics for pain management. If pain severely affects the person’s mobility and quality of life, total knee arthroplasty may be considered [73].

The 2012 EULAR recommendations focused on core non-pharmacological strategies for management of hip and knee OA. Generally in agreement with ACR guidelines, EULAR advocates that treatment take an individualized approach including a personal management plan involving OA education, education about exercise and weight loss, an exercise regimen, and a reduction in adverse mechanical factors as needed [15]. Most recently, McAlindon et al. (2014) published OARSI guidelines for the non-surgical management of knee OA. These guidelines suggest a graded approach to management, recommending land and water-based exercise, strength training, self-management education programs and weight management as core treatments appropriate for all individuals, management of pain with analgesics and NSAIDs as appropriate, and referral for consideration of orthopaedic surgery if other treatments are found ineffective [74].

1.5.1 Patient Engagement in Self-Management

A key aspect of the clinical recommendations outlined above is the emphasis placed on patient behaviours. For people living with knee OA, like other chronic conditions, the main
burden of day-to-day care falls to them [75]. As such, active self-management is necessary to ensure optimal health outcomes [76,77]. Generally speaking, the term “self-management” is used to describe the various strategies an individual uses to maintain their health and live well with one or more chronic diseases [78]. Several authors have highlighted common tasks that relate to successful self-management across chronic diseases (Table 1.1, right column). Performance of these tasks has been posited to be enabled by several key skills that enhance one’s ability to self-manage (Table 1.1, left column).

Table 1.1. Self-management skills and tasks

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<thead>
<tr>
<th>Self-management skills [75]</th>
<th>Self-management tasks [75,79,80]</th>
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<tbody>
<tr>
<td>Resource utilization</td>
<td>Gaining knowledge of the disease and treatment</td>
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<tr>
<td>Problem solving</td>
<td>Collaborating with healthcare professionals to develop care plans/goals</td>
</tr>
<tr>
<td>Decision making</td>
<td>Adhering to treatment plans</td>
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<tr>
<td>Forming partnerships with healthcare providers</td>
<td>Self-monitoring health status</td>
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<tr>
<td>Taking action</td>
<td>Accessing support and services when needed</td>
</tr>
<tr>
<td></td>
<td>Managing effects of illness on important life roles (physical, social, emotional)</td>
</tr>
<tr>
<td></td>
<td>Engaging in lifestyle habits that protect and promote health</td>
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The diversity of skills and tasks required for optimal self-management of chronic conditions such as knee OA highlights the need for engaged patients who are actively involved as partnering members of the care team [76,81]. Owing to this, “patient engagement” is a rapidly growing area of research, as researchers endeavour to measure, describe, and improve engagement among chronic disease populations [82]. Despite the expanding literature, a precise
Definition of patient engagement is yet to be agreed upon. Frequently, patient engagement is equated with the construct of “patient activation”, or the knowledge, skills and confidence patients possess for active self-management [83]. Other authors have defined patient engagement in terms of action, equating it to behaviours individuals (or families) take to facilitate their knowledgeable and skillful involvement as active members of their care team [84]. Others, still, have highlighted the role of emotion in patient engagement in health management [85]. Thus, patient engagement may be best described as an umbrella term used not only to describe the taking of actions (such as those outlined in Table 1.1 above), but also to indicate the psychological qualities required to effectively self-manage one’s health and chronic condition(s) [86].

Patients who report higher levels of engagement tend to report better health outcomes, thought to be due to greater participation in health behaviours [87]. For example, emerging literature utilizing the “Patient Activation Measure (PAM) [88] has demonstrated that individuals who report higher levels of activation also tend to perform more self-management behaviours, including medication adherence and PA [83,87,89–91]. Skolasky et al. (2011) demonstrated that 6.7% of individuals at lowest level of activation as defined by the PAM participated in PA five or more times in the previous week, relative to 16.2 % of individuals at the highest level of activation [90]. Additionally, Fowles et al. (2009) found individuals who reported exercising 0-3 days per week had a significantly lower mean PAM score (66.88; SD not reported), relative to people reporting four or more days of exercise in a week (73.29; SD not reported; $p < 0.001$) [92].

In addition to the emerging literature on patient activation as an indicator of engagement, evidence from the widely implemented Arthritis Self-Management Program (ASMP) suggests
beliefs regarding one’s ability to self-manage may be related to the performance of certain health behaviours within arthritis populations. The ASMP is a six week group education program covering a different aspect of successful arthritis self-management each week. The program explicitly attempts to improve participants’ beliefs about their ability to effectively manage the consequences of arthritis, or self-efficacy for self-management [75]. This focus on self-efficacy draws on the Social Cognitive Theory (SCT)-based claim that efficacy beliefs are a primary determinant of future behaviour [93]. As such, self-efficacy for self-management may be seen as an element of patient engagement. Research suggests self-management education programs improve self-efficacy for self-management of arthritis, performance of some behaviours, and psychological status. In a meta-analysis of all randomized controlled trials (RCTs) assessing the ASMP, Brady et al. (2011) reported the program leads to significant improvements in participants’ confidence in their ability to self-manage (effect size = 0.33-0.34), while also increasing the use of self-management strategies such as cognitive symptom management techniques (effect size = 0.40), and physician communication (effect size = 0.31) at one-year follow-up. Additionally, the program yields modest, transient increases in PA behaviours such as self-reported aerobic (effect size = 0.21) and stretching/strengthening exercises (effect size = 0.18) that do not extend beyond six months [94]. While this evidence suggests more positive beliefs about one’s arthritis self-management abilities may be related to the performance of health behaviours, it may also suggest such beliefs are not as strongly related to PA participation as other health behaviours, despite the importance of PA in arthritis management.

Due to the emerging nature of research in this area, relatively little is known about how levels of patient engagement relate to the health-related outcomes among arthritis populations. Furthermore, no reports were able to be located assessing how levels of patient engagement
relate to objective measures of important self-management behaviours such as PA. These gaps in the literature highlight the need for further study particularly within arthritis populations, a topic which will be returned to in Chapter 3. Such work may provide further insight into the benefits to be expected from involving arthritis patients more greatly in their care.

1.5.2 Physical Activity and Knee Osteoarthritis

As indicated by international guidelines, regular participation in PA is a cornerstone component of optimal self-management of knee OA. PA is defined as any bodily movement produced by skeletal muscles that results in energy expenditure [95]. A looming body of evidence states that regular PA is immensely beneficial for health and is associated with the prevention of a multitude of chronic conditions including diabetes, cancer, obesity, hypertension, bone and joint disease, depression, and all-cause mortality [96–99]. In a 2010 systematic review, Warburton et al. reported an inverse dose-response relationship in which increasing amounts of PA were associated with a decreasing risk of developing most of these chronic diseases [100]. As a result, the Canadian Society for Exercise Physiology (CSEP) guidelines suggest that adults of all ages should engage in at least 150 minutes per week of moderate-to-vigorous PA (MVPA) [100]. It is recommended this activity be performed in bouts of 10-minutes or more, as evidence suggests that three 10-minute bouts distributed throughout the day are as effective as a single bout of 30 minutes [101]. In addition, CSEP guidelines recommend adding at least two days per week of muscle and bone strengthening activities to obtain the benefits of an active lifestyle [102].

In addition to the holistic benefits discussed, a considerable body of evidence demonstrates that PA yields disease-specific benefits to those living with knee OA.
Deconditioning due to inactivity is common in this population, but greater levels of fitness obtained through aerobic exercise may increase capacity for effortful daily tasks and enhance quality of life [103]. Additionally, strength training helps mitigate muscle weakness and stabilize the joint, decreasing loading across the knee and improving joint functioning [104]. Several systematic reviews have compiled evidence that aerobic exercise and strength training both safely reduce pain and improve functioning in people living with knee OA [98,105–110]. In 2015, Fransen et al. provided an update to their Cochrane Review on the effects of exercise on knee OA and concluded there is high quality evidence for the therapeutic role of exercise, reporting a 12% decrease in pain and a 10% improvement in physical function. Additionally, they found a marginal but significant improvement of quality of life (4 points on 100-point scale) at 2-6 months follow-up [103]. Interestingly, both strength training and aerobic exercise appear to be similarly effective for symptom relief, with small to moderate effect sizes roughly equal to that of over-the-counter analgesics but without the harmful side effects [15]. Lower impact activities such as aquatic exercise are also effective for symptom relief in knee OA, and may provide an excellent starting point for individuals living with severe symptoms or other comorbidities [15].

Other forms of PA are also emerging as effective treatment modalities for knee OA. For example, a 2013 review of yoga interventions for people living with musculoskeletal conditions including OA found moderate effect size (0.61) for improvements in pain, function, and psychological outcomes [111]. Additionally, Tai Chi has been recommended in the 2012 ACR guidelines [73], as it has been found to reduce pain, increase physical function, enhance strength, and improve psychological outcomes [112,113]. At large, the literature suggests that among a variety of safe and available modalities, engaging in some form of regular MVPA commensurate
with one’s abilities will benefit knee OA symptoms, decrease risk of comorbidities, and improve psychological status. Because of this, enhancing participation in PA represents a high-impact area for intervention within the knee OA population.

1.6 Measuring Physical Activity

Valid and reliable measurement of PA is essential to determine the effectiveness of different PA promotion interventions. Different methods exist for obtaining estimates of activity levels. Estimates of energy expenditure are most accurately calculated by heat production (requiring a calorimeter), use of doubly-labeled water, or indirect calorimetry. These methods, however, lack feasibility in terms of cost and ability to be used for extended durations in the context of people’s daily lives [114]. Questionnaires are commonly used to quantify individuals’ activity levels because of their cost-effectiveness and ease of delivery, however questionnaires rely on memory and may be subject to reporting bias [115]. Furthermore, questionnaires may lack the precision necessary for detecting changes in daily PA levels [116].

More recently, objective measures of PA have become available in the form of wearable activity trackers. Wearable trackers may be worn for extended durations with minimal burden in the context of daily life and are not subject to the recall bias of questionnaires [114]. Activity trackers can be pedometers, accelerometers, or integrated multi-sensor systems [116]. While pedometers are limited to counting steps, accelerometers are able to detect motion in one, two, or three planes and can quantify the duration and intensity of a wearer’s activities. A number of accelerometers are currently available, the most popular including the ActiCal (Bio-Lynx, Montreal, PQ), RT3 (StayHealthy, Monrovia, CA), and Actigraph (Actigraphcorp, Pensacola, FL) [117]. These devices quantify PA in terms of “counts” averaged per period of time (usually
in 1-minute epochs), and regression models are used to convert the average counts min\(^{-1}\) into estimates of energy expenditure or intensity of activity. The Actigraph has been most commonly used in research and is able to be flexibly programmed with different models for analyzing activity counts, but its accuracy for predicting energy expenditure and intensity of activities has been shown to have limits [116–118]. For example, Lyden et al. (2011) showed the Actigraph underestimated the intensity of activities of daily living by up to 2.0 Metabolic Equivalents (METs), graded treadmill running by 2.4 METs, and basketball by 3.2 METs [117]. Furthermore, its hip-worn locale and limitation to use during waking-hours may not reliably measure non-ambulatory exercise activities such as cycling [119], as well light activities (around the home, for example) that are nevertheless relevant to overall energy expenditure [120].

Multi-sensor systems combine accelerometers with skin sensors that integrate information from other sources (e.g. heart rate, temperature) in an effort to provide a more accurate quantification of energy expenditure [116]. The BodyMedia SenseWear® Mini armband (SW; Pittsburgh, PA), for example, is worn on the upper triceps and incorporates demographic information with data from a triaxial accelerometer and skin sensor (detecting galvanic skin response, heat flux, and temperature) into proprietary algorithms to estimate steps, activity intensity, and energy expenditure. The SW is designed to be worn 24-hours a day, and provides additional information on sleep quality and duration. The SW has been validated in adult populations [121,122], including people living with rheumatoid arthritis (RA; [123]), people with knee OA who had undergone total knee arthroplasty (TKA; [124]), and people living with hip OA pre or post total hip arthroplasty [125]. The device has generally been found to have good validity when compared to references, though a previous version was shown to overestimate energy expenditure during intense activity in people with RA [123], and during
activities of daily living (particularly arm-based activities such as raking leaves) in patients with end-stage hip OA [125]. Importantly, energy expenditure measurements from the SW have been found to be strongly correlated with indirect calorimetry during sedentary activity and light activities \((r = 0.9)\) [126]. Furthermore, the SW is known to be more sensitive for differentiating between sedentary behaviours and light activities compared to Actigraph [126,127], likely because of its skin sensor and arm-based locale. Prior pilot testing in people living with RA found the device to be well-tolerated for 1-week durations while being worn 24 hours per day [128]. Thus, the SW is an appealing candidate for quantifying PA in research in the knee OA population.

1.7 How Active are People with Arthritis?

The vast majority of Canadians accumulate insufficient MVPA – 17% of men and 14% of women accumulate 150 minutes of objectively-measured MVPA in a week [129]. While this is a public health concern, people living with arthritis are less active [30,130]. Dunlop et al. (2011) quantified the PA levels of participants with knee OA using accelerometers, finding that 12.9% of men and 7.7% of women with the condition were meeting recommended PA guidelines [131]. Similarly, a 2013 meta-analysis estimated that people with knee OA were achieving a mean 50 minutes per week of objectively-measured MVPA, with as few as 13% meeting PA guidelines [132]. These low levels of PA in the knee OA population may be explained by disease-related factors (pain, disability, fatigue, fear of flare up), personal factors (lack of time, stress, lack of motivation), and environmental factors (lack of access to facilities such as pools, bad weather conditions) [133–135]. Moreover, the belief that OA is a result of “wear and tear” on the body may induce people’s fear of further joint damage if they are active [108,130].
Certain demographic factors have also been associated with PA participation in the knee OA population. A systematic review by Stubbs et al. (2015) found higher age, female sex, non-white ethnicity, and more severe OA symptoms to be consistent predictors of lower PA participation across studies [136]. Evidence from single studies suggest that other factors such as income [137], social functioning [138], and spousal support [139] may also be related to PA participation, but further research is needed to confirm these findings.

1.8 The Emerging Risk of Sedentary Behaviour

Low levels of PA in the knee OA population are particularly concerning given the emerging association of sedentariness with poor health outcomes. Sedentary behaviour has been defined as any behaviour of intensity ≤ 1.5 METs while in a sitting or lying position [140]. When measured (e.g. by accelerometer), sedentary activities are operationalized as any measured activity ≤ 1.5 METs. Strong links have been established between sedentary time and risk of metabolic syndrome, cardiovascular disease, diabetes, myocardial infarction, and all-cause mortality [141–147]. For example, Wilmot et al. (2012) conducted a meta-analysis comparing the studies of self-reported sedentary time (i.e. sitting or TV-viewing), assessing the differences within each study between the highest and lowest categories of participation in sedentary behaviour. The authors reported the most sedentary individuals had a 112% increased risk of diabetes, 147% increased risk of a cardiovascular event, 90% increased risk of death from a cardiovascular disease, and a 49% increased risk of all-cause mortality when compared to the least sedentary individuals [148]. Importantly, these increases in risk were independent of MVPA level, suggesting that decreasing sedentary time in favor of light activities may provide additional protection against various chronic diseases [143,148].
In addition to the cardiometabolic and physical health risks of high levels of sedentary time, it is thought that the method by which sedentary time is accrued may also present a health risk. Prolonged bouts (two-hour) of off-loading the hind limbs of rodents have been associated with maladaptive physiological responses such as decreased lipoprotein lipase (a muscle-based protein that transports triglycerides from the blood into the muscles) activity and decreased high-density lipoprotein (“good” cholesterol) in the off-loaded muscles compared to non-offloaded muscles [149]. Evidence of this “inactivity physiology” has been accompanied by observational and experimental human studies that suggest breaking up periods of lying down or sitting with periods of light activity every 20-30 minutes lowers one’s risk factors for chronic disease [150,151].

Aside from cardiometabolic health, sedentary time may also be a risk factor for poor functional outcomes. A report by Seguin et al. (2012) assessed the relationship between sedentary time and physical functioning in over 61,000 post-menopausal women. Over a mean follow-up period of 12 years, the authors reported a dose-response relationship linking increasing amounts of sedentary time to decreasing physical function [152]. Similarly, Dunlop et al. (2015) reported every additional hour of objectively-measured daily sedentary behaviour was associated with a 46% increase in the risk of disability in one or more activities of daily living among adults over 60 years from the NHANES cohort in the US [153]. Furthermore, sedentary time has been linked to poor health outcomes among knee OA populations. Reports from the OA Initiative, a prospective cohort of 4796 adults aged 45-79 years living with knee OA, demonstrated significant positive associations between sedentary time, high blood pressure [154], and functional decline (as indicated by decreased gait speed and chair-stand rate) [155,156]. Additionally, Dunlop et al. (2014) demonstrated an inverse relationship between time spent
performing objectively-measured light activity and onset of disability [157]. The mounting body of evidence regarding the risks of a sedentary lifestyle for poor OA and other health outcomes suggests that decreasing prolonged sedentary time could be an important additional component of optimal knee OA self-management.

1.9 Supporting Participation in Physical Activity

The previous literature highlights the need to support greater PA participation within the knee OA population. In particular there is a need for the development of effective interventions to encourage MVPA and decrease prolonged sedentary activity. Efforts to promote PA fall under the umbrella of “self-management support”, a term that refers to the array of activities undertaken to engage patients to more optimally self-manage their disease. The dominant paradigm in supporting self-management has been to provide educational interventions designed to enhance patients’ skill and confidence to engage in self-management activities, as in the ASMP. As mentioned above, these programs are based on SCT, aiming to increase self-efficacy for self-managing the consequences of arthritis. While a Cochrane review concluded self-management education programs to be effective at improving PA adherence [158], the relatively modest, transient effects as reported by meta-analysis [94] suggest that a more targeted intervention approach based on effective behavioural strategies may be necessary for more meaningful increases in PA.
1.9.1 Behavioural Theory – Theory of Planned Behaviour

Behavioural theory provides a useful starting point in understanding potential determinants of behaviour that may be targeted by interventions. While several behavioural theories have been applied to understand health behaviour, the Theory of Planned Behaviour (TPB) has frequently been applied to the PA domain [159,160]. The TPB posits intentions as the immediate antecedents of behaviour, with intentions being determined by an individual’s instrumental and affective attitudes toward the behaviour (i.e. “would this behaviour be beneficial/fun for me?”), subjective norms (i.e. “what do important others think of me performing this action?”), and perceived behavioural control (i.e. “how able am I to perform the behaviour?”) [161]. Perceived behavioural control was designed to be conceptually similar to Bandura’s construct of self-efficacy [162]. Figure 1.1 provides diagram of the TPB constructs and their posited relations.

Figure 1.1. Theory of Planned Behaviour construct diagram. The dashed line indicates the effect of perceived behavioural control on behaviour insofar as it reflects actual control over the behaviour (source: http://people.umass.edu/aizen/tpb.diag.html; reproduced with permission).
Evidence suggests the TPB is useful for explaining PA, with meta-analyses finding its constructs are able to explain 42-45% of the variance in PA-related intentions, and 27-36% of the variance in PA behaviour [159,160]. Thus, the TPB provides an appropriate motivational framework to inform the development of a PA-promotion intervention. Specifically, the TPB suggests the inclusion of intervention elements aimed to improve instrumental and affective attitudes towards PA, enhance norms about PA participation among people with knee OA, and build PBC for being active while living with knee OA.

1.9.2 Behaviour-Change Techniques for Physical Activity Promotion

Because of the widespread efforts to develop effective interventions for PA promotion, a body of evidence has accrued that may be leveraged to discern effective components of behavioural interventions. These have been dubbed “behaviour change techniques” (BCTs), defined as “observable and replicable components” of interventions designed to change behaviour [163]. A well-established BCT is goal setting. Several meta-analyses from healthy [164], obese [165], diabetic [166,167], older [168] and arthritic [169] participants have integrated goal setting as a key element of effective PA-support interventions. Indeed, the setting of goals can be considered analogous to the formation of intentions towards a behaviour as described in the TPB. This provides a role for persuasive education and information aimed to enhance attitudes, subjective norms, and PBC towards a target behaviour [170].

While the formation of goal intentions is necessary for behaviour change, intentions do not explain the majority (~70%) of the variation in behaviour. This phenomenon is referred to as the “intention-behaviour gap” [171]. A strategy aimed to bridge this gap is “action planning”, which is a BCT for the specification of the precise context – “the how, where, when, and with
whom” – for the execution of a goal-related behaviour. Thus, action planning can be seen as the formation of subordinate goals aimed towards the achievement of a super-ordinate goal. A common representation of action planning is the use of “SMART” (Specific, Measurable, Achievable, Realistic, Time-bound) goals [172]. For example, one may accomplish the overall goal intention to “become more active” by creating a SMART goal to “walk around the park nearby at 7:00 pm each night of the week, for two months”. Thus, action planning result in the development of a concrete plan to be executed in a defined context, allowing for environmental cueing of the desired behaviour [173]

Action planning has been related to the achievement of a variety of behavioural goals, including PA goals [174]. For example, Sniehotta et al. (2006) used detailed action planning as a component of an intervention to increase and maintain adherence to exercise among cardiac rehabilitation patients. Seventy-one percent of the intervention group met recommended levels of PA participation relative to 42% of controls, and engaged in 84 more minutes per week of exercise ($p < 0.01$) [175]. A key element in this goal setting and action planning process may be the identification and problem solving of potential barriers. This process aims to ensure the achievability of a goal intention, an important component of enhancing an individual’s control beliefs regarding a behaviour [93]. A meta-analysis of BCTs to promote PA among diabetic populations found interventions incorporating barrier identification and problem solving were significantly more effective at increasing PA (Standardized Mean Difference [SMD] = 0.81) than those that did not (SMD = 0.31; $p = 0.004$) [176].

Once goals have been set, encouraging individuals to monitor their behaviour may enhance the likelihood of successful behaviour change. Self-monitoring is a BCT aimed to increase awareness of behaviour relative to one’s goals, and is typically accomplished through
the use of paper diaries or logs for individuals to track activities and goal progress, as in the ASMP [75,177]. Within general populations, systematic reviews have demonstrated that prompting self-monitoring is a key component of effective PA promotion interventions [164,166,178]. For example, a meta-regression assessing BCTs associated with increased success in diet and PA interventions found the use of self-monitoring and at least one other BCT (e.g. goal review) was associated with increased performance of targeted diet and PA behaviours [164]. Similarly, a more recent systematic review of reviews by Greaves et al. (2013) found the use of a “cluster” of self-regulatory behaviours including goal setting and self-monitoring to be associated with greater PA among behaviour change interventions [166].

In addition to adoption (i.e. initial behaviour change), BCTs oriented towards assisting with maintenance of PA are also important as evidence suggests adherence to PA among people with knee OA tends to decline over time [179,180]. This decline is troubling, as ongoing adherence is necessary to maintain health benefits [98,179]. An example of a maintenance-oriented strategy is the provision of follow-up contact from healthcare providers. In a meta-analysis of PA-support interventions in general populations, Fjeldsoe et al. (2011) found a higher percentage of interventions that made use of follow-up prompts (88%) were successful at maintaining increases in PA compared to those that did not (66%) [181]. Relatedly, Jordan et al. (2010) concluded follow-up “booster” sessions were effective for promoting exercise adherence in patients with musculoskeletal conditions [158]. Importantly, such follow-up contact may be flexibly and cost-effectively delivered via phone or other remote technology. The contact may itself incorporate a variety of BCTs, including the provision of feedback on performance, goal review, or prompting continued goal setting and self-monitoring [166,182]. Evidence supports the effectiveness of phone-based PA promotion interventions, with a systematic review by Eakin
et al. (2007) finding 69% of reported telephone PA-support programs to be effective at increasing PA [182]. The mean effect size for successful interventions was 0.5, which varied between 0.24 and 1.19. Importantly, interventions extending beyond 6-months were also successful at promoting PA maintenance [182]. While no studies within OA populations were located that expressly tested a phone-based intervention for PA promotion, a few studies have used phone contact to successfully support general self-management among people with knee OA [183–185], suggesting telephone-based follow-up strategies may be effective for changing health behaviour among people living with OA.

1.10 Web-based Interventions to Promote Physical Activity

Approximately 83% of Canadians use the internet in their homes [186]. As an intervention modality the internet offers the benefits of being able to reach a wide audience at a low cost while being flexible for participant use [187,188]. Web-based PA-promotion interventions commonly include education modules, self-monitoring tools, barrier identification, feedback provision, and opportunities for online social interaction [189]. Among general populations, these interventions have been found to be effective for promoting PA, though modest in effect size (0.15) [187,190,191]. By contrast, a 2014 systematic review assessing the effectiveness of web-based PA-promotion interventions among chronic disease populations found 43% of studies reporting significant increases in PA participation over controls [192].

Despite the mixed results, the immense reach of internet and digital interventions has led to increasing interest in utilizing digital media to support self-management in people living with chronic diseases. Within the knee OA population, two studies were located that assessed online interventions aimed to promote PA among people with arthritis. The first was an online version
of the ASMP that featured a discussion center, exercise logs, medication diaries, tailored exercise programs, and an education “helpbook”. A total of 651 participants (63.9% with OA) completed 1-year follow up, reporting modest but significant improvements in health distress and self-reported global health, but no changes in other outcomes or PA behaviour [193]. More recently, Bossen et al. (2013) tested the “Join2move” intervention, a web-based platform designed to promote engagement in a PA behaviour of a participant’s choice at a self-paced rate over nine weeks. The site provided arthritis education and prompted users to steadily increase PA participation. The study suffered from low adherence, as 46% of participants completed a minimum two-thirds of the intervention modules. However, at the 12-month follow up the intervention group demonstrated a mean increase of 24 minutes per day of objectively-measured MVPA [192]. Follow-up interviews demonstrated low motivation, presence of physical problems, and low mood contributed to non-adherence. Additionally, the absence of a human contact was cited as a barrier to engagement [194]. This problem was also reported as a barrier to intervention success from telephone interventions [182], suggesting that the use of mediated interventions may be most effective when paired with an in-person component. While further work is necessary to clarify if fully web-mediated interventions will be effective for promoting PA within arthritis populations, the above evidence does not rule out the potential role for web-based components of PA-support programs.

1.11 Wearable Activity Trackers as Tools to Promote Physical Activity

There is emerging evidence supporting interventions using wearable activity trackers to promote PA in various populations. Bravata et al. (2009) conducted a meta-analysis of trials that used pedometers to promote PA, finding that intervention participants took a mean 2491 more
steps per day relative to control groups (95% CI: 1098; 3885 steps per day) across eight trials. These changes corresponded with modest but significant decreases in BMI and blood pressure [195]. Similarly, a meta-analysis of nine studies found that pedometer-driven interventions yielded a mean weight reduction of 1.27 kg (95% CI: -1.85, -0.70) across diabetes [196,197], cancer [198], and obese populations [199,200].

More recently, companies such as Garmin, Fitbit, and Jawbone have developed accelerometer-based activity trackers designed as motivational tools to increase PA. These devices offer a host of features unavailable to the pedometer, including the ability to track intensity of activities as opposed to steps alone, user-friendly smartphone or web-based interfaces that synchronize with the tracker and allow a user to monitor their data and log behaviour over time, and platforms for social interaction among users in the form of online message boards or social media. A 2014 systematic content analysis of features implemented in consumer wearable activity trackers found the devices include a variety of evidence-based BCTs for promoting PA [201], including self-monitoring, feedback provision, and goal setting. Additionally, wearable trackers appear acceptable for use in chronic disease populations. Mercer et al. (2016) conducted a study on the acceptability of wearing commercially available activity trackers among older adults with chronic illnesses including arthritis. Participants wore a variety of consumer activity trackers (clip-on and wristband styles) for three days each. Despite not being familiar with activity trackers prior to enrollment, participants found the trackers useful and acceptable, and a majority (73%) intended to purchase one following study completion [202]. Additionally, Feehan et al. (2014) reported high ratings of usability and acceptability of a wristband-style activity tracker among people living RA, suggesting these monitors could be appropriate for use in populations living with chronic musculoskeletal pain [128].
Early evidence from studies employing accelerometer-based consumer wearable activity tracker-based interventions has shown mixed results for changing PA behaviour or related outcomes. A few studies have reported positive effects. For example, pilot studies have indicated significant within-group increases in PA and decreases in sedentary behaviour among healthy volunteers, but did not use a control group [203,204]. Additionally, a randomized trial assessing the use of a group-based behavioural weight-loss program with or without the use of an activity tracker showed the group using the tracker lost significantly more weight (mean = -6.59 kg) than the usual care (mean = -0.89 kg; \( p < 0.04 \)), whereas the other intervention group did not [205].

Other studies, however, have reported null findings relative to control groups [206–208]. For example, Thompson et al. (2014) assessed a PA-support intervention delivered to older adults (mean age = 79.5 years) who were sedentary and overweight. The study employed a cross-over design wherein intervention participants received a wearable activity tracker and an online PA-support resource for 24 weeks, at which point the intervention was removed and given to the control for another 24 weeks. No significant differences were seen in PA or other health outcomes, suggesting an elderly adult population may not be amenable to this type of intervention. Further work is needed to determine how to effectively integrate wearable activity trackers into self-management support interventions.

1.11.1 Use of Wearable Activity Trackers in Arthritis Populations

Evidence on the use of activity trackers within arthritis populations is relatively sparse. Four studies were identified that incorporated activity trackers to promote PA, all pedometers. Two studies incorporated the use of a pedometer into a modified version of the ASMP. For
example, Talbot et al. (2003) tested the efficacy of a home-based walking program delivered in combination with the ASMP in comparison to an ASMP-only control group. The walking program group received a pedometer, step goals (incrementally increased weekly), logbooks, and five minute feedback sessions weekly with the program nurse on the previous week’s activity. While no symptom benefits were seen, a group-time effect was found at post-test and follow-up with participants in the walking program increasing their step count by 23%, compared to a 15% drop in the ASMP-only group. A 21% gain in isometric strength was also found, relative to a small loss seen in the control group [209]. Yip et al. (2007) modified the ASMP by adding an exercise component as well as encouraging the formation of weekly PA-related action plans. The use of wearable activity trackers in this study was relatively limited, as participants were given a pedometer for a total of three days during the intervention to encourage walking. After 16 weeks, the intervention group was found to have significant increases in self-efficacy for self-management, performance of several self-care activities, and a decrease in pain. Additionally, the intervention group had increased their self-reported participation in light exercise (e.g. walking, tai chi) from a mean 5.6 (4.48) hours per week to a mean 7.17 (5.18) hours per week, whereas the control group had not ($p < 0.001$) [210]. Fontaine and Haaz (2006) assessed the effects of a 12-week lifestyle PA program on health outcomes in adults with fibromyalgia [211]. The program consisted of group education sessions teaching self-monitoring, goal setting, and problem solving. Participants received a pedometer and daily diary and were asked to increase lifestyle PA time by five minutes per week. The lifestyle PA group increased their daily step counts from a mean of 2337 at baseline to 3970 post-intervention, an increase of roughly 70% (control step count not reported). Seventy-one percent of participants in the lifestyle PA group reported improved health status, compared to 25% of the education control group ($p < 0.02$).
Most recently, Katz et al. (2015) conducted a three-arm RCT to test whether people living with RA would increase their daily step count when provided with pedometer intervention (Group 2) or a pedometer + step targets (Group 3) over an education control (Group 1). Both intervention groups significantly increased daily steps, with the Group 2 achieving a mean increase of 2132 (2698) steps ($p < 0.002$), and Group 3 a mean increase of 1299 (2389) steps ($p < 0.02$) [212].

Promoting PA is a key component of efforts to support optimal self-management among patients with knee OA. As a whole, the PA promotion literature is suggestive of the potential effectiveness of interventions that incorporate self-regulatory BCTs with ongoing mediated follow-up. While the evidence on how best to incorporate digital elements into PA promotion interventions among arthritis populations is evolving, early evidence indicates potential effectiveness of wearable trackers. In addition, the collection of PA data that are shareable in real-time (by modern consumer activity trackers such as Fitbit) with care providers may facilitate accountable and collaborative behaviour change. Thus, a major aim of this thesis was the development of a pilot RCT protocol for an intervention that leverages these strategies (Chapter 2).

1.12 The Role of Pilot Studies

Pilot studies occupy an important place within intervention development. A pilot study is typically conducted to inform the feasibility and design of a Phase III RCT. Pilot studies may have goals relating to process (assessment of study protocols), resources (assessment of time and budgetary issues), management (assessment of any human or data management issues that may arise), and scientific (assessment of intervention safety, efficacy, and variance of effect size) aspects of the larger trial [213]. Given the goals of a pilot study, sample sizes are not determined
on the basis of power to detect a particular effect size. Rather, the focus is on ensuring the adequate testing of study protocols to ensure success of a larger future trial designed with appropriate statistical power [213,214].
Chapter 2: Track-OA Study Protocol

2.1 Objective

The first objective of this thesis was to develop a protocol for a pilot randomized controlled trial (RCT) to test the feasibility and preliminary efficacy of a novel physical activity (PA) counseling intervention that uses a consumer activity tracker to support greater PA engagement among people with knee osteoarthritis (OA). This protocol has been published, and thus begins with a more brief and focused discussion of the previous background provided in Chapter 1.

The reader will note that because the following chapter features a protocol paper published before data were collected, the future tense was used throughout. The analysis in Chapter 3 and discussion in Chapter 4 return to the conventional past tense.

2.2 Background

Osteoarthritis (OA) is the most common chronic joint disease, affecting 10-15% of people in North America [55]. The knee joint is most commonly affected, with knee OA a leading cause of chronic pain and functional limitation that can decrease one’s ability to participate in daily activities and reduce quality of life [3]. Due to increasing rates of obesity and aging population demographics, the prevalence of OA in Canada is projected to more than

double within a generation with associated costs ($27.5 billion in 2010) projected to increase to $1.45 trillion by 2040 [1].

OA remains a condition with no cure, and current non-surgical treatments are aimed at alleviating symptoms while maintaining high quality of life. PA is a core first-line treatment [73,74], with both aerobic exercise and strength training known to safely reduce pain and improve functioning in this population [98,105–110]. A 2015 Cochrane review reported people with knee OA who exercised experienced a 12% decrease in pain, 10% improvement in physical function, and 4% improvement in quality of life immediately following treatment [103]. Regular PA is also known to provide global health benefits that help manage or prevent chronic comorbidities such as hypertension, cardiovascular disease, or diabetes that commonly develop in people with this condition [100]. National PA guidelines state that all adults should participate in at least 150 minutes of moderate-to-vigorous PA (MVPA) per week in bouts of 10 minutes or more to obtain the health benefits of an active lifestyle [100].

Despite these recommendations, the knee OA population remains highly inactive. People living with knee OA spend roughly 10 hours of their waking day in sedentary behaviours [155] and obtain 50 minutes per week of MVPA [156]. As few as 13% of this population meet recommended activity guidelines [131,132]. Insufficient PA in the knee OA population is particularly concerning given the emerging association of sedentary behaviour with poor health outcomes, including increased risk of metabolic syndrome, cardiovascular disease, diabetes, myocardial infarction, and all-cause mortality [141–144]. Reflective of this, Australian PA guidelines now recommend breaking up sitting time as often as possible throughout the day [215]. Greater levels of sedentary behaviour independent of MVPA participation have also been
associated with poorer physical functioning in people with knee OA [155,156]. As such, there is a clear need to promote greater activity levels and reduced sedentary time in this population.

PA promotion interventions among chronic disease populations have varied in format, setting, mode of delivery, and techniques employed to elicit behaviour change. A 2008 systematic review and meta-analysis found PA promotion interventions among chronically ill populations yielded a small to moderate effect size (0.45; 95% CI: 0.38, 0.52) that was associated with 945 additional steps per day and 48 additional PA minutes per week. Interventions employing behaviour-oriented strategies such as goal setting, action plan formation, self-monitoring, and provision of feedback were associated with higher effect sizes than interventions focusing on education or cognitive strategies (such as motivational interviewing or problem solving) alone [216]. Evidence has also been emerging supporting the use of wearable activity trackers such as pedometers or accelerometers for PA promotion. Activity trackers provide an objective measurement of activity output that facilitates goal-setting and self-monitoring while serving as an environmental cue towards activity [201]. A 2009 meta-analysis of trials that used pedometers to promote PA found intervention participants took 2491 more steps per day relative to control groups (95% CI: 1098; 3885 steps per day) across eight trials, with modest statistically significant accompanying decreases in BMI and blood pressure [195]. Pedometer interventions have also been effectively employed in arthritis populations. For example, Talbot et al. (2003) combined a pedometer-driven walking program aimed at incrementally increasing daily step counts with self-management education for people with knee OA and compared this program to a group receiving self-management education alone. The intervention group achieved a 23% increase in daily steps, as well as a statistically significant
increase in isometric strength, suggesting arthritis populations may also benefit from the use of these devices [209].

Following recent technological improvements, sophisticated accelerometer-based activity trackers are now available for consumer use as motivational tools to increase PA. These devices offer a host of features unavailable to the pedometer, including the ability to track intensity of activities as opposed to steps only, and user-friendly smartphone or web-based interfaces that graphically depict activity over time. Modern activity trackers encourage users to set specific activity goals (e.g. # of steps) and monitor progress throughout the day, providing immediate feedback on goal achievement. As an additional benefit, web-based hosting and social network functionality of the user-interfaces facilitate ease of communication about activities between individuals and their healthcare team. Owing to their recent development, few studies report employing these devices as PA promotion tools, however a systematic content analysis of consumer wearables concluded the devices featured a number of evidence-based techniques for promoting PA [201]. Additionally, results from studies in 2013 and 2015 employing a clip-on activity tracker noted significant increases in light, moderate, and vigorous PA and decreases in sedentary time [203,204], whereas use of an armband activity monitor as a component of diet and PA interventions led to weight loss in overweight and obese subjects [205,206]. While various models of wearable trackers are presently available (e.g. hip clip-ons, wristbands, ankle-straps), a popular consumer wristband accelerometer, the Fitbit Flex (Fitbit Inc., San Francisco, CA), demonstrated high ratings of wearability and usability in a prior pilot study among arthritis patients conducted by our group [128]. Thus, the proposed study outlines a pilot randomized controlled trial of a novel PA intervention that leverages evidence-based behaviour-change
techniques and the Fitbit Flex activity tracker to promote greater activity levels among people living with knee OA.

2.3 Objectives and Hypotheses

The primary objectives of the present study are to pilot and collect feasibility data on trial processes, resources, and management, and to assess the preliminary efficacy of a PA-promotion intervention for increasing bouted MVPA in people with knee OA. The proposed intervention consists of three components: 1) a 1.5 hour in-person small group session including a physiotherapist-led education module, personalized activity counseling and action planning, 2) the use of a Fitbit Flex activity tracker, and 3) weekly physiotherapist follow-up phone calls to modify activity levels as needed. Secondary objectives related to efficacy include assessing if the intervention decreases bouted sedentary time, improves knee OA disease severity, and improves patient engagement.

It is hypothesized that the intervention will: 1) increase bouted MVPA time (bout ≥ 10 minutes), 2) decrease bouted sedentary time (bout > 20 minutes), 3) increase patient engagement, 4) decrease pain, and 5) increase functional ability in people with knee OA.

2.4 Methods

This protocol is guided by the Standard Protocol Items: Recommendations for Intervention Trials (SPIRIT) 2013 guidelines [217]. This study has received approval from the University of British Columbia Clinical Research Ethics Board (H14-02631), and the study was registered on ClinicalTrials.gov (NCT02313506).
2.4.1 Study Design

The TRACK-OA study will be carried out at Arthritis Research Canada (Richmond, BC), and the Mary Pack Arthritis Centre (Vancouver, BC). Participants will be recruited from the community in the Greater Vancouver Area. The study is a two-group pilot RCT with a stepped-wedge design. The stepped-wedge is a trial design in which all participants receive the intervention but the time point at which the intervention is received is randomized (immediate, or after five week delay) (see Figure 2.1 for trial flowchart). After receiving informed consent from the participants, baseline measures will be collected.
Figure 2.1. TRACK-OA trial flowchart.

**Recruitment**
Assessed for eligibility

**Baseline Assessment [Week 0]**
Bouted MVPA time, bouted sedentary time (SenseWear Mini Armband), KOOS, PIH Demographic Data

**Randomization of participants**

**Immediate-intervention group**
Education/action-planning session; Fitbit Flex; weekly phone calls and emails as needed with PT to revisit activity goals and address questions regarding PA

**Delayed-intervention group**
Regular activity pattern

**First Follow-up Assessment [Week 5]**
Bouted MVPA time, bouted sedentary time (SenseWear Mini Armband), KOOS, PIH, Adverse Events

**Immediate-intervention group**
Reduced intervention (continue Fitbit use, PT available by email)

**Delayed-intervention group**
Education/action-planning session, Fitbit Flex; weekly phone calls and emails as needed with PT to revisit activity goals and address questions regarding PA

**Second Follow-up Measures [Week 10]**
Bouted MVPA time, bouted sedentary time (SenseWear Mini Armband), KOOS, PIH, Adverse Events
2.4.2 Participants

A convenience sample of 36 participants will be recruited from the community by way of community posters and web-based advertisements. Interested participants will complete a web-based screening questionnaire and eligible participants are phoned for further screening, obtainment of informed consent, and study enrollment.

2.4.3 Eligibility Criteria

Participants are included if they 1) possess a physician confirmed diagnosis of knee OA or are both over 50 years, and have experienced four weeks of pain, aching, or discomfort in or around the knee during the last year (equal to or more than 28 separate or consecutive days) [218], 2) have no previous diagnosis of inflammatory arthritis, connective tissue diseases, fibromyalgia, or gout, 3) have no history of using disease modifying anti-rheumatic drugs or gout medications, 4) have no prior knee arthroplasty, 5) are not on the waitlist to receive total knee arthroplasty, 6) have no history of acute knee injury in the past six months, 7) have not had lower extremity or back surgery in the past 12 months, 8) have an email address and daily access to a personal computer with internet access.

Individuals are excluded if they 1) have a BMI of $\geq 40$ kg/m$^2$, 2) have received a steroid injection in a knee in the last six months, 3) have received a hyaluronate injection in a knee in the last six months, 4) are using medications that impair activity tolerance (such as beta-blockers), and 5) have an inappropriate level of risk for increasing their unsupervised PA as identified by the Physical Activity Readiness Questionnaire (PAR-Q) 2014 [219]. Specifically, if an individual answers ‘Yes’ to any conditions described in the General Health Questions section, they will complete a series of standardized follow-up questions. Any individual who does not
pass the PAR-Q will require physician clearance to participate, and those with severe health issues such as a heart or cardiovascular condition will be deemed ineligible under this criterion. In some cases an individual may fail the PAR-Q on the basis of their knee OA alone. In these instances, further clarification questions will be asked to determine whether physician clearance is required as per the procedure outlined in Table 2.1.

**Table 2.1.** An example of applying the PAR-Q to determine eligibility for the randomized controlled trial.

<table>
<thead>
<tr>
<th>PAR-Q Questions</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Health Section</strong></td>
<td></td>
</tr>
<tr>
<td>6. Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue problem that could be made worse by becoming more physically active?</td>
<td>If “yes” due ONLY to knee OA, answer follow-up questions 1a and 1b of PAR-Q. If “yes” due to other problems, complete entire follow-up section.</td>
</tr>
<tr>
<td><strong>Follow-up Section</strong></td>
<td></td>
</tr>
<tr>
<td>1a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?</td>
<td>If “yes”, the person will require physician clearance. If “no”, the person passes this criterion.</td>
</tr>
<tr>
<td>1b. Do you have joint problems causing pain, recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra, or spondylolysis/pars defect?</td>
<td>If “yes” ONLY to knee OA causing pain, then ask clarifying questions below. If “yes” to other conditions, the person will require physician clearance.</td>
</tr>
<tr>
<td><strong>Clarifying Questions</strong></td>
<td></td>
</tr>
<tr>
<td>1. How severe are your symptoms after physical activity? 2. After physical activity, do your symptoms last longer than 2 hours?</td>
<td>If mild symptoms for &lt; 2 hours, no physician clearance necessary. Otherwise, require physician clearance.</td>
</tr>
</tbody>
</table>
2.4.4 Outcome Measures

2.4.4.1 Descriptive Measures

Demographic information including age, sex, income, level of education, height, weight, presence of comorbidities, whether an individual received a physician diagnosis of knee OA, and time since onset are collected to describe the sample and compare group randomization at baseline.

2.4.4.2 Feasibility Data

To address the primary objective, data relating to trial feasibility will be collected. As suggested by Thabane et al. (2010) [213], these data will be organized according to Process, Resources, Management, and Scientific issues. Setting benchmarks for feasibility data is beneficial to inform larger-scale assessments of this intervention in the future [213]. Thus, benchmark criteria for success were set in accordance with the goals of an upcoming proof-of-concept study featuring the present intervention (see Table 2.2). Detailed information on the recruitment process will be collected, including the number of individuals who contact us, the source of recruitment, and the reason for non-eligibility or withdrawal of interest. Adherence to study protocols (education and training session attendance, telephone follow-up, Fitbit use, outcome measure collection) will be assessed for each participant by determining whether a participant completed each component of the study. It has been determined that at least four days of data are required to obtain accurate estimates of PA participation from the SenseWear Mini armband (SW) [220]. Time to complete online questionnaires will be collected from the online survey system. As the cost of activity monitors (Fitbit and SW) in this study is a concern, extremely high equipment retention and reliability is required. Management issues such as
unforeseen challenges with the host location, study personnel, or data collection that challenge study logistics or success will be carefully documented. Safety issues and adverse events will be tracked throughout the study (see Risk Management section below). Feasibility data will be tracked and logged in a detailed administrative database and summarized for presentation at study completion. Treatment effect and variance estimates will be calculated to inform sample size calculations for the larger trial. These calculations will be carried out assuming a randomized trial with two equal-sized groups, a two tailed significance threshold (alpha) of 0.05, and power of 0.8 to detect a clinically important result between groups on bouted MVPA and sedentary time outcomes.

Table 2.2. Feasibility data to be collected and criteria for success.

<table>
<thead>
<tr>
<th>Feasibility Data Category</th>
<th>Item of interest</th>
<th>Success Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>Recruitment rate</td>
<td>2 participants / week</td>
</tr>
<tr>
<td></td>
<td>Consent rate</td>
<td>≥ 90%</td>
</tr>
<tr>
<td></td>
<td>Dropout rate</td>
<td>≤ 10%</td>
</tr>
<tr>
<td></td>
<td>Adherence to protocols</td>
<td>4 days x 20 hours for each SenseWear week; 100% completion of online questionnaires; mean 5 days / week of Fitbit use</td>
</tr>
<tr>
<td>Resources</td>
<td>Equipment loss/reliability</td>
<td>100% equipment retention</td>
</tr>
<tr>
<td></td>
<td>Personnel</td>
<td>Sufficient personnel to execute the trial efficiently</td>
</tr>
<tr>
<td>Management</td>
<td>Location, logistics, personnel, data</td>
<td>No criteria set</td>
</tr>
<tr>
<td>Scientific</td>
<td>Intervention effect, variation, safety</td>
<td>No criteria set</td>
</tr>
</tbody>
</table>
2.4.4.3 Patient-Centered Outcome Measures

2.4.4.3.1 Primary Outcome – Bouted MVPA time

Bouted MVPA time will be measured by the SW. The SW armband uses multi-modal information and proprietary algorithms to estimate 24-hour free-living activity levels (steps, energy expenditure, vigorousness of activity). Measurements are recorded in 1-minute epochs from the device’s triaxial accelerometer and sensors detecting galvanic skin response, skin temperature, and heat flux. It is initialized using proprietary software, and the armband is placed comfortably on the upper triceps and worn all hours of the day except during water-based activities. The SW assesses PA vigorousness in terms of Metabolic Equivalent of Task (MET). Activities ≥ 3.0 METs are considered MVPA, thus MVPA is operationalized as any activity that generates an output of ≥ 3.0 METs for bouts of 10 minutes or more as assessed by the SW. Bouts of MVPA lasting ≥ 10 minutes are selected as the outcome measure of interest (as opposed to total MVPA time) because of the health promoting benefits of this activity pattern as recommended by national PA guidelines (100). Allowing for up to a two minute drop below MVPA threshold has been proposed as a reasonable approach for coping with real-world scenarios that may interrupt PA (i.e. waiting to cross the road at a stop light for one minute while walking) [221], and has been employed in national PA assessment studies using accelerometers [129,222]. Thus, dropping below 3.0 METs for more than two minutes within a bout of activity lasting 10 minutes or more will constitute the end of a bout of MVPA [223].

2.4.4.3.2 Secondary Outcome – Bouted Sedentary Time

Sedentary behaviour is defined as any waking behaviour characterized by an energy expenditure ≤ 1.5 METs while sitting or reclining [224]. Because prolonged sedentary time is of
primary concern [215], sedentary time is operationalized as any wakeful (e.g. non-sleeping) behaviour generating ≤ 1.5 METs for a continuous bout of > 20 minutes as assessed by the SW (with no tolerance for breaks).

2.4.4.3.3 Secondary Outcome – Disease Status

Measures of knee OA disease status are assessed with the Knee injury and OA Outcome Score (KOOS). The KOOS questionnaire was developed for use in a population recovering from knee injury, but has been shown to be a reliable and valid measure of knee status for the OA population [225–227]. The questionnaire makes use of five separately-interpreted subscales that assess 1) pain, 2) other symptoms, 3) function in daily life, 4) function in sport and recreation, and 5) knee-related quality of life. Each of these subscales is assessed by a five-point Likert scale from 0-4, with 0 being “No Problems” and 4 being “Extreme Problems”. Each subscale score is transformed to a 0-100 scale, with 0 representing no knee problems and 100 representing extreme knee problems. The KOOS contains all items from the Western Ontario McMaster OA Index [228] in its original form but also includes questions about functioning in sports and recreation as well as quality of life, both particularly relevant for the purposes of this intervention [229].

2.4.4.3.4 Secondary Outcome – Patient Engagement

The Partners in Health Scale (PIH) is used to assess changes in patient engagement. The PIH was developed to provide a generic tool for objective assessment of patient self-management skill and behaviour to provide more targeted self-management interventions to those who most need it. The self-rated scale includes 12 items that probe six principles of patient
engagement related to successful chronic disease self-management, including whether patients 1) have knowledge of their condition, 2) follow a treatment plan agreed on with healthcare professionals, 3) actively share in decision making with healthcare professionals, 4) monitor and manage signs and symptoms of their condition, 5) manage the impact of conditions on the physical, emotional, and social aspects of life, and 6) adopt lifestyles that promote health. Each item is rated on a 9-pt scale, with 0 indicating the highest self-management and 8 indicating the lowest self-management (min-max: 0-96). The PIH has been shown to have good internal consistency (Cronbach’s α = 0.82) and construct validity [80].

2.4.5 Assessments

Assessment of outcome measures will occur at three time points – baseline (T0), Week 5 (T1), and Week 10 (T2) – with the exception of demographic information (collected at baseline only), and adverse events (collected at T1 and T2 only). Both the KOOS and PIH will be uploaded to an online survey system hosted on a secure local server at Arthritis Research Canada, and the SW will be delivered to participants prior to each data collection week.

2.4.6 Randomization

Once informed consent is received and baseline measures have been collected, participants will be randomly assigned to one of two groups (immediate-intervention group or delayed intervention group). As per the stepped-wedge design, the delayed-intervention group will receive the intervention after a five week waiting period (i.e. immediately following T1 follow-up assessment; see Figure 2.2). A study statistician (CHG) not involved in the day-to-day operation of the trial will randomly assign participants in blocks to each group using a computer-
Figure 2.2. Intervention delivery as per stepped-wedge design. Dotted box refers to the reduced program (discontinuation of follow-up phone calls).

Based random number generator and a 1:1 allocation ratio. Block sizes will be concealed from study staff and randomly varied to prevent prediction of group allocation. The statistician will pass group allocations back to study research coordinators (CC, NG) who will arrange for intervention delivery as appropriate. Group assignments will be accessible only to the study research coordinators.

2.5 Intervention

2.5.1 Education and Training Session

The education and training session are delivered at the Mary Pack Arthritis Center by a physiotherapist and research staff member to groups of two to four participants. The education module runs for roughly 40 minutes. A study physiotherapist leads a discussion on the causes and nature of knee OA, cornerstone treatments of the disease, and the role of PA and exercise in
the management of OA. Common myths about knee OA are discussed and dispelled (e.g. “exercise makes my knee OA worse”), and a discussion of various types of PA and exercise appropriate for individuals with the condition is given. In addition, the emerging risks of a sedentary lifestyle are presented, and the importance of reducing sedentary time is emphasized. Finally, symptom-management strategies are discussed, including how to manage common problems that may arise when becoming active. Increasing activity by ‘listening to one’s body’ is a key message in the education module, and ultimately the intent is to increase the participant’s knowledge about how to be physically active while having knee OA. Following the education module, the Fitbit Flex is given to each participant and 30-minutes of training is provided. Participants then work individually with the physiotherapist to set personalized PA goals and create a weekly action plan. This component of the intervention is derived from Brief Action Planning – a structured, patient-centered method of setting goals and developing action plans based on the principles of motivational interviewing. Brief Action Planning first evokes a participant’s ideas of goals that are personally suitable, builds a specific action plan, and finishes by evoking a confidence statement (0-10 scale) [230]. A “barrier identification/problem solving” step was also added to the Brief Action Planning framework, which the physiotherapist will use to direct participants to set goals related to increasing MVPA participation and interrupting sedentary time. The education and training session will take an estimated 1.5 hours.

2.5.2 Fitbit Flex

Following the education and training session, participants will be asked to wear the Fitbit 24 hours/day (unless charging) for the remainder of the study. The Fitbit Flex is a removable tracker (housing a triaxial accelerometer and five light LED display) inside of a wristband worn
on the non-dominant wrist. The Fitbit user-interface is an easy-to-use web-based application that graphically displays a user’s activities over the course of the day including total steps taken, calories burned, and distance traveled. Interaction with the user-interface may occur on a self-directed basis.

2.5.3 Telephone Follow-up

Participants will be asked to share their Fitbit activity data with the physiotherapist they work with during the education session. This is accomplished using Fitbit’s online social networking function where users can privately share their Fitbit activity “profile” with Fitbit “Friends”. Participants add the physiotherapist as a “Friend”, thus allowing the physiotherapist to view the participant’s activity data. These data will be used to inform the content of a 20-minute weekly phone call to each participant from the physiotherapist (for the first four weeks of the intervention only). Like the goal setting portion of the education session, these conversations are derived from a Brief Action Planning protocol and are designed to respect participant autonomy while increasing confidence in PA participation. Furthermore, the physiotherapist may be contacted by email to address participant questions throughout the duration of the intervention as they arise.

2.6 Risk Management and Safety Monitoring

Adverse events during the study will be tracked both by self-report on the online outcome measure questionnaire and by study physiotherapists during follow-up phone calls. In the online questionnaire, participants are asked if they experienced any negative outcomes (presented as a list of outcomes and allowing for free form entry at the end of the questionnaire) as a result of
becoming more physically active since their enrollment in the study. They are asked to specify when the event occurred, and if the event was experienced before. In an open-format response, participants are asked to describe the symptoms they experienced, any medical help they sought as a result, and any other relevant information. Any participants reporting adverse events will be immediately contacted and, if necessary, assessed by a study physiotherapist before being referred for appropriate care as needed.

2.7 Data Management

Data will be stored in confidential servers on the Arthritis Research Canada premises. Participant ID’s are assigned upon enrollment, with a secondary ID assigned upon randomization. To ensure anonymity, participants are referred to by their study ID in emails and verbal communications where necessary. Access to all computer files with participant information will be limited to the study team, and individual files will be password protected. SW data will be downloaded by a staff member (JY), who is blinded to participant’s group assignment, using SW Professional Software 8.0, and exported to Excel (Microsoft, Redmond, WA) and processed in MatLab (The MathWorks, Inc., Natick, MA). Data quality will be monitored on an ongoing basis by study staff, and backups will be saved weekly. The final de-identified data set will be provided to a blinded study statistician for analysis.

2.8 Sample Size Calculation

As pilot studies are primarily concerned with feasibility and generating estimates that will inform future studies’ power and sample size calculations, sample size or power calculations were not deemed necessary for this trial [213]. A convenience sample of 36 participants was
estimated to allow sufficient piloting of study protocols and estimates of feasibility measures to inform a future trial.

2.9 Statistical Analysis

Descriptive measures will be tabulated and summarized by count, percentage, or mean and 95% confidence interval (CI) and compared for differences between groups. Integrity of the randomization process will be monitored. SW measurements for each time point will be considered valid if they include at least four days with at least 20 hours of wear time each day [231]. Feasibility data will be collated and compared against benchmarks for success. When assessing preliminary intervention efficacy the stepped-wedge design allows for analyses of differences between groups as well as temporal patterns. Changes in bout MVPA, bout sedentary time, KOOS score, and PIH score will assessed by a multiple regression model including variables for group, time, and group-time interaction. The effect of blocking will be considered in the analysis. Planned comparisons will be used to compare group means for differences at first follow-up (Week 5), a delay effect, and for temporal changes intervention efficacy. All analyses will be conducted using IBM SPSS Version 20 (Armonk, NY).

2.10 Dissemination and Knowledge Translation

Patient collaborators from the Arthritis Research Canada’s Arthritis Patient Advisory Board (APAB) were consulted during the study design process to provide insight into patient values and concerns regarding PA and use of wearable activity trackers. Open channels of communication will be maintained with APAB during the study for patient perspectives on challenges or changes to study protocols. Study results will be featured on the Arthritis Research
Canada website, as well as the lab website hosted through the University of British Columbia. Furthermore, results will be disseminated through the Arthritis Research Canada monthly e-newsletter, and through a presentation at an APAB monthly meeting. Results will be shared with the scientific community by way of publication and conference presentation.

2.11 Discussion

This paper presents a pilot RCT protocol to assess the feasibility of an intervention designed to increase MVPA and decrease sedentary time in a sample from the knee OA population. The program guides participants in setting personally-relevant activity goals based on their preferences and level of ability, and slowly increase PA participation over time. It is hoped that this patient-centered approach of gradually integrating greater activity into one’s existing life framework may enhance adherence to PA over time, a recognized challenge [98]. A potential limitation of this intervention is the technological skill requirement, which could act as a barrier to some individuals. However, there are several strengths. First, the use of the stepped-wedge trial design preserves the integrity of a randomized experiment while not withholding a potentially beneficial intervention from study participants. Conventional cross-over designs are impractical for PA promotion interventions as washout-period lengths have not been established and may be of considerable duration. Furthermore, the stepped-wedge design allows for assessment of lag-time effects, which may be relevant for people with arthritis as they may experience delays in the delivery of care. Piloting this trial format will be important in determining any feasibility challenges (e.g. delayed-group participant dropout) that may need addressing in future studies.
Second, there is evidence to suggest the emphasis on action-oriented behavioural strategies for PA promotion may be more effective than cognitive or educational methods [216]. Third, the enhanced ability for participants to self-monitor goal progress and receive ongoing feedback that comes through use of an activity tracker may increase awareness of PA behaviour and enhance activity-related self-efficacy, a known determinant of PA [51]. Fourth, the sharing of Fitbit data between participants and study physiotherapists encourages accountability and provides an opportunity to deliver more specific and personally relevant follow-up support to participants throughout the study. The feasibility metrics such as recruitment rate, dropout rate, adherence, and resource requirements collected in this study will be used to estimate the time, resources, and sample size required for a full-scale RCT. Furthermore, the experience gained from executing study protocols and the feedback provided from staff and participants will allow for improvement and refinement of trial elements and procedures to ensure the success of a future study to test the efficacy of this intervention. Pending the results of this pilot study, a full-sized trial will be designed and conducted in the Greater Vancouver Area in late 2015 and early 2016.

2.12 Trial Status

The trial began recruitment in February 20, 2015, and is presently open for recruitment. Recruitment will close when 36 participants have been randomized. It is anticipated this target will be met in August 2015.
Chapter 3: Exploratory Analysis of the Association of Patient Engagement and Physical Activity

3.1 Background

The TRACK-OA study outlined in the previous chapter represents an effort to support physical activity (PA) among people living with knee osteoarthritis (OA). This effort is reflective of the growing emphasis on supporting patients to actively engage in the self-management of their disease [76,81]. As outlined in Chapter 1, highly engaged patients are those who report having the knowledge and skills required to effectively self-manage their condition [83]. In other words, engaged patients are those who possess the capacity to actively collaborate with their care team, adhere to treatments, monitor their symptoms, manage the impact of their disease on their life roles, and adopt lifestyles that promote health [75,79]. They have sufficient personal resources to maintain their wellbeing, and are supported by effective use of the healthcare partnerships and services available to them.

The growing body of work in this area suggests patients who report higher levels of engagement tend to have more positive health outcomes, thought to be related to greater participation in important self-management behaviours such as adherence to medication and exercise [83,90,91]. However, as mentioned in Chapter 1, several notable gaps remain. First, no studies were located that assessed how levels of patient engagement relate to objectively-measured behavioural outcomes relevant to health (such as PA). Furthermore, little investigation of the correlates of patient engagement in arthritis populations has been undertaken. As a PA-promotion intervention that assessed a measure of patient engagement (Partners in Health Scale [PIH]) as well as an objective measure of bouted moderate-to-vigorous physical activity
(MVPA) and bouted sedentary time (BodyMedia SenseWear Mini [SW]), the TRACK-OA study provided a unique opportunity for a first exploration of whether patients’ levels of engagement are related to the objective performance of two key self-management behaviours. Thus, the aim of the present study was to conduct an exploratory analysis of the baseline data from TRACK-OA to evaluate the relationship between objectively-measured MVPA, sedentary time, and patient engagement in a sample of people living with knee OA.

3.2 Objectives

The objective of this cross-sectional study was to assess the association between 1) objectively-measured bouted MVPA time (bouts ≥ 10 minutes at ≥ 3.0 Metabolic Equivalents [METs]) and patient engagement as measured by the PIH, and 2) objectively-measured bouted sedentary time (bouts > 20 minutes at ≤ 1.5 METs) and the PIH. It was hypothesized that 1) patient engagement would be positively associated with bouted MVPA time, and 2) patient engagement would be negatively associated with bouted sedentary time. Because the PIH is an inverted scale where higher levels of engagement are denoted by lower scores, these hypotheses can be rephrased as an expected negative relationship between bouted MVPA and PIH score, and an expected positive relationship between bouted sedentary time and PIH score.

3.3 Methods

3.3.1 Research Design and Study Procedure

This cross-sectional study was conducted as a secondary analysis of the baseline data collected as a part of the TRACK-OA study. The detailed TRACK-OA study protocol was
published previously [233], and is included in Chapter 2 above. The published protocol (up to the collection of baseline measures) was adhered to for this study.

3.3.2 Participants and Recruitment

Participants were recruited from the Greater Vancouver area, and were enrolled if they met all TRACK-OA study eligibility criteria and provided informed consent for participation in the study.

3.3.3 Outcome Measures

Chapter 2 provides a detailed description of the outcome measures. Briefly, demographic information (age, sex, income, education, marital status, living situation), general health variables (rating of current health, change over past year, comorbidities), and measurements of knee OA symptoms and physical function (Knee Injury and OA Outcome Score [KOOS]) were collected [229]. The main explanatory variable of interest was the PIH, a 12-item generic patient-reported outcome measure of patient engagement assessing an individual’s perceived knowledge, skills, and participation in a variety of aspects of self-management. Items on the scale are scored from 0-8, with a total possible score between 0 – 96 where higher score indicates lower patient engagement. [79]. The main outcome variables of interest were 1) bouted MVPA time (bout ≥ 10 minutes at ≥ 3.0 METs with a two minute tolerance for falling below the threshold), and 2) bouted sedentary time (bout > 20 minutes of ≤ 1.5 METs with any measurement above 1.5 METs disrupting the bout) as measured by the SW. Participants were asked to wear the SW for a total of seven days, and were included if they provided at least four days of data with ≥ 20 hours of wear time [231].
3.3.4 **Statistical Analysis**

Cleaning of the complete TRACK-OA dataset was undertaken by a study biostatistician prior to the secondary analysis, and the baseline dataset was re-checked for errors upon receipt. Univariate descriptions including boxplots and histograms of each variable were made, with attention paid to outliers or possible data errors. Descriptive demographic variables were summarized in terms of percentage or frequency as appropriate. Measures of central tendency and distribution (mean, standard deviation [SD]), minimum [min] and maximum [max] were calculated for age [years], Body Mass Index (BMI; [kg/m²]), number of comorbidities, bouted MVPA [minutes], sedentary time [minutes], PIH score, KOOS score [scored by subscale]. Demographic and outcome variable summary statistics were tabulated. Bivariate relationships between the collected variables were evaluated with scatterplots and a correlation matrix. Unadjusted correlations were calculated using Pearson’s r. The provision of a complete dataset including demographic information permitted the investigation of a variety of variables and relationships within the data, including an exploratory regression analysis to adjust for potential confounders of the relationships of interest (PIH, bouted MVPA, and bouted sedentary time) within the dataset. The presence of straight-line relationships between PIH score and bouted MVPA time, as well as PIH score and bouted sedentary time were visually assessed. If the data did not suggest other relationships, a multiple regression modeling procedure would be undertaken. However, if the data suggested other relationships or assumptions were violated, data transformations were undertaken (e.g. log transformation). If transformations were not effective, alternative methods (discretization of variables, non-parametric tests) were considered.
To achieve the first study objective, a multivariable regression model was built to assess the association between PIH and bouted MVPA. Several potential confounders previously known from the literature were present in the dataset, including age, sex, BMI, KOOS subscales, and number of comorbidities [136,234]. A forward selection model building procedure was selected to balance the need to control for potential confounders within the dataset while maintaining a parsimonious model [235]. During this process the main explanatory variable of interest, the PIH, was held in the model (i.e. the “forced-in” variable [236]) and potential confounders present in the dataset were sequentially added to model bouted MVPA ($y_{MVPA}$). In each round the most significant variable was retained and added to the model, and the process was repeated for the remaining variables. Non-significant variables were not retained in the final model. Interaction terms between significant variables were also assessed. An alpha of 0.1 was used as a cut-off for inclusion of variables in the model. Variables suspected to be confounders (by altering estimated beta values of other variables in the model by ≥ 20%) were retained even if they did not reach significance. Model fit was assessed using a likelihood-ratio test comparing the expanded model to the nested model for significantly better fit. Diagnostic residuals plots were created, and Shapiro-Wilk tests for normality of residuals were conducted. If heteroscedasticity of residuals was visually present, the Bartlett test for homogeneity of variance would be undertaken. An overall alpha of 0.05 was used to assess significance of the model and model variables.

To accomplish the second objective, a multivariable regression model was built to assess the relationship between PIH and bouted sedentary time ($y_{sed}$), as well as the five potential confounders mentioned previously. The same model building and assumption checking process outlined above was followed. All analyses were conducted in the R Statistical Analysis Package.
[237] using RStudio version 0.99.467 [238].

### 3.4 Results

Between December 2014 and April 2015, a total of 130 individuals were screened, 35 were eligible and 34 consented to participate in the study. Baseline survey responses and SW measurements of at least four days were completed by all participants, and all 34 participants were included in the analysis. Figure 3.1 provides a depiction of the recruitment flow.

Participants were [mean (SD)] 55.5 (8.6; min = 33, max = 67) years, had a BMI of 27.2 ([4.7]; min = 18.3, max = 36.0) kg/m$^2$, and reported a mean of 2.8 (2.1; min = 0, max = 9) comorbidities. The sample was predominantly female (82.4%). All participants had at least completed high school, with the majority (61.7%) possessing at least a bachelor’s degree. The majority of the sample was married or common law (73.5%) and 41.2% had a household income of over $100,000. Most individuals felt their health was at least “good”, with 32.4% rating their health as “very good”, and 17.6% rating their health as “excellent”. The large majority felt their health was about the same as it was a year previous (79.4%). Demographic data are viewable in Table 3.1.
Figure 3.1. Participant recruitment into TRACK-OA study up to baseline measurements.

- Sent Screening Phase 1 Questionnaire (n=130)
  - Did not complete questionnaire: n=21
- Completed Screening Phase 1 (n=109)
  - Did not meet inclusion criteria: n=49
  - Refused to participate: n=10
- Completed Screening Phase 2 (n=50)
  - Did not meet inclusion criteria: n=6
  - Refused to participate: n=9
- Consented (n=35)
  - Withdrew: n=1
- Baseline Measurements (n=34)
Table 3.1. Summary of Demographic Information

<table>
<thead>
<tr>
<th>Personal Characteristics (n = 34)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Female – n (%)</td>
<td>28 (82.4)</td>
</tr>
<tr>
<td>Age - mean (SD) years</td>
<td>[min = 33, max = 67] 55.5 (8.6)</td>
</tr>
<tr>
<td>Body Mass Index – mean (SD) kg/m²</td>
<td>[min = 18.3, max = 36.0] 27.2 (4.7)</td>
</tr>
<tr>
<td>Number of Comorbidities – mean (SD) #</td>
<td>[min = 0, max = 9] 2.8 (2.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Highest Level of Education – n (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 8 or lower</td>
<td>0</td>
</tr>
<tr>
<td>Grade 9 to 10</td>
<td>0</td>
</tr>
<tr>
<td>Grade 11 to 13</td>
<td>5 (14.7)</td>
</tr>
<tr>
<td>Trades certificate, vocational school diploma, apprenticeship</td>
<td>2 (5.9)</td>
</tr>
<tr>
<td>Non-university certificate below Bachelor’s level</td>
<td>6 (17.6)</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>6 (17.6)</td>
</tr>
<tr>
<td>University above Bachelor’s</td>
<td>15 (44.1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total household income per year before taxes – n (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Under $12,000</td>
<td>2 (5.9)</td>
</tr>
<tr>
<td>$12,001 – $24,000</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>$24,001 – $40,000</td>
<td>2 (5.9)</td>
</tr>
<tr>
<td>$40,001 – $60,000</td>
<td>5 (14.7)</td>
</tr>
<tr>
<td>$60,001 – $80,000</td>
<td>0</td>
</tr>
<tr>
<td>$80,001 – $100,000</td>
<td>3 (8.8)</td>
</tr>
<tr>
<td>Over $100,000</td>
<td>14 (41.2)</td>
</tr>
<tr>
<td>Prefer not to answer</td>
<td>7 (20.6)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Current Marital Status – n (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Married / Common Law</td>
<td>25 (73.5)</td>
</tr>
<tr>
<td>Separated / Divorced</td>
<td>5 (14.7)</td>
</tr>
<tr>
<td>Widowed</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Never married</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (5.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In general, would you say your health is: n (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>6 (17.6)</td>
</tr>
<tr>
<td>Very good</td>
<td>11 (32.4)</td>
</tr>
<tr>
<td>Good</td>
<td>13 (38.2)</td>
</tr>
<tr>
<td>Fair</td>
<td>4 (11.8)</td>
</tr>
<tr>
<td>Poor</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compared to one year ago, how would you rate your health in general now? n (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Much better now</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>Somewhat better now</td>
<td>1 (2.9)</td>
</tr>
<tr>
<td>About the same</td>
<td>27 (79.4)</td>
</tr>
<tr>
<td>Somewhat worse now</td>
<td>5 (14.7)</td>
</tr>
<tr>
<td>Much worse now</td>
<td>0</td>
</tr>
</tbody>
</table>
Summary statistics (Table 3.2) indicated a mean PIH score of 24.3 ([16.4]; min = 2, max = 70). The distribution of PIH scores indicated a right skew, with the majority (55%) of the sample scoring between 0 and 20 (Figure 3.2).

**Figure 3.2. Histogram distribution of Partners in Health (PIH) score**

The mean daily bouted MVPA time of 53.9 ([62.4]; min = 0, max = 299.8) minutes indicated a physically active sample. The distribution of bouted MVPA time was right skewed, with 70% of the sample achieving under an hour of bouted MVPA per day, but with one individual achieving over three hours per day, and another achieving over four hours per day (Figure 3.3). The sample reported 508.9 (178.9) minutes, or about 8.5 hours of daily bouted sedentary time. The distribution indicated a left skew, with 62% of participants obtaining over eight hours of bouted sedentary time per day (last three histogram bins), but with one participant achieving under two hours (Figure 3.3).
Table 3.2. Summary of bouted MVPA, bouted sedentary time, Partners in Health, and knee OA status variables.

<table>
<thead>
<tr>
<th>Measurement Variables</th>
<th>Males (n = 6)</th>
<th>Females (n = 28)</th>
<th>All (n = 34)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outcome variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bouted MVPA(^1) (SD)</td>
<td>114.5 (112.8)</td>
<td>40.9 (37.6)</td>
<td>53.9 (62.4)</td>
</tr>
<tr>
<td>mean daily minutes</td>
<td>[12.5, 299.8]</td>
<td>[0.0, 142]</td>
<td>[0.0, 299.8]</td>
</tr>
<tr>
<td>Bouted Sedentary Time(^2) (SD)</td>
<td>384.7 (228.7)</td>
<td>525.8 (160.6)</td>
<td>508.9 (178.9)</td>
</tr>
<tr>
<td>mean daily minutes</td>
<td>[116.0, 718.7]</td>
<td>[136.3, 761.0]</td>
<td>[116.0, 761.0]</td>
</tr>
<tr>
<td><strong>Explanatory Variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partners in Health Scale mean (SD)</td>
<td>33.5 (23.4)</td>
<td>22.4 (14.3)</td>
<td>24.4 (16.4)</td>
</tr>
<tr>
<td>0 - 96; 0 = highest engagement</td>
<td>[7.0, 70.0]</td>
<td>[2.0, 50.0]</td>
<td>[2.0, 70.0]</td>
</tr>
<tr>
<td>KOOS Subscales mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>71.3 (15.1)</td>
<td>71.6 (16.7)</td>
<td>71.6 (16.2)</td>
</tr>
<tr>
<td>[Min, Max]</td>
<td>[50.0, 86.1]</td>
<td>[38.9, 97.2]</td>
<td>[38.9, 97.2]</td>
</tr>
<tr>
<td>Symptoms</td>
<td>77.4 (16.8)</td>
<td>69.0 (14.7)</td>
<td>70.5 (15.2)</td>
</tr>
<tr>
<td>[Min, Max]</td>
<td>[50.0, 96.4]</td>
<td>[39.3, 96.4]</td>
<td>[39.3, 96.4]</td>
</tr>
<tr>
<td>Function – Activities of Daily Living</td>
<td>81.9 (18.9)</td>
<td>79.7 (16.1)</td>
<td>80.1 (16.4)</td>
</tr>
<tr>
<td>[Min, Max]</td>
<td>[57.3, 100.0]</td>
<td>[45.6, 100.0]</td>
<td>[45.6, 100.0]</td>
</tr>
<tr>
<td>Function – Sports and Recreation</td>
<td>60.0 (16.7)</td>
<td>52.0 (29.3)</td>
<td>53.4 (27.4)</td>
</tr>
<tr>
<td>[Min, Max]</td>
<td>[40.0, 80.0]</td>
<td>[0.0, 95.0]</td>
<td>[0.0, 95.0]</td>
</tr>
<tr>
<td>Knee-related Quality of Life</td>
<td>58.3 (11.6)</td>
<td>48.7 (17.9)</td>
<td>50.4 (17.3)</td>
</tr>
<tr>
<td>[Min, Max]</td>
<td>[43.8, 75.0]</td>
<td>[6.3, 75.0]</td>
<td>[6.3, 75.0]</td>
</tr>
</tbody>
</table>

\(^1\) MVPA bouts ≥ 10 minutes ≥ 3 METs; \(^2\) Sedentary time bouts > 20 minutes ≤ 1.5 METs;
Two to three outliers were detected for both the bouted MVPA time and bouted sedentary time variables. Upon investigation, none were considered erroneous and removal did not drastically alter mean estimates or bivariate relationships. Thus all data points were retained in the dataset during further analysis. KOOS scores varied from a mean of 80.1 (16.4) on the
Function in Activities of Daily Living subscale to 50.4 (17.3) on the Knee-related Quality of Life subscale (Table 3.2 above).

### 3.4.1 Bivariate relationships

Side-by-side notched box plots were generated to illustrate differences between sexes in PIH score, bouted MVPA, and bouted sedentary time (Figures 3.5 and 3.6 below). While the male and female median values on each variable differ, the wide boxes indicate large inter-quartile ranges, while wide notches indicate large 95% confidence intervals (CI) for the true population male medians. The “folding over” illustrates the 95% CI estimate for the true population median extends past the 1\textsuperscript{st} quartile (Figures 3.4, 3.5 [top]), and 3\textsuperscript{rd} quartile (Figure 3.5 [bottom]).

**Figure 3.4.** Notched box plots indicating Partners in Health (PIH) score by sex. Box width proportional to $\sqrt{n}$.
Figure 3.5. Notched box plots indicating bouted MVPA (top) and sedentary time (bottom) by sex. Box width proportional to $\sqrt{n}$.
The wide notches and variable widths in the boxplots illustrate wide within-sex variation and uneven numbers of males and females, suggesting formal between-sexes significance testing would not be appropriate. Differences between sexes in terms of mean bouted MVPA and bouted sedentary time were marked. Males (n = 6) obtained a mean 114.5 (112.8) minutes, while females (n = 28) obtained 40.9 (37.6) minutes of daily bouted MVPA. Median MVPA time was less different between the sexes, with a median value for males of 59.1 minutes and females of 33.7 minutes. Males participated in a mean 384.7 (228.7) minutes of bouted sedentary time, whereas women participated in a mean 525.8 (160.6) minutes. Similarly, median bouted sedentary time was less different between the sexes, with the median value for males of 387.8 minutes and females of 556 minutes. Additionally, males reported a mean PIH of 33.5 (23.4), whereas females reported a mean of 22.4 (14.3) (medians 28.5 and 17.5 for males and females, respectively). KOOS subscales were similar between the sexes, with the exception of the Function in Sport/Recreation and Knee-related Quality of Life subscales, where males scored 8-10 points higher (i.e. less severe disease status) than females.

According to Cohen, the magnitude of correlation coefficients of $\leq 0.10$ are considered weak, $0.30$ to $0.49$ are considered moderate, and $\geq 0.5$ are considered strong [239]. Unadjusted bivariate analyses found weak non-statistically significant correlations between most potential model variables (Table 3.3). A weak positive correlation was found between the PIH score and bouted MVPA time ($r = 0.21, p = 0.24$), whereas there was a weak negative relationship between PIH and bouted sedentary time ($r = -0.06, p = 0.75$). A moderate negative relationship was found between bouted MVPA time and number of comorbidities ($r = -0.30; p = 0.089$). Statistically significant moderate negative correlations were found between BMI and bouted MVPA ($r = -0.37; p = 0.033$), as well as age and bouted MVPA ($r = -0.36; p = 0.035$). Bouted
MVPA time had weak to small positive correlations with KOOS subscales, whereas bouted sedentary time had weak to small negative correlations with KOOS subscales. Weak positive relationships were found between bouted sedentary time and age (r = 0.19; p = 0.28) and number of comorbidities (r = 0.27; p = 0.12), whereas a statistically significant strong correlation was found between bouted sedentary time and BMI (r = 0.70, p < 0.001). A statistically significant strong negative correlation was found between bouted MVPA time and bouted sedentary time (r = -0.75 p < 0.001).

Table 3.3. Correlation Matrix of Measured Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Bouted MVPA</td>
<td>1.00</td>
<td>-0.75²</td>
<td>0.21</td>
<td>-0.36¹</td>
<td>-0.37¹</td>
<td>-0.30</td>
<td>0.01</td>
<td>0.00</td>
<td>0.10</td>
<td>0.07</td>
<td>0.13</td>
</tr>
<tr>
<td>2. Bouted Sedentary</td>
<td>1.00</td>
<td>-0.06</td>
<td>0.19</td>
<td>0.70²</td>
<td>0.27</td>
<td>-0.10</td>
<td>-0.13</td>
<td>-0.18</td>
<td>-0.20</td>
<td>-0.06</td>
<td></td>
</tr>
<tr>
<td>3. PIH</td>
<td>1.00</td>
<td>0.11</td>
<td>-0.19</td>
<td>-0.28</td>
<td>0.15</td>
<td>0.25</td>
<td>0.21</td>
<td>0.15</td>
<td>0.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Age</td>
<td>1.00</td>
<td>-0.13</td>
<td>0.21</td>
<td>-0.21</td>
<td>-0.07</td>
<td>-0.36¹</td>
<td>-0.32</td>
<td>-0.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. BMI</td>
<td>1.00</td>
<td>0.31</td>
<td>-0.12</td>
<td>-0.22</td>
<td>-0.17</td>
<td>-0.17</td>
<td>-0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. # of Comorbidities</td>
<td>1.00</td>
<td>-0.26</td>
<td>-0.35¹</td>
<td>-0.31</td>
<td>-0.21</td>
<td>-0.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. KOOS Pain</td>
<td>1.00</td>
<td>0.71²</td>
<td>0.86²</td>
<td>0.78²</td>
<td>0.75²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. KOOS Symptoms</td>
<td>1.00</td>
<td>0.63²</td>
<td>0.70²</td>
<td>0.71²</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>9. KOOS Function ADL</td>
<td>1.00</td>
<td>0.76²</td>
<td>0.66²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. KOOS Function Sport/Rec</td>
<td>1.00</td>
<td>0.71²</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. KOOS QOL</td>
<td>1.00</td>
<td></td>
<td></td>
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</tbody>
</table>

¹ p < 0.05; ² p < 0.001

Scatterplots were used to assess unadjusted relationships between bouted MVPA time or bouted sedentary time and PIH. Figure 3.6 plots bouted MVPA time as a function of PIH score. The plot illustrates the weighting of PIH scores towards 0, or high patient engagement, and
illustrates the weak positive relationship between bouted MVPA and PIH such that bouted
MVPA time increases with decreasing patient engagement.

Figure 3.6. Bouted MVPA time as a function of Partners in Health Scale (PIH) (shaded area represents 95% confidence band for the fitted line).

Figure 3.7 (below) plots bouted sedentary time as a function of PIH score, illustrating the weak negative relationship between the two variables. While there does exist an outlier at the high end of the PIH scale, removal of the data point did not alter the calculated r value for PIH and bouted sedentary time. Neither plot readily suggested non-straight-line relationships. Additional univariate and bivariate plots are viewable in Appendix B. In bivariate analysis, the pain subscale of the KOOS questionnaire was found to have high correlations (i.e. r > 0.7) with other KOOS subscales.
3.4.2 Multiple Regression Modeling of Bouted MVPA Time

Since there is evidence to suggest knee OA disability is mediated by pain [240], the KOOS pain subscale alone was deemed a reasonable proxy for knee OA disease status and thus was the one KOOS variable used in the model building process. The initial bouted MVPA time analysis yielded a model in which the residuals were significantly non-normal according to the Shapiro-Wilk test and visually heteroscedastic. Thus, the data were transformed using the Yeo-Johnson adaption of the Box-Cox transformation procedure. The Box-Cox procedure allows for the determination of a power transformation with a high likelihood of yielding normally distributed residuals [241]. The Yeo-Johnson adaptation of this procedure is identical in nature, but allows for zero values within the data, of which there was one [242]. Results from this
procedure suggested a log-transformation was an acceptable choice, and is preferable to some other transformations in its relative clarity of interpretation. Thus the \( y_{MVPA} \) variable was transformed by taking the natural logarithm of \( (y_{MVPA} + 1) \), yielding the transformed dependent variable \( \ln_{MVPA} \). The forward selection model-building process was then reiterated.

Bivariate analyses suggested the main predictor of interest, PIH, was not related to bouted MVPA time. The initial model building process in which the PIH variable was held within the model further determined the PIH variable was not associated with bouted MVPA, and the nature of the relationship did not change based on the addition of other potential confounders. Thus, the PIH was dropped from the model, and a best fitting model was built to describe associations with \( \ln_{MVPA} \). Table 3.4 (below) provides a summary of this final model building process:

\[
\ln_{MVPA} = 10.45 - 0.15x_{BMI} (Kg/m^2) - 0.042x_{Age} (years) - 0.71x_{sex} (0=male).
\]

When holding other variables in the model constant, BMI was significantly associated with \( \ln_{MVPA} \), with an increase of 1 unit in BMI associated with a 0.15 unit decrease in \( \ln_{MVPA} \) (95% CI: \([-0.21, -0.09]\); \( p < 0.001 \)). Age was significantly associated with \( \ln_{MVPA} \), with an increase of 1 year associated with a decrease of 0.042 units of \( \ln_{MVPA} \) (95% CI: \([-0.078, -0.0045]\); \( p < 0.03 \)). Female sex was significantly associated with \( \ln_{MVPA} \) at the 0.1 level, but not the 0.05 level. As it is known to be related to MVPA participation and altered the age estimated beta value by > 20% suggesting confounding, it was left in the model. Being female was associated with a 0.71 decrease in \( \ln_{MVPA} \) (95% CI: \([-1.52, 0.10]\); \( p = 0.07 \)). No other variables were significantly associated with bouted MVPA time, and no significant interaction terms were found. Residuals were not significantly non-normal according to a Shapiro-Wilk test and were visually
homoscedastic. Overall, the model adjusted $R^2$ was 0.49, indicating model variables were able to explain 49% of the variance in bouted MVPA time within the sample.

Table 3.4. Model regression coefficients from forward selection procedure to determine independent variables associated with bouted MVPA.

<table>
<thead>
<tr>
<th>Model</th>
<th>Variable</th>
<th>Regression Coefficient</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
<th>F</th>
<th>$R^2$ (adj)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>7.22</td>
<td>0.98</td>
<td>7.37</td>
<td></td>
<td>15.02*</td>
<td>0.30</td>
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<tr>
<td></td>
<td>BMI</td>
<td>-0.14</td>
<td>0.04</td>
<td>-3.87</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>10.58</td>
<td>1.38</td>
<td>7.68</td>
<td>&lt; 0.001</td>
<td>14.51*</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>-0.15</td>
<td>0.03</td>
<td>-4.75</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.05</td>
<td>0.02</td>
<td>-3.14</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Step 3 (final model)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
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<td>1.33</td>
<td>7.84</td>
<td>&lt; 0.001</td>
<td>11.42*</td>
<td>0.49</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
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<td>0.03</td>
<td>-4.91</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.04</td>
<td>0.02</td>
<td>-2.29</td>
<td>&lt; 0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sex (male = 0)</td>
<td>-0.71</td>
<td>0.40</td>
<td>-1.79</td>
<td>&lt; 0.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* $p < 0.001$

3.4.3 Multiple Regression Modeling of Bouted Sedentary Time

Similar to bouted MVPA, bivariate analyses suggested the PIH was not related to bouted sedentary time. As above, the initial model building process in which the PIH variable was held within the model determined the PIH variable remained unrelated to bouted sedentary time even after the addition of potential confounders. Thus, the PIH was again dropped from the model, and the forward selection process was repeated to create a model that included only those
variables significantly related bouted sedentary time in the present sample. Residuals were not significantly non-normal according to a Shapiro-Wilk test and were visually homoscedastic.

Table 3.5 provides the summary of the final bouted sedentary time model building process. The final model was:

\[ y_{\text{sed}} = -375.70 + 27.47x_{\text{BMI}} \text{ (Kg/m}^2\text{)} + 156.01x_{\text{sex (0=male)}}. \]

When holding other variables in the model constant, BMI was significantly associated with \( y_{\text{sed}} \), with an increase of 1 unit in BMI associated with an increase of 27.47 minutes of daily bouted sedentary time (95% CI: [18.72, 36.22]; \( p < 0.001 \)). Female sex was also significantly associated with a 156.01 minute increase in bouted sedentary time (95% CI: [50.09, 261.92]; \( p < 0.01 \)) over males. No other variables were significantly associated with \( y_{\text{sed}} \), and no significant interaction terms were found. Residuals were not significantly non-normal according to a Shapiro-Wilk test and were visually homoscedastic. Overall, the model adjusted \( R^2 \) was 0.58, suggesting model variables were able to explain 58% of the variance in bouted sedentary time within the sample.

<table>
<thead>
<tr>
<th>Model</th>
<th>Variable</th>
<th>Regression Coefficient</th>
<th>Standard Error</th>
<th>t</th>
<th>p</th>
<th>F</th>
<th>R^2 (adj)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Intercept</td>
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<td>132.36</td>
<td>-1.75</td>
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</tr>
<tr>
<td></td>
<td>BMI</td>
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<td>5.61</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Step 2 (final model)</td>
<td>Intercept</td>
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<td>127.72</td>
<td>-2.94</td>
<td>&lt; 0.001</td>
<td></td>
<td>0.58</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
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<td>4.29</td>
<td>6.40</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sex (male = 0)</td>
<td>156.01</td>
<td>51.93</td>
<td>3.00</td>
<td>&lt; 0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\* \( p < 0.001 \)
Chapter 4: Discussion, Limitations, Conclusion

The role of the engaged patient in the proactive self-management of chronic diseases is increasingly recognized [76,81]. In the context of knee osteoarthritis (OA), a physically active lifestyle is a pillar of optimal self-management because of the disease-specific and holistic health benefits for people living with the condition [98,100]. In addition, emerging evidence highlights the independent functional [243,244] and cardiometabolic health [145–147,245] risks of prolonged sedentary behaviour. Despite this, the knee OA population remains insufficiently active [132] and largely sedentary [131]. It is unclear, however, whether patients who report being more engaged in self-management of their knee OA tend to be more active or less sedentary.

The purposes of this thesis were to develop a protocol of a pilot study to test an intervention to support greater physical activity (PA) participation among people living with knee OA, and to utilize the baseline data from this study to explore the relationship between levels of patient engagement and key PA behaviours. Chapter 1 presented an overview of the relevant background, including a discussion of knee OA, its management, the central role of the engaged patient in good self-management, and the important yet underutilized role of PA. Evidence-based strategies for PA promotion were described to inform the development of a new PA promotion intervention aimed at the knee OA population. Chapter 2 provided the published protocol for the TRACK-OA pilot randomized controlled trial (RCT) to test the feasibility and preliminary efficacy of this intervention, an activity counseling and lifestyle PA-support program that included the use of a consumer wearable activity tracker and weekly telephone follow-up. Chapter 3 outlined a cross-sectional analysis of the TRACK-OA baseline data to assess the relationship between the Partners in Health Scale (PIH), a measure of patient engagement, and
objectively-measured bouted MVPA and bouted sedentary time. As participating in regular PA is a key component of knee OA self-management, it was hypothesized that the level of patient engagement would positively correlate with MVPA (i.e. negative relationship between PIH score and bouted MVPA time), and negatively correlate with sedentary time (i.e. positive relationship between PIH score and bouted sedentary time). Results, however, suggested that PIH was not associated with time spent in MVPA or sedentary activity. This chapter provides a discussion of the results from the Chapter 3 exploratory analysis. Follow-up data from the TRACK-OA study were not included in this thesis. Thus, no discussion of the TRACK-OA study is given in this chapter, and will instead be reserved for a future manuscript.

4.1 Exploratory Analysis

4.1.1 Univariate Results

4.1.1.1 Partners in Health

The present sample reported [mean (SD)] 24.4 (16.4) on the PIH. As the worst possible PIH score is 96, this suggests a relatively high level of patient engagement. Comparison of the present sample’s PIH score with other studies must be made with caution due to changes in the wording and number of items on the scale over the past several years [79,80,246]. However, the high level of engagement indicated by this sample is in line with other studies of mixed chronic disease populations. For example, a 2015 pragmatic RCT by the developers of the PIH, the Flinders Group, aimed to test the effectiveness of their generic self-management program for improving health outcomes among community dwelling adults with various chronic illnesses [247]. Their sample was predominantly retired, with a mean age of 70 years. The majority of the sample lived with cardiovascular disease (64%), and 23% had arthritis. Using a version of the
PIH that included 14 questions (possible scores from 0-126, where 0 is the highest patient engagement), the sample reported a mean PIH score of 28.9 (16.1) in the intervention group, and 28.7 (13.6) in the control group, indicating a relatively high level of engagement at baseline [247]. In another study, Heijman’s et al. (2015) conducted a population-based survey to assess the association between health literacy and patient engagement in self-management as measured by the PIH among people living with chronic illness in the Netherlands [248]. A wide variety of education levels (high school to advanced degrees), incomes, and diseases were represented (13% musculoskeletal conditions). The majority (68%) of the sample was between 45 and 74 years, and 49% had been living with their chronic condition for over 10 years. In their analysis, the PIH was scored by subscales created using factor analysis, rather than as a composite score. Additionally, scoring of the scale was inverted relative to that of the version used in the present analysis, making the values scored from 0-8, with 8 representing the highest possible level of engagement. The mean score across subscales was found to be 6.8 (0.8), suggesting a high level of patient engagement among a national sample living with a variety of chronic illnesses. One study using the PIH in an arthritis-specific population was able to be located. Brand et al. (2010) assessed the outcomes of a new model of care for lower-limb OA patients in Australia, using a version of the PIH similar to the present study where 0 was the highest score and 96 was the lowest score. The 123 participants in the study reported a mean of 45.9 (16.4), suggesting a more moderate level of patient engagement. Participants were predominantly female (76.4%) with mean age of 66 years, and were referred to the study primarily by orthopaedic clinics and reported a mean of 6.5, 6.2, and 6.3 on a 0-10 scale for pain, functional disability, and other symptoms respectively. The majority were overweight or obese, with a median BMI of 32.4 (first and third quartiles: 29.0, 38.1) kg/m^2, and the majority (63%) lived with multimorbidity
Participants in TRACK-OA, on the other hand, were younger (mean age 55.5 years), lower BMI (mean = 27.2 kg/m²), and had more mild to moderate knee OA as indicated by the Knee Injury and OA Outcome (KOOS). Such differences in sample characteristics may have contributed to differences in PIH scores.

4.1.1.2 Bouted Moderate-to-Vigorous Physical Activity

Previous research has suggested that the knee OA population is highly inactive, and does not tend to achieve recommended levels of 150 minutes per week of bouted MVPA time [132]. For example, Dunlop et al. (2011) reported 504 men with radiographic knee OA participated in a mean 9.2 (14.7) daily minutes of bouted MVPA per day, whereas the 607 women sampled engaged in 5.4 (10.9) daily minutes [131]. Similarly, a meta-analysis reported people with knee OA engaged in a mean 50 minutes of bouted MVPA per week, with 13% of the sample meeting PA guidelines [132]. At baseline the TRACK-OA sample indicated roughly 54 minutes of bouted MVPA per day. Extrapolated, that suggests over 350 minutes per week of MVPA, far in excess of established PA recommendations [250].

Several factors relating to the characteristics of the sample and the measurement tools used to measure MVPA may have contributed to this marked difference. First, the TRACK-OA sample demographics were not representative of the larger knee OA population from which they were drawn. For example, a systematic review by Wallis et al. (2013) demonstrated over 21 studies of 3266 people living with knee OA, a mean age of 64 years, a BMI of 30 kg/m², with 63% female [132]. By contrast, the present sample was 82% female with a mean age of 55.5 years and a BMI of 27.2 kg/m². As older age and higher BMI have been associated with lower MVPA [136,232], it is possible these factors contributed to the disparity seen in MVPA time.
between the present study and others. Furthermore, as TRACK-OA was advertised as a PA-related study, it is possible that individuals in the sample exhibited a selection bias and were already highly active and health conscious in their everyday lives compared to other knee OA samples.

While the TRACK-OA sample may be more active than the general knee OA population, an additional contributor to the high measured MVPA participation in this sample could be the PA measurement tool used in this study. Whereas previous reports have used the Actigraph accelerometer to estimate MVPA time in people with knee OA [132,243], the present study used the SW. Key differences between these instruments are their locale (SW = arm; Actigraph = hip), their use of a skin sensors (SW included; Actigraph not), and their recommended wear time (SW = 24 hours/day; Actigraph = waking hours only). The arm-based locale and skin sensors contribute to the SW being a more sensitive measurement tool, allowing it to more accurately assess energy expenditure [116]. Indeed, these properties appear to yield improved accuracy for detecting differences between light and sedentary behaviour over the Actigraph [251]. This yields the possibility that previous estimates using the Actigraph underestimated MVPA time among people with knee OA. Additionally, whereas the Actigraph is removed before sleep, the SW is worn all hours of the day. Thus, it is possible the SW may detect meaningful contributions to daily bouted MVPA that previous estimates using Actigraph could not.

4.1.1.3 Bouted Sedentary Time

Estimates of objectively-measured sedentary behaviour within OA populations are relatively limited. The present sample participated in about 8.5 hours of bouted sedentary time, similar to the multi-center American OA Initiative cohort [243]. This research, however, was
not considering sedentary time in prolonged bouts, a behaviour pattern thought to be particularly associated with health risks [150,245]. It is possible the present sample would have indicated more total sedentary time if no bout criteria had been used.

No studies specifically assessing bouted sedentary time within an arthritis population could be located, though there is some evidence from other populations with chronic conditions. Healy et al. (2015) showed that a sample of individuals who were overweight or obese and had diabetes (mean age = 58.6 years) engaged in 151 minutes per day of bouted sedentary time, in bouts ≥ 30 minutes [252]. A separate study by Judice et al. (2015) investigating the association between sedentary bout durations and abdominal obesity in older adults (mean age = 75 years) found the sample (n = 351) spent 32.4% of their waking day (roughly 5 hours) in sedentary bouts at least 20 minutes in duration [253]. Those in the TRACK-OA study partook in markedly more bouted sedentary time than these samples. Several factors, may have contributed to this. First, knee OA symptoms, particularly pain, are a known barrier to PA [134,135,254], and may motivate people to remain seated or limit light activities where possible. Second, Judice et al. studied a predominantly retired older adult population [253], whereas the TRACK-OA sample was predominantly of working age. While increasing age has generally been associated with increasing sedentary time [255,256], there is some evidence that it may decrease with retirement. Godfrey et al. (2014) found employed individuals spent 78% of their day in sedentary activity, compared to 74.7% of the day for retirees of any age. This relationship was primarily the result of employed adults engaging in a mean of two more prolonged bouts (> 55 minutes) per day of sedentary behaviour than retirees [257]. A third factor contributing to the divergent estimates is the differing criteria for what constitutes “bouted” sedentary time. For the present analysis, the bout criterion was based on an experimental study demonstrating adaptive physiological
responses to breaking up sedentary bouts every 20 minutes [151]. At this relatively early stage in the development of evidence surrounding risks of sedentary behaviour the bout cut-off is somewhat arbitrary [252], prompting others to use bouts of 30 or more minutes. Unfortunately, such differing bout criteria impair comparison between studies.

4.1.2 Bivariate Relationships and Multiple Regression

4.1.2.1 Bouted Moderate-to-Vigorous Physical Activity and Partners in Health Scale

As a patient’s level of engagement is indicated by self-rated knowledge and abilities in a broad range of self-management activities such as working with their care team, adhering to treatment, and pursuing habits that support health, it was hypothesized that higher competency in these areas would be associated with greater MVPA time, as it is considered a core treatment for knee OA [73]. However, results indicated a small, non-statistically significant positive bivariate relationship between PIH and bouted MVPA. When adjusting for age, BMI, and sex in a regression model, the relationship diminished, suggesting a patient’s level of engagement and daily MVPA time may be independent. Thus, the first hypothesis of this study was not supported.

Various factors could account for the lack of a detectable relationship. It is possible the results reveal a true null association, suggesting that despite the important role of PA in the management of knee OA, people living with this condition may consider themselves knowledgeable and skillful participants in their health without undertaking regular MVPA. Such a finding would be in contrast to previous evidence suggesting more engaged patients (as indicated by higher levels of patients activation or self-efficacy for self-management) tend to participate more in self-management behaviours, including exercise [87,89,90,94]. While
clarifying work is required to confirm these findings, a possible explanation could relate to patient engagement being measured by self-ratings of knowledge and ability. Self-ratings of one’s self-management ability are limited by an individual’s understanding of what constitutes effective disease management. Thus, if knowledge of the importance of MVPA in the treatment of knee OA is low, patients may feel themselves to be managing well despite low PA participation. In line with this hypothesis is the finding that about one quarter of OA patients in British Columbia receive appropriate recommendations to exercise for the management of their condition from health care professionals [258].

It is also possible that a true relationship between these patient engagement and bouted MVPA time does exist, as suggested by previous work [87,89,90,94], but was not detected due to important differences in study design. First, factors relating to the measurement tools used in this study may have contributed to the lack of a detectable relationship. The present study measured patient engagement using the PIH, whereas other studies have tended to assess patient activation via the Patient Activation Measure (PAM) [83]. The PIH and PAM assess similar domains of knowledge and skills related general self-management, however the PAM includes motivational items regarding an individual’s beliefs and confidence surrounding their role in managing their health that are absent from the PIH [83]. The evolving nature of the patient engagement construct [86,259] means that no gold standard measurement tool is presently agreed upon. However, it is possible that these motivational components of patient engagement are important components in its relationship with MVPA.

A second key difference between this and other studies is the use of an objective measure of MVPA, whereas previous studies have relied on self-report. Agreement between self-report and objectively-measured PA is not strong, and evidence indicates estimates of PA by self-report
are typically higher [260,261]. Furthermore, the items used in other studies assessing patient engagement and PA outcomes have not assessed time spent in specific intensities of PA, but instead relied on self-reported frequency of exercise. As such, it is possible that the nature of the relationship between PA and patient engagement varies depending on the method of PA assessment used.

Finally it is worth noting that the sample indicated a relatively high level of engagement (mean PIH = 24.4) and a relatively high amount of bouted MVPA time (mean 53.9 minutes). Thus, a positive relationship may yet exist across the spectrum of patient engagement but was not discernible at high levels of both variables. Further work among a larger, more representative sample with broader ranges of MVPA participation and patient engagement is warranted to explore the relationship between these variables in the knee OA population further.

4.1.2.2 Bouted Moderate-to-Vigorous Physical Activity, Age, BMI, and Sex

Small to moderate non-significant bivariate relationships were found between bouted MVPA time and several other variables. However, aside from an expected large inverse relationship between bouted MVPA and bouted sedentary time, significant associations were found between bouted MVPA and age, as well as bouted MVPA and BMI. After transforming the bouted MVPA variable with a logarithmic transformation, the multiple regression analysis revealed BMI and age to be significantly and independently associated with bouted MVPA time in this sample. The variable for sex was marginally significant and was included as a potential confounder in the final model.

These findings are consistent with previous research on PA participation within knee OA and general populations that find PA decreases with increasing age [136,232,234]. For example,
Chmelo et al. (2013) assessed predictors of MVPA participation among an American sample living with knee OA, finding age to be significantly negatively correlated with steps per day ($r = -0.21; p < 0.01$), and MVPA ($r = -0.22; p < 0.01$) [262]. Similarly, Lee et al. (2013) reported the percentage of a large cohort ($n = 1089$) classified as completely inactive (i.e. no 10-minute bouts of MVPA in the previous week) increased with increasing age group from 33.7% of individuals aged 49-59 years, to 65.3% among those 70-79 years [263].

Evidence for a relationship between BMI and MVPA within the knee OA population is mixed. For example, Lee et al. (2013) reported a decreased likelihood of meeting PA guidelines among individuals of increasing weight class. Whereas 17.9% of individuals of normal weight met recommended PA guidelines, 12.5% of overweight individuals and 3.6% of obese individuals did [263]. Additionally, Murphy et al. (2008) conducted a case-control study assessing the impact of pain and fatigue on daily PA among women with and without OA. BMI differed significantly between groups during bivariate comparisons (OA group mean = 31.0 (5.6) kg/m$^2$; non-OA group mean = 24.7 (3.8) kg/m$^2$; $p < 0.001$), but did not remain significantly associated with PA in adjusted models [264]. As well, Chmelo et al. (2013) found small, non-significant associations between BMI and MVPA time [262]. Some authors have posited the existence of a self-reinforcing relationship between BMI and knee OA, where OA-related symptoms lead to decreases in PA, leading to increased weight, which further erodes joint health [49]. As a cross-sectional study, the present findings cannot provide insight into causality. However, these results lend support to the association between BMI and MVPA among people living with knee OA and suggests further investigation of the directionality of this relationship is warranted.
In agreement with previous literature among the knee OA population, the sample indicated marked sex differences in MVPA time. Between-sex means were influenced by outliers and differed greatly (males about 70 more minutes) whereas medians differed less (males about 25 more minutes). While no minimum clinically important difference has been defined for MVPA, as little as 15 minutes of exercise per day has been associated with a 14% decreased risk of all-cause mortality and an additional three years of life expectancy in a general population cohort [265]. This suggests even small differences in PA may be clinically relevant for health outcomes, and that females living with knee OA may be particularly important targets for PA-promotion efforts.

4.1.2.3 Bouted Sedentary Time and Partners in Health Scale

While studies have assessed associations between MVPA behaviours and patient engagement [92,94], the present study appears to be the first to measure the relationship between any measure of sedentary time and a measure of patient engagement. On the basis of the health risks associated with sedentary behaviour patterns [145], it was hypothesized that more engaged patients would indicate less bouted sedentary time. Results from the present analysis did not support this hypothesis, and no association between PIH and bouted sedentary time was found.

A potential explanation for these results is the relatively recent emergence of sedentary behaviour as a risk factor for poor health outcomes [245]. As discussed above, levels of patient engagement indicated by the PIH are self-rated and depend on an understanding of what constitutes “good” self-management. However, little is known about the uptake of knowledge surrounding sedentary behaviour or whether it is perceived as a health risk by the OA population. Limited knowledge of general Canadian PA guidelines has been reported, with as few as 10%
and 5% of the general public reporting knowledge of MVPA and children’s sedentary behaviour guidelines respectively [266]. Thus, it is possible that even engaged patients remain ignorant of the risks associated with prolonged sedentary behaviour patterns. Further work will be useful in determining the extent to which knee OA patients perceive a sedentary lifestyle as a risk to their joints or overall health, and whether more engaged patients are more proactive in mitigating these risks.

4.1.2.4 Bouted Sedentary Time, BMI, and Sex

Whereas some studies have assessed the relationship between physical function-related outcomes using sedentary time (non-bouted) as an explanatory variable [243,244,267], few studies have assessed factors that contribute to sedentary time in arthritis populations. Studies from non-clinical populations have found several person-level variables associated with sedentary behaviour, including age and employment status [255]. Evidence for an association between sex and sedentary time is mixed. Studies of sedentary behaviour measured by TV-viewing time have tended to find males to participate in slightly more sedentary time than females [268,269]. Other studies conducted using an accelerometer or questionnaire to assess sedentary behaviour in community-dwelling older adults, however, found no association with sex [270,271]. For example, Arnardottir et al. (2013) studied an older Icelandic population, finding men to engage in half an hour more sedentary time per day than women [269]. By contrast, in the present study female sex was found to be significantly positively associated with bouted sedentary time in the final regression model (i.e. after adjusting for BMI). A few factors may have contributed to this association. First, as few studies have reported on the relationship between bouted sedentary time and sex, it may be possible that the sexes are similar in their
overall amount of sedentary behaviour but differ in their patterns of accumulating it. Second, 
greater participation in bouted sedentary behaviour among women with knee OA may be related 
to knee OA symptoms, as evidence suggests women experience more severe knee OA symptoms 
than men [29]. Third, sampling variation due to the small pool of males (n = 6) in this study may 
also have altered results relative to what may be found in larger samples. Given the poor health 
outcomes associated with sedentary time, additional research assessing whether women are at 
greater risk for prolonged periods of sedentary behaviour is warranted.

Consistent with previous work outlining the association between sedentary time and 
overweight and obesity [146], the present study found strong statistically significant associations 
between bouted sedentary time and BMI. This relationship is particularly concerning, as 
increased adipose tissue has been suggested to compromise joint health both mechanically and 
metabolically, exacerbating knee OA symptoms and increasing risk for comorbidity [49]. 
Emerging evidence suggests breaking up bouts of sedentary time may lead to decreases in 
cardiometabolic risk factors [150,272], and that displacing sedentary behaviour in favor of light 
activity is associated with lower weight [151] and better physical function [243] among people 
with knee OA. Thus, these findings support the need for interventions such as the TRACK-OA 
program that take a targeted approach to the disruption of prolonged sedentary bouts among 
people with knee OA.

4.2 Strengths and Limitations

4.2.1 TRACK-OA Protocol

There are several limitations to the TRACK-OA protocol. With regard to RCT 
methodology, the gold standard is the fully-blinded trial in which neither the participants nor the
staff administering the intervention or performing the analysis are aware of group allocations. However, a major issue in the testing of behavioural interventions is the difficulty in blinding participants to their intervention group. Furthermore, there may be practical limits on the ability to effectively blind all staff involved in study administration. These facts may introduce experimenter bias into the results, jeopardizing the internal validity of the trial. To mitigate the potential for this as much as possible, randomization was performed by an investigator (Dr. Goldsmith) who was not involved with study operations, and blocks of random sizes were used to prevent study staff from ascertaining group allocations by process of elimination. Furthermore, to ensure consistency, standardized scripts were developed for use by staff members while conducting the intervention, and the data analyst was blinded to individual identities and group allocations to prevent any selective use and reporting of statistics. Additionally, the staff member handling collection and analysis of study data was blinded to group allocations. Despite these efforts, a potential for experimenter bias in the results must be acknowledged.

As a pilot study, the sample size for TRACK-OA was determined not on the basis of a power calculation to detect a meaningful difference between groups, but rather by considering the number of participants deemed necessary to adequately test the feasibility of a larger-scale intervention. Thus, inferences about intervention efficacy will be better made in upcoming studies that include larger sample sizes. Despite these limitations, the TRACK-OA intervention has several strengths highlighted previously in section 2.11, including the use of a stepped-wedge design, an emphasis on action-oriented strategies for PA promotion, the ability to share participant activity data with study physiotherapists to aid in goal setting and overcoming of barriers, and the person-centered approach to self-management support.
4.2.2 Exploratory Analysis

Certain limitations require acknowledgement. The first and most major limitations of this study surround it being an opportunistic secondary analysis of data collected for another purpose. As such, the sample size was limited and not representative of the greater knee OA population, decreasing the external generalizability of the findings. An important limitation of the sample was its inclusion of six male participants, compromising the ability to assess differences in sex. Additionally, consideration of potential confounders was limited to those variables available in the dataset, and insights about causality may not be drawn from the cross-sectional study design employed. Future studies may address these limitations by utilizing a prospective design, a more representative sample including sufficient numbers of male and female participants to adequately power assessments of sex differences (i.e. by employing sex-stratified sampling), and a purposeful collection of potential confounders that may relate to both the explanatory and outcome variables. Second, while no measure of patient engagement has been described as a gold standard, measures such as the PAM have employed a broader definition of the construct and have undergone more thorough psychometric testing [83,88,90]. Thus, future research assessing relationships between health-related outcomes among people with knee OA may consider alternate measures of patient engagement.

Despite these limitations, the analysis has several strengths. First, whereas previous reports have relied on self-report PA data, the present study assessed the association between patient engagement and objective measures of PA behaviour. The use of an objective measure decreases bias and error in reporting of PA, and provides clear criteria for assessing the time spent in MVPA and sedentary activity [115]. Furthermore, the use of the multi-modal SW arm-
based activity monitor allows better differentiation between sedentary and light behaviour than other objective measures [120]. Finally, the data collected at baseline during the TRACK-OA study represented a high standard of quality, with 100% participant adherence to wearing the SW activity monitor as well as full questionnaire completion.

4.2.3 Study Implications and Future Directions

As a leading cause of chronic pain and functional disability, OA represents a major public health challenge. With the combined impacts of an increasingly overweight, aging, and sedentary population, the burden of this condition will become immense. While much work has been undertaken to highlight the benefits of increasing participation in MVPA and decreasing sedentary time in knee OA, effective interventions to implement this knowledge and increase engagement in these core self-management tasks are needed. The TRACK-OA intervention represents the first step in the development of a new strategy to help fill this gap.

Engaged patients are thought to be instrumental in meeting the challenges presented by chronic disease. Efforts to support more optimal self-management will be aided by a more thorough understanding of the qualities and behaviours exhibited by patients who report being actively engaged in their health. Additionally, understanding the relationships between patient engagement and health-related outcomes will provide insight into benefits that may come from increasing patient engagement in arthritis management. The analysis undertaken in Chapter 3 provided a first exploration of how levels of patient engagement relate to the objectively-measured performance of key PA self-management behaviours, bouted MVPA and sedentary time. While further work is necessary, for now clinicians may be prudent not to assume that more engaged knee OA patients necessarily perform more MVPA, or less prolonged sedentary
activity. Indeed, PA-support interventions such as TRACK-OA may be required across the spectrum of patient engagement in this population.

4.2.4 Conclusion

The overarching goals of this thesis were to develop a protocol to pilot test a new intervention to enhance PA participation and gain a greater understanding of the relationship between patient engagement and PA among people living with knee OA. Chapter 1 outlined the state of knowledge on the role of PA in the self-management of knee OA and effective techniques for enhancing PA participation, and Chapter 2 leveraged this knowledge in the development of the TRACK-OA intervention designed to increase bouted MVPA time and decrease bouted sedentary time. Baseline data from the TRACK-OA study was utilized in Chapter 3 to answer the main research question posed in this thesis: what is the relationship, if any, between a knee OA patient’s current level of engagement and the performance of objectively-measured bouted MVPA and sedentary time? Participants reported relatively high engagement and high MVPA, but no significant relationships were found between PIH and bouted MVPA or bouted sedentary time. A detailed discussion of these results was provided in Chapter 4, and further research in this area was advocated.

In the context of the growing emphasis on supporting patients to actively self-manage their health, this thesis broke new ground in the patient engagement literature by exploring the relationship between an objective measure of PA and patient engagement in an arthritis sample. The limited relationships are suggestive that knee OA patients’ level of engagement may be largely independent of their PA, and other factors may determine objectively-measured MVPA and sedentary time among this population. Further work investigating the correlates and
outcomes related to patient engagement will provide insight into the potential benefits of increasing patients’ active participation in health, and may ultimately assist with providing more targeted and tailored support to individuals living with knee OA.
Bibliography


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Appendices

Appendix A  TRACK-OA Study Materials

The following materials were used during the TRACK-OA pilot study. Section A.1 and A.2 include the screening questionnaires, whereas section A.3 is the baseline questionnaire (a composite of all outcome measures) in word format. Please note that these questionnaires were modified from the present version for use on a secure, online system. All text was copied verbatim. Section A.4 includes the Brief Action Planning flowcharts modified from Gutnick et al. (2014) [230].
A.1  Track-OA Study Screening Questionnaire – *Phase 1*

*Instructions for the research team members [for internal use only]:*

This screening questionnaire is hosted on the Arthritis Research Centre of Canada’s Limesurvey System. The Limesurvey is fully secure.

Welcome to the TRACK OA Screening Questionnaire! To see if you meet the health criteria for the TRACK OA study, please provide your answers for the following questions. A member of the research team at the Arthritis Research Centre of Canada will contact you to confirm your eligibility to participate.

The information you provide will be kept strictly confidential.

**Phase 1 (online):**

1. You are a…
   - [ ] Potential study participant
   - [ ] Research staff. (Please enter your initials: _________)

2. Has your doctor ever told you that you have Osteoarthritis in your knee(s)?
   - [ ] Yes  (If YES, skip to Q5)
   - [ ] No

   **[Questions 3 and 4 are Marra’s Knee Pain Questions – “yes” to both indicates >80% Are you 50 years or older?]**
   - [ ] Yes
   - [ ] No

3. Have you felt pain/discomfort in or around the knee during the previous year that lasted more than 28 separate or consecutive days?
   - [ ] Yes
   - [ ] No

4. Has a doctor ever told you that you have any of the following conditions:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Rheumatoid arthritis</td>
<td>[ ] Yes</td>
</tr>
<tr>
<td>b. Gout</td>
<td>[ ] Yes</td>
</tr>
<tr>
<td>c. Fibromyalgia</td>
<td>[ ] Yes</td>
</tr>
<tr>
<td>d. Ankylosing Spondylitis</td>
<td>[ ] Yes</td>
</tr>
<tr>
<td>e. Psoriatic arthritis</td>
<td>[ ] Yes</td>
</tr>
<tr>
<td>f. Polymyalgia rheumatica</td>
<td>[ ] Yes</td>
</tr>
<tr>
<td>g. Connective tissue diseases, such as systematic lupus erythematosus or</td>
<td>[ ] Yes</td>
</tr>
</tbody>
</table>
5. Do you have a history of using disease-modifying anti-rheumatic drugs (DMARD) or gout medications?
   □ Yes □ No □ Not Sure

6. Have you been using medication that may impair physical activity tolerance (e.g., beta blockers)?
   □ Yes □ No □ Not Sure

7. Have you had total joint (e.g., knee or hip) replacement surgery?
   □ Yes (If YES, skip to Q10) □ No

8. Are you currently on a waiting list for total joint (e.g., knee or hip) replacement surgery?
   □ Yes □ No

9. Have you had acute injury to the knee in the past six months?
   □ Yes □ No

10. Have you had a steroid injection in your knee(s) within the past six months?
    □ Yes □ No

11. Have you had a hyaluronate injection in your knee(s) within the past six months?
    □ Yes □ No

12. In the past 12 months, have you had surgery in your back, hip, knee, foot or ankle joints?
    □ Yes □ No

13. Do you have an email address?
    □ Yes □ No

    If YES, what is your email address? _________________________________

14. Do you have daily access to the Internet or a smartphone?
    □ Yes □ No

15. How did you learn about our study?

    JointHealth e-blast □
    Email □
    Newsletter □
    Friend or family member □
    Arthritis Research Centre’s Website □

    Flyer in my physician's office □
    Flyer at a community centre or library □
    Craigslist / Kijiji □
    Other, please specify □ _____________________________
16. Do you have any additional information about your health that you would like to share with us?

____________________________________________________

________________________________________________________________________

Conclusion Page:
Thank you for completely the screening questionnaire. You will be contacted within 1 work day to confirm your eligibility.

Please provide your contact information:

First name ______________________

Last name ______________________

Phone number ______________________

The best time to contact you ______________________

<table>
<thead>
<tr>
<th>Participant’s Eligibility (To be completed by the Screener)</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is this participant eligible for Phase 2 screening?</td>
<td>[ ] Yes</td>
</tr>
</tbody>
</table>

[For internal use only]:
A participant is eligible to participate in the Phase 2 screening if he/she answers
“Yes” to Q.2 or “No” to Q.2 with “Yes” to Q.3-4.
“No” to Q.5-13
“Yes” to Q.14-15
* If a participant is eligible, he/she will be contacted by the study’s research coordinator for Phase 2 screening
A.2 Track-OA Study Screening Questionnaire – Phase 2

Participant ID number: _____________  Interviewer Initials: _____  Date: _____________

MM / DD / YYYY

Interviewer Instructions:
- Read questions and record responses as indicated below.
- Interviewer instructions are italicized throughout. Do not read to participants.

Introduction: Hi, may I please speak with ________________. My name is _______________. I’m calling from UBC and the Arthritis Research Centre of Canada to follow-up on a Fitbit study called Track-OA. Thanks again for filling out the study online screening questionnaire, in order to determine your eligibility, I would like to ask you a few questions.

1. How tall are you? _____ feet ____ inches or ___cm [dropdown box]

2. How much do you currently weigh? ____(lbs/kg) [dropdown box]

3. Do you have a history of using any of the following medications? (check all apply)

☐ Methotrexate (MTX)
☐ Sulfasalazine (SSZ)
☐ Hydroxychloroquine (HCQ)
☐ Actemra/RoActemra
☐ Cimzia
☐ Enbrel
☐ Humira
☐ Orencia
☐ Remicade
☐ Rituxan/Mab Ther
☐ Simponi
☐ Xeljanz
☐ Allopurinol
☐ Febuxostat
☐ Colchicine
☐ Pegloticase
☐ Probenecid
<table>
<thead>
<tr>
<th>Questions</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Has your doctor ever said that you have a heart condition ☐ OR high blood pressure☐?</td>
<td>☐  Yes</td>
</tr>
<tr>
<td>5. Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?</td>
<td>☐  Yes</td>
</tr>
<tr>
<td>6. Do you lose your balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).</td>
<td>☐  Yes</td>
</tr>
<tr>
<td>7. Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? PLEASE LIST CONDITION(S) HERE:__________________________________</td>
<td>☐  Yes</td>
</tr>
<tr>
<td>8. Are you currently taking prescribed medications for a chronic medical condition? PLEASE LIST CONDITION(S) HERE:__________________________________</td>
<td>☐  Yes</td>
</tr>
<tr>
<td>9. Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer NO if you had a problem in the past, but it does not limit your current ability to be physically active. PLEASE LIST CONDITION(S) HERE:__________________________________</td>
<td>☐  Yes</td>
</tr>
<tr>
<td>10. Has your doctor ever said that you should only do medically supervised physical activity?</td>
<td>☐  Yes</td>
</tr>
</tbody>
</table>

If you answered YES to one or more of the Q.4-10, COMPLETE the following questions:

11. Do you have Arthritis, Osteoporosis, or Back Problems?
   If the above condition(s) is/are present, answer questions 11a-11c  
   If ☐ No go to Q.12

11a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?  
   (Answer NO if you are not currently taking medications or other treatments)  
   ☐  Yes ☐  No

11b. Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?  
   ☐  Yes ☐  No
11c. Have you had steroid injections or taken steroid tablets regularly for more than 3 months?  
☐ Yes ☐ No

12. Do you have Cancer of any kind?  
If the above condition(s) is/are present, answer questions 12a-12b  
If ☐ No go to Q.13

12a. Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?  
☐ Yes ☐ No

12b. Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?  
☐ Yes ☐ No

13. Do you have a Heart or Cardiovascular Condition?  
This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm  
If the above condition(s) is/are present, answer questions 13a-13d  
If ☐ No go to Q.14

13a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies?  
(Answer NO if you are not currently taking medications or other treatments)  
☐ Yes ☐ No

13b. Do you have an irregular heartbeat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)  
☐ Yes ☐ No

13c. Do you have chronic heart failure?  
☐ Yes ☐ No

13d. Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?  
☐ Yes ☐ No

14. Do you have High Blood Pressure?  
If the above condition(s) is/are present, answer questions 14a-14b  
If ☐ No go to Q.15

14a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)  
☐ Yes ☐ No
14b. Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication?  
(Answer YES if you do not know your resting blood pressure)  
☐ Yes ☐ No

15. Do you have any Metabolic Conditions?  
This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes  
If the above condition(s) is/are present, answer questions 15a-15e  
If ☐ No go to Q.16

15a. Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?  
☐ Yes ☐ No

15b. Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.  
☐ Yes ☐ No

15c. Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, OR the sensation in your toes and feet?  
☐ Yes ☐ No

15d. Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?  
☐ Yes ☐ No

15e. Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?  
☐ Yes ☐ No

16. Do you have any Mental Health Problems or Learning Difficulties?  
This includes Alzheimer’s, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome  
If the above condition(s) is/are present, answer questions 16a-16b  
If ☐ No go to Q.17

16a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)  
☐ Yes ☐ No
16b. Do you ALSO have back problems affecting nerves or muscles?

---

17. Do you have a Respiratory Disease?
This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 18a-18d

If No go to Q.18

17a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

---

17b. Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?

---

17c. If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?

---

17d. Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?

---

18. Do you have a Spinal Cord Injury?
This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 18a-18c

If No go to Q.19

18a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)

---

18b. Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?

---

18c. Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?
19. Have you had a Stroke?
   This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event
   If the above condition(s) is/are present, answer questions 9a-9c
   If ☐ No go to Q.20
   19a. Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)
       ☐ Yes ☐ No
   19b. Do you have any impairment in walking or mobility?
       ☐ Yes ☐ No
   19c. Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?
       ☐ Yes ☐ No

20. Do you have any other medical condition not listed above or do you have two or more medical conditions?
    If you have other medical conditions, answer questions 19a-19c
    ☐ Yes ☐ No
   20a. Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?
       ☐ Yes ☐ No
   20b. Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?
       ☐ Yes ☐ No
   20c. Do you currently live with two or more medical conditions?
       ☐ Yes ☐ No

Please list your medical condition(s) and any related medication here:
_________________________________________________________________________________________
_________________________________________________________________________________________
_________________________________________________________________________________________
A participant is eligible to participate in the study if he/she answers
- “No” to Q.4-10 OR
- “Yes” to one or more of Q3-9 accompanied with “No” to Q.11-20.

<table>
<thead>
<tr>
<th>Participant’s Eligibility (To be completed by the Screener)</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is this participant eligible?</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Interviewer Notes:

*Interviewer: I will email or mail you a copy of the study consent form (Get email address). This document describes the details of the study. Please take the time to read it over before you send the consent form to me.*
Dear Participant,

Thank you for taking part in the TRACK-OA project. Please take about 30 minutes to complete the questions that follow. They cover areas related to your health, your physical activities and use of health services.

Please answer each question to your best ability. You may use the text box at the end of the survey to add your comments.
Information About You

1. What is your year of birth?

2. Are you:  □ 1  Male  □ 2 Female

3. What is the highest level of education you have completed? (Please check (✓) one box).

   □ 1  Grade 8 or lower
   □ 2  Grade 9 to 10
   □ 3  Grade 11 to 13 (including GED–General Education Diploma)
   □ 4  Trades certificate, vocational school diploma, apprenticeship
   □ 5  Non-university certificate below Bachelor’s level
   □ 6  Bachelor’s degree
   □ 7  University degree, certificate or diploma above Bachelor’s degree

4. To identify the general region you live in, enter the first 3 digits in your postal code

____________________

5. What is your total household income per year before taxes?

   □ 1  Under $12,000
   □ 2  $12,001 – $24,000
   □ 3  $24,001 – $40,000
   □ 4  $40,001 – $60,000
   □ 5  $60,001 – $80,000
   □ 6  $80,001 – $100,000
   □ 7  Over $100,000
6. Which of the following best describes your current marital status:

☐ 1 Married / Common Law
☐ 2 Separated / Divorced
☐ 3 Widowed
☐ 4 Never married
☐ 5 Other (please specify): ______________________

7. Which of the following best describes your current living arrangements?

☐ 1 Living alone in a house or apartment (i.e. independent)
☐ 2 Living in a house or apartment with your spouse or significant other
☐ 3 Living in a house or apartment with your relatives or with others
☐ 4 Living in a house or apartment with dependants (children)
☐ 5 Living in a house or apartment with elderly relatives whom you take care of
☐ 6 Living in a nursing home or other residential care facility
☐ 7 Other (please specify): ______________________
Your Health

We would like to know about your overall health. Health refers not only to the absence of disease or injury, but also physical, mental and social wellbeing.

8. What is your current height and weight?  **Height** ___ ft ___ in or ____ cm
   **Weight** _____ lbs or ____ kg

9. In general, would you say your health is: (Please check (✓) one box).
   □1   □2   □3   □4   □5
   Excellent   Very good   Good   Fair   Poor

10. **Compared to one year ago**, how would you rate your health in general now? (Please check (✓) one box).
    □1   □2   □3   □4   □5
    Much better now   Somewhat better now   About the same   Somewhat worse now   Much worse now

11. Have you been diagnosed with any of the following medical problems?
   a) Rheumatoid arthritis
      □1   □2
      Yes   No
   b) Osteoarthritis
      □1   □2
      Yes   No
   c) Fibromyalgia/
      □1   □2
      Yes   No
   d) High blood pressure (hypertension)
      □1   □2
      Yes   No
   e) Heart problems (such as angina, heart attack, heart valve problems)
      □1   □2
      Yes   No
   f) Circulation problems (such as hardening of arteries, varicose veins, claudication, foot or leg ulcers, others)
      □1   □2
      Yes   No
|   |   
|---|---
g) Digestive system problems (such as inflammatory or irritable bowel disease, colitis, Crohn’s disease, hiatus hernia, gall stones, pancreatitis, gastritis, others) | Yes | No |
h) Ulcer problems (such as stomach ulcers, or peptic ulcer disease) | Yes | No |
i) Allergies (such as hay fever, dermatitis, allergies to medication, food allergy) | Yes | No |
j) Diabetes | Yes | No |
k) Breathing problems (such as asthma, emphysema, bronchitis, fibrosis, lung scarring, TB, pneumonia, infection, common cold, others) | Yes | No |
l) Liver problems (such as cirrhosis, hepatitis or serious liver damage) | Yes | No |
m) Kidney, bladder or urinary problems (such as kidney failure, nephritis, kidney stones, urinary tract infection, prostate problems, bladder control problems, others) | Yes | No |
n) Cerebrovascular problems (such as stroke, blood clot or bleeding in the brain, cerebrovascular accident, or transient ischemic attach [TIA]) | Yes | No |
o) Neurological problems (such as epilepsy, seizures, multiple sclerosis, Parkinson’s, paraplegia, quadriplegia, paralysis, Alzheimer’s, dizziness, others) | Yes | No |
p) Skin problems (such as eczema, others) | Yes | No |
q) Psoriasis (excluding the scalp) | Yes | No |
r) Headaches (such as migraine, tension, stress, sinus, others) | Yes | No |
s) Mental or emotional problems (such as depression, anxiety, substance abuse: alcohol, drugs, others) | Yes | No |
t) Gynaecological problems | Yes | No |
u) Osteoporosis | Yes | No |
v) Cancer | Yes | No |
w) Blood problems | Yes | No |
x) Other problems *(please list:__________________)* | Yes | No |
About your knees

This information will help us keep track of how you feel about your knees and how well you are able to perform your usual activities.

Symptoms

1. Do you have swelling in your knee?

☐ 1 Never ☐ 2 Rarely ☐ 3 Sometimes ☐ 4 Often ☐ 5 Always

2. Do you feel grinding; hear clicking or any other type of noise when your knee moves?

☐ 1 Never ☐ 2 Rarely ☐ 3 Sometimes ☐ 4 Often ☐ 5 Always

3. Does your knee catch or hang up when moving?

☐ 1 Never ☐ 2 Rarely ☐ 3 Sometimes ☐ 4 Often ☐ 5 Always

4. Can you straighten your knee fully?

☐ 1 Never ☐ 2 Rarely ☐ 3 Sometimes ☐ 4 Often ☐ 5 Always

5. Can you bend your knee fully?

☐ 1 Never ☐ 2 Rarely ☐ 3 Sometimes ☐ 4 Often ☐ 5 Always

Stiffness

The following questions concern the amount of joint stiffness you have experienced during the last week in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.
6. How severe is your knee joint stiffness after first wakening in the morning?

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

7. How severe is your knee stiffness after sitting, lying or resting later in the day?

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

Pain

8. How often do you experience knee pain?

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
Never    Monthly    Weekly    Daily    Always

What amount of knee pain have you experienced in the last week during the following activities?

9. Twisting/pivoting on your knee

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

10. Straightening knee fully

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

11. Bending knee fully

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme
12. Walking on flat surface

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

What amount of knee pain have you experienced in the last week during the following activities?

13. Going up or down stairs

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

14. At night while in bed

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

15. Sitting or lying

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

16. Standing upright

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

Function & Daily Living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself.

For each of the following activities please indicate the degree of difficulty you have experienced in the last week due to your knee.
17. Descending stairs

[ ] None [ ] Mild [ ] Moderate [ ] Severe [ ] Extreme

18. Ascending stairs

[ ] None [ ] Mild [ ] Moderate [ ] Severe [ ] Extreme

19. Rising from sitting

[ ] None [ ] Mild [ ] Moderate [ ] Severe [ ] Extreme

For each of the following activities please indicate the degree of difficulty you have experienced **in the last week** due to your knee.

20. Standing

[ ] None [ ] Mild [ ] Moderate [ ] Severe [ ] Extreme

21. Bending to floor/pick up an object

[ ] None [ ] Mild [ ] Moderate [ ] Severe [ ] Extreme

22. Walking on flat surface

[ ] None [ ] Mild [ ] Moderate [ ] Severe [ ] Extreme

23. Getting in/out of car

[ ] None [ ] Mild [ ] Moderate [ ] Severe [ ] Extreme
24. Going shopping

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

25. Putting on socks/stockings

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

26. Rising from bed

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

27. Taking off socks/stockings

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

For each of the following activities please indicate the degree of difficulty you have experienced in the last week due to your knee.

28. Lying in bed (turning over, maintaining knee position)

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme

29. Getting in/out of bath

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None    Mild    Moderate    Severe    Extreme
30. Sitting

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

31. Getting on/off toilet

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

32. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

33. Light domestic duties (cooking, dusting, etc)

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

Function, sports and recreational activities

The questions should be answered thinking of what degree of difficulty you have experienced during the last week due to your knee.

34. Squatting

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme

35. Running

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5
None  Mild  Moderate  Severe  Extreme
36. **Jumping**

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5

None  Mild  Moderate  Severe  Extreme

37. **Twisting/pivoting on your injured knee**

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5

None  Mild  Moderate  Severe  Extreme

38. **Kneeling**

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5

None  Mild  Moderate  Severe  Extreme

**Quality of Life**

39. **How often are you aware of your knee problem?**

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5

Never  Monthly  Weekly  Daily  Constantly

40. **Have you modified your life style to avoid potentially damaging activities to your knee?**

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5

Not at all  Mildly  Moderately  Severely  Totally

41. **How much are you troubled with lack of confidence in your knee?**

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5

Not at all  Mildly  Moderately  Severely  Totally

42. **In general, how much difficulty do you have with your knee?**

☐ 1  ☐ 2  ☐ 3  ☐ 4  ☐ 5

None  Mild  Moderate  Severe  Extreme
Partners in Health Scale

*Please circle the number that most closely fits your answer*

1. My knowledge of my condition is:

   0 1 2 3 4 5 6 7 8

   Very Good  Satisfactory  Poor

2. My knowledge of the treatment of my condition is:

   0 1 2 3 4 5 6 7 8

   Very Good  Satisfactory  Poor

3. My ability to take my medication as directed by my doctor is:

   0 1 2 3 4 5 6 7 8

   Very Good  Satisfactory  Poor

4. My ability to share in decisions made about the management of my condition with my doctor or health service provider is:

   0 1 2 3 4 5 6 7 8

   Very Good  Satisfactory  Poor

5. My ability to arrange and attend appointments as recommended by my doctor or health service provider is:

   0 1 2 3 4 5 6 7 8

   Very Good  Satisfactory  Poor
6. My understanding of why I need to check and record symptoms is:

0 1 2 3 4 5 6 7 8

Very Good Satisfactory Poor

7. My ability to check and record my symptoms is:

0 1 2 3 4 5 6 7 8

Very Good Satisfactory Poor

8. My understanding of what to do when my symptoms get worse is:

0 1 2 3 4 5 6 7 8

Very Good Satisfactory Poor

9. My ability to take the right action when my symptoms get worse is:

0 1 2 3 4 5 6 7 8

Very Good Satisfactory Poor

10. My ability to deal with effects of my condition on physical activities is:

0 1 2 3 4 5 6 7 8

Very Good Satisfactory Poor

11. My ability to deal with the effects of my condition on social life is:

0 1 2 3 4 5 6 7 8

Very Good Satisfactory Poor
12. My progress towards adopting habits that improve my health is:

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We welcome your comments. Please use the space for any suggestions you would like to make.

*Thank you for taking the time to answer these questions!*
A.4 Modified Brief Action Planning Protocols

Flowchart 1: Activity Counseling, 1st Session

1. “Do you have any idea about the kind of physical activities you want to try?”

2a. Have an idea

What are some problems that might get in the way? Can you think of any solutions?

2b. Not sure (offers suggestions)

1. Ask about schedule
2. What kind of activities might fit into that time?
3. Offer some suggestions if needed

3. SMART Action Plan

4. Discuss barriers and solutions

5. “How confident are you that you can carry out your plan (on a scale from 0-10)?”

6a. If confidence 0-6
   “This is a good start!”

6b. If confidence is 7-10
   “That’s great!”

7a. Problem Solving:
   “Any ideas about what might raise your confidence?”

8a. Yes

9. Suggestions for overcoming barriers

10. Re-assess confidence

8b. No

11. “Would it be helpful to check on how things are going with your plan in about 2 weeks’ time?”

12. Set date to check on progress

---

Flowchart 2: Sedentary-time Counseling, 1st Session

1. “Do have any idea about ways you could decrease your sitting time throughout the day?”

2a. Have an idea

2b. Not sure (offers suggestions)

3. SMART Action Plan

4. Discuss barriers and solutions

5. “How confident are you that you can carry out your plan (on a scale from 0–10)?”

6a. If Confidence 0-6
   “This is a good start!”

   7a. Problem Solving:
   “Any ideas about what might raise your confidence?”

   8a. Yes

   8b. No

   9. Suggestions for overcoming barriers

   10. Re-assess confidence

6b. If Confidence is 7-10
   “That’s great!”

11. “Would it be helpful to check on how things are going with your plan in about 2 week’s time?”

12. Set date to check on progress

---

Flowchart 3: Activity Counseling, Phone Follow-up

1. Review initial plan & Fitbit dashboard

2. How did it go with your plan?”

3a. Successfully carried out plan
   4a. Congratulate success
   5a. “Would you like to make your goal more challenging?”
   6a. No
   7a. How would you like to modify your plan?

3b. Partially carried out plan
   4b. Recognize achievement
   5b. “What did you find was getting in the way of your plan?”
   6b. Yes
   7b. How would you like to modify your plan to make it more achievable?

3c. Did not carry out plan
   4c. Reassure that this is common
   6c. Discuss solutions

8. Assess confidence (0-10)
   Problem solve if <7

9. Reiterate goal
   (update on form if necessary)

10. Set date to check progress

---


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Flowchart 4: Sedentary-time Counseling Phone Follow-up

1. Review initial plan

2. How did it go with your plan?"

3a. Successfully carried out plan
   - 4a. Congratulate success
   - 5a. [If not breaking up sitting after every 20-mins]
     "Would you like to make your goal more challenging?"
   - 6a. No
   - 7a. How would you like to modify your plan?
   - 8. Assess confidence (0-10)
     Problem solve if ≤7
   - 9. Reiterate goal
     (update on form if necessary)
   - 10. Set date to check progress

3b. Partially carried out plan
   - 4b. Recognize achievement
   - 5b. "What did you find was getting in the way of your plan?"
   - 6b. Yes
   - 7b. How would you like to modify your plan to make it more achievable?

3c. Did not carry out plan
   - 4c. Reassure that this is common
   - 6c. Discuss solutions

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Appendix B  Graphical Outputs

B.1  Univariate Plots
B.2 Bivariate Plots

Bouted MVPA vs. PIH

Bouted MVPA vs. Age

Bouted MVPA vs. BMI

Bouted MVPA vs. # comorbidities
Bouted MVPA vs. KOOS-Pain

Bouted MVPA vs. KOOS -Symptoms

Bouted MVPA vs. KOOS-ADL

Bouted MVPA vs. KOOS-Sport/Rec

Bouted MVPA vs. KOOS-QOL