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The Utilization of Physical Literacy to Understand Physical Activity in Individuals with a History of Anterior Cruciate Ligament Reconstruction

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THE UTILIZATION OF PHYSICAL LITERACY TO UNDERSTAND PHYSICAL ACTIVITY IN INDIVIDUALS WITH A HISTORY OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

DISTRIBUTION

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Health Sciences at the University of Kentucky

By

Rachel Renee Kleis
Lexington, Kentucky

Co-Directors: Dr. Johanna Hoch, Associate Professor of Athletic Training and Clinical Nutrition and Dr. Rachel Hogg-Graham, Assistant Professor of Health Management

Lexington, Kentucky

2022

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ABSTRACT OF DISSERTATION

THE UTILIZATION OF PHYSICAL LITERACY TO UNDERSTAND PHYSICAL ACTIVITY IN INDIVIDUALS WITH A HISTORY OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

Injury to the anterior cruciate ligament (ACL) is common in physically active populations. Anterior cruciate ligament reconstruction (ACLR) is commonly performed after injury in order to restore joint stability and knee function and return patients to desired levels of physical activity. However, not everyone will return to their pre-injury levels of sport after surgery and recent evidence reveals that individuals with a history of ACLR are less likely to meet the recommended physical activity guidelines. Specifically, previous literature has reported that individuals with a history of ACLR take fewer daily steps and participate in less moderate-to-vigorous physical activity compared to their healthy counterparts. This is problematic as physical inactivity is linked to the development of numerous illnesses and diseases and results in billions of dollars in health care costs annually.

While numerous studies have sought to identify factors that impact physical activity participation in individuals with history of ACLR, evidence to date has focused primarily on physical and psychological factors such as knee pain, decreased muscular strength, and fear of reinjury. These physical and psychological factors fail to account for personal, social, and environmental factors that may serve as facilitators or barriers to physical activity participation in this population. Physical literacy is the motivation, confidence, physical competence, and knowledge and understanding to value physical activity across a lifespan. This multidimensional concept may be an essential factor to investigate as it accounts for personal, social, and environmental factors that may influence physical activity participation. Physical literacy has been linked to physical activity participation, overall health, and quality of life in youth and adolescent populations. Additionally, the individual components of motivation, confidence, and knowledge have been shown to influence rehabilitation success, return to activity rates, and physical activity participation after ACLR, while physical competence has been shown to improve fundamental movement skills. Understanding the role of physical literacy and its individual components in a young adult population with a history of ACLR could provide insight into additional factors that serve as facilitators or barriers to physical activity participation.
The purpose of this dissertation was to explore personal, social, and environmental factors associated with physical activity and examine the relationship between physical literacy and physical activity in individuals with a history of ACLR. The purposes of these studies were to determine if physical literacy and its components are associated with self-reported and objectively measured physical activity and to explore perceptions of physical literacy and experiences with physical activity after ACLR. The results of these studies indicate that physical literacy is associated with self-reported and objectively measured physical activity in young adults with a history of ACLR. Specifically, self-description of physical literacy explained approximately 12% of the variance of self-reported physical activity while the physical competence component explained approximately 30% of the variance in objectively measured physical activity. Additionally, individuals with a history of ACLR described how aspects of motivation, confidence, physical competence, and knowledge influence physical activity participation after ACLR. The results of this study support the use of physical literacy for understanding and predicting physical activity in young adults with a history of ACLR.

KEYWORDS: Anterior Cruciate Ligament Reconstruction, Physical Activity, Physical Literacy, Motivation, Confidence, Physical Competence

Rachel Renee Kleis

07/12/2022
Date
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CHAPTER 1. INTRODUCTION

1.1 Background

Participation in sport and recreation is the leading cause of musculoskeletal injury in youth, with one in three participants seeking medical attention each year.\(^1\) Knee injury is the second most common injury reported in emergency departments\(^2\) accounting for approximately 600,000 injuries per year.\(^3\) However, knee injuries account for the highest percentage of severe injuries which often require surgical intervention.\(^4\) Specifically, anterior cruciate ligament (ACL) injury accounts for approximately 250,000 injuries in the United States annually, resulting in millions of dollars in associated medical costs.\(^5,6\) Anterior cruciate ligament reconstruction (ACLR) is the standard of care in the United States for patients wishing to continue athletic activities,\(^7,8\) while conservative treatment is generally reserved for less active or sedentary individuals.\(^9\) Rates of ACLR have increased by 60% in the last two decades\(^10,11\) with an estimated incidence rate of 43.5 per 100,000 person-years.\(^11\) The goal of reconstructive surgery is to restore mechanical joint stability and knee function,\(^12,13\) decrease the risk of post-traumatic osteoarthritis (PTOA) development,\(^9\) and return patients to pre-injury level of sport and activity.\(^8,14-16\)

Despite these goals, there is consistent evidence of adverse outcomes following ACLR. Knee PTOA is the predominant condition affecting long-term joint health following ACLR.\(^12\) However, knee pain and/or dysfunction,\(^17,18\) lower patient reported outcome (PRO) scores,\(^15,19\) decreased muscular strength,\(^17,20\) altered biomechanics,\(^21\) and increased BMI and fat mass\(^22\) are also commonly reported. Additionally, individuals may experience psychological symptoms including decreased self-efficacy regarding their knee, kinesiophobia, fear of reinjury, pain catastrophizing, anxiety, and depression.\(^23,24\)
These physical and psychological impairments often result in decreased health-related quality of life (HRQL) in both the short- and long-term.\textsuperscript{19,24} Health-related quality of life is a multifaceted outcome that incorporates a patient’s priorities, goals, values, and perceived well-being, while also encompassing their physical, emotional, psychological, and social status.\textsuperscript{15} It has been demonstrated that individuals with a history of ACLR report decreased HRQL compared to population norms\textsuperscript{15} and healthy-matched controls,\textsuperscript{25} and that HRQL may further decrease in patients with secondary/revision surgeries\textsuperscript{20} and/or with diagnosed osteoarthritis.\textsuperscript{26} Further, it has been demonstrated that HRQL is significantly associated with moderate-to-vigorous physical activity (MVPA) in individuals experiencing knee symptoms after ACLR, suggesting that physical activity could be a critical component in symptom management.\textsuperscript{27} This is important, as return to sport rates and physical activity participation following ACLR are often used to determine treatment success.\textsuperscript{28}

Regular engagement in MVPA has been associated with numerous health benefits, while physical inactivity and/or sedentary lifestyles are associated with increased risk of morbidity and mortality.\textsuperscript{29,30} Physically active people tend to live longer lives and have less risk of developing chronic diseases like diabetes, cardiovascular disease, and cancers.\textsuperscript{29} Physical activity participation is known to promote body positivity and self-esteem, support mental health, increase bone density and improve balance and joint mobility.\textsuperscript{29,30} The US Department of Health and Human Services recommends that adults complete 150 minutes per week of MVPA\textsuperscript{30} as it is associated with the greatest reductions in morbidity and mortality.\textsuperscript{30,31} Despite the known benefits, it is estimated that less than 50\% of adults meet these guidelines\textsuperscript{29} regardless of previous injury history. The Centers for Disease
Control and Prevention estimates that inadequate physical activity results in $117 billion dollars spent on healthcare each year.\textsuperscript{29} Additionally, approximately 10\% of premature deaths are attributed to physical inactivity\textsuperscript{30} with obesity serving as a proxy to many adverse health conditions.\textsuperscript{32} Decreased physical activity and the presence of obesity are both independently associated with decreases in HRQL and self-reported health, but MVPA appears to be the most important factor when predicting adverse outcomes.\textsuperscript{32} Therefore, it is important to investigate factors that facilitate and inhibit an individual’s ability to participate in physical activity across a lifespan.

Examining the role of physical activity on health outcomes may be especially important in individuals with a history of musculoskeletal injury, as return to sport rates and physical activity participation remain low following ACLR. Approximately 50-65\% of patients return to preinjury levels of sport after unilateral ACLR,\textsuperscript{33,34} while only 23\% of individuals return to preinjury levels of sport after bilateral ACLR.\textsuperscript{20} This is concerning as approximately 28\% of individuals suffer subsequent ACL injuries after primary ACLR.\textsuperscript{35} Additionally, individuals with a history of ACLR participate in less physical activity across a lifespan and are much less likely to achieve recommended levels of MVPA compared to their uninjured peers.\textsuperscript{7,36} Finally, individuals with a history of ACLR take fewer daily steps than their healthy counterparts and do not meet the recommendation of 10,000 steps per day.\textsuperscript{36} Given these findings, it is likely that interruption in physical activity and/or sport participation due to ACLR negatively impacts lifelong physical activity participation.\textsuperscript{36,37}
1.2 Theoretical Frameworks for Physical Activity Promotion

Due to the documented consequences of physical inactivity, numerous theoretical models have been used to explain and/or predict physical activity behaviors. Specifically, the Theory of Planned Behavior (TPB),\textsuperscript{38} Self-Determination Theory (SDT),\textsuperscript{39,40} the Health Belief Model (HBM),\textsuperscript{41} and the Transtheoretical Model (TTM)\textsuperscript{42} are used frequently when examining physical activity participation. In general, each theoretical approach identifies constructs that may be salient for engaging in health behaviors and/or explain why an individual may or may not perform the health behavior in question. Specifically, these frameworks often examine personal, societal, and environmental contexts that may impact an individual’s intention and willingness to effectively engage in the behavior. To date, the majority of ACLR research has focused on personal factors to explain physical inactivity but examining societal and environmental contexts may uncover additional information about physical activity participation after ACLR.

The TPB states that a combination of behavioral, normative, and control beliefs form the intention to perform health behaviors.\textsuperscript{38} Specifically, an individual is more likely to engage in the behavior when they have positive attitudes, social/subjective norms, and perceived behavioral control toward the health behavior. SDT proposes that human motivation exists along a continuum and that individuals are more likely to be perform a behavior or pursue goals when their needs for autonomy, competence, and relatedness are met.\textsuperscript{39,40} The continuum includes amotivation, four forms of external motivation, and intrinsic motivation.\textsuperscript{39,40} While human motivation is complex, SDT theorizes that individuals are more likely to continue behaviors as motivation becomes more self-determined (i.e., intrinsic). The HBM posits that individuals will not engage in health
behaviors unless they view some personal threat and believe the benefits of the behavior outweigh the barriers. Prior to engaging in a health behavior, individuals will evaluate the susceptibility and severity of health conditions related to the health behavior and assess the potential benefits and barriers of engaging in the behavior. The theory suggests an individual is more likely to perform the behavior if they perceive a greater threat to their health; if they believe the behavior will effectively reduce the threat; and if there are limited barriers to participation. Finally, the TTM states that individuals can move through five stages when participating in a health behavior—precontemplation, contemplation, preparation, action, and maintenance. Individuals may utilize up to ten cognitive, affective, and/or evaluative processes of change to progress through the five stages. The TTM suggests that interventions to improve health behaviors should utilize strategies associated with the individual’s specific stage of change. The utilization of theoretical frameworks to examine physical activity participation after ACLR have been limited but identifying relevant constructs to develop targeted intervention strategies may improve life-long physical activity participation after ACLR.

1.3 Physical Literacy

Physical literacy is another factor that is proposed to positively influence physical activity participation across a lifespan. Physical literacy is defined as the “motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life”. To date, the relationship between physical literacy and physical activity participation and health outcomes has been primarily explored in child and adolescent populations, but these investigations have yielded positive results. For example, significant correlations have been observed between
physical literacy and physical activity participation, cardiorespiratory fitness, body composition, and HRQL.\textsuperscript{46-48} The individual components of confidence, motivation, and physical competence also significantly correlated with MVPA,\textsuperscript{49,50} and individuals with higher domain confidence, motivation, and physical competence scores are 1-2 times more likely to meet physical activity guidelines.\textsuperscript{49} While the role of physical literacy in adulthood is less defined, recent investigations reveal significant relationships between physical literacy and self-reported physical activity in undergraduate students in China.\textsuperscript{51} Additionally, motivation, confidence, and physical competence remain significantly correlated to physical activity in undergraduate students.\textsuperscript{51} Finally, pilot interventions have been shown to improve composite physical literacy scores in first-year university students\textsuperscript{52} and physical activity behaviors in sedentary adults.\textsuperscript{53}

The influence of physical literacy on physical activity participation has not been explicitly explored in patients who have undergone ACLR, but investigations into individual components of physical literacy are well documented. Specifically, confidence (self-efficacy), motivation, and physical competence (movement quality) have been shown to be key components for rehabilitation success and return to sport and activity. In a qualitative study examining decisions to return to sport, confidence and self-motivation were key themes in individuals that ultimately returned to sport after ACLR.\textsuperscript{54} Another qualitative study identified a “fear of re-injury versus confidence continuum” where some individuals were able to regain confidence to return to a preferred level of activity, while others lack confidence in their knee which led to avoidance of activity.\textsuperscript{55} Finally, numerous studies have demonstrate biomechanical adaptions in jump-landing,\textsuperscript{56,57} hopping,\textsuperscript{58,59} and running activities\textsuperscript{60} in individuals with a history of ACLR which may negatively impact
physical competence. As a whole, these results indicate that physical literacy may be a key factor for improving physical activity participation after ACLR and warrants further exploration.

1.4 The Problem

Injury to the ACL commonly occurs in young, active individuals, which causes a disruption in PA patterns during the developing years. Additionally, the majority of individuals are not returning to pre-injury levels of sport and physical activity despite adequate knee function and medical clearance after surgical reconstruction. Physical activity participation in youth has previously been correlated with PA participation into adults, so these disruptions to physical activity, even if temporary, may negatively impact long-term physical activity participation after ACLR. At this time, decreased physical activity participation in individuals with a history of ACLR has been largely attributed to decreases in physical function and psychological impairments. However, it is likely that additional barriers for returning to sport and physical activity participation exist. Thus, there is a need to explore the influence of personal, social, and contextual factors on physical activity participation and to understand how these factors may change over time. Without adequate knowledge of why and how physical activity is impacted after ACLR, it is likely rehabilitation protocols and physical activity promotion efforts will remain unsuccessful and return to sport/activity rates will remain low. Obtaining a greater understanding of these factors will aid in the development of targeted intervention strategies for promoting physical activity and improving health outcomes following ACLR in both the short- and long-term.
1.5 Purpose

There are four purposes of this dissertation. The first purpose is to discuss existing theoretical models and identify relevant constructs to explain physical activity participation. The second purpose is to identify personal and social correlates of MVPA in individuals with a history of ACLR. The third purpose is to examine the relationship between objectively measured MVPA and components of physical literacy in individuals with a history of ACLR. The fourth purpose is to explore the perceptions and experiences of physical literacy to gain an understanding of how physical literacy impacts physical activity participation in individuals with a history of ACLR.

The studies within this dissertation will address the following aims:

1. To explore existing theoretical implications and identify constructs associated with physical activity participation.
2. To create a novel theoretical model to predict return to sport and physical activity participation in individuals with a history of ACLR.
3. To examine personal and social correlates that predict self-reported physical activity participation in individuals with a history of ACLR.
4. To examine the relationship between objectively measured physical activity and motivation, confidence, physical competence, and physical activity knowledge in individuals with a history of ACLR.
5. To understand and describe individual experiences with physical literacy and physical activity post-ACLR.
1.6 Overview

The methods, results, discussion, limitations, and conclusion for each of the aims are as follows. Chapter 2 will examine and summarize theoretical implications relevant for each study by examining behavior change models that are utilized to explain and/or predict physical activity participation in adults. Additionally, Chapter 2 will present a novel theoretical model designed to predict and improve physical activity participation in individuals with a history of ACLR. Chapter 3 will examine personal and social factors associated with self-reported physical activity participation in individuals with a history of ACLR. Chapter 4 will examine the relationship between objectively measured physical activity and individual components of physical literacy in individuals with a history of ACLR. Finally, Chapter 5 will identify individuals who perform above and below expected physical activity participation and qualitatively explore physical literacy and physical activity from the perspective of individuals with a history of ACLR.

1.7 Operational Definitions

Throughout these studies, the following definitions will be used:

1. Health-Related Quality of Life (HRQL): multifaceted outcome that encompasses a patient’s physical, emotional, psychological, and social status and incorporates patient’s priorities, goals, values, and perceived well-being.\(^{15}\)
2. Psychosocial: the intersection of psychological and social factors that influence individual thoughts, cognitive processes, and behaviors.
3. Physical Literacy: the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life.\textsuperscript{45}

4. Physical Competence: a person’s ability to perform fundamental movement patterns within various environments. Physical competence can be used interchangeably with movement competence.\textsuperscript{66}

5. Social Determinants of Health: complex conditions in which individuals are born, grow, live, work, and age which continuously shape the overall health of the person.\textsuperscript{67}

1.8 Assumptions

The primary assumptions for the dissertation are as follows:

Chapter 3:

1. Participants were cleared to return to pre-injury levels of sport and/or physical activity.
2. Participants answered all questionnaires honestly and to the best of their abilities.

Chapter 4:

1. Participants were cleared to return to pre-injury levels of sport and/or physical activity.
2. Participants answered all questionnaires honestly and to the best of their abilities.
3. Participants performed all functional tasks to the best of their abilities.
4. Participants wore their accelerometer every day and kept accurate recordings of activities within their daily wear log.
5. Participants performed their normal routines to accurately reflect physical activity participation.

Chapter 5:

1. Participants were cleared to return to pre-injury levels of sport and/or physical activity.

2. Participants answered all question honestly and to the best of their abilities.

1.9 Delimitations

The delimitations of this dissertation are as followed:

Chapter 3:

1. Participants were between the ages of 18-40.

2. Participants were at least 1-year post-operative index ACLR.

3. Participants had a history of one or more ACLRs.

4. Participants with and without meniscal pathology and with ACL revision surgeries were included.

5. Participants had no other ligamentous repair at the time of their ACLR.

6. Participants had no history of surgery to their index limb in the last year.

7. Participants had no injury to their lower extremity within the past 6 weeks.

8. Participants did not have any conditions that affected their ability to participate in physical activity.

Chapter 4 and Chapter 5:

1. Participants were between the ages of 18-40.

2. Participants were at least 1-year post-operative index ACLR.
3. Participants had a history of unilateral or bilateral ACLR.

4. Participants with and without meniscal pathology were included.

5. Participants had no other ligamentous repair at the time of their ACLR.

6. Participants had no history of surgery to their index limb in the last year.

7. Participants had no injury to their lower extremity within the past 6 weeks.

8. Participants did not have any conditions that affected their ability to participate in physical activity.

1.10 Limitations

Chapter 3:

1. Data was collected remotely during the COVID-19 pandemic which may impact physical activity participation.

2. Physical activity was self-reported which may not accurately reflect true physical activity participation.

3. Some PRO questionnaires utilized in this study have not been validated for use in an ACLR population.

4. Some PRO questionnaires utilized in this study were altered from the original format to better fit the sample population.

Chapter 4:

1. Some PRO questionnaires and functional assessments utilized in this study have not been validated for an ACLR and/or adult population.

2. The physical activity observation period lasted 7 days and may not adequately represent true physical activity patterns.
3. Documentation of occupation and/or organized sport of participants did not occur.

Chapter 5:

1. The number of participants were pre-determined via positive/negative deviance so full data saturation may not have occurred.
2. Results may not be generalizable to all ACLR patients due to a small sample size.
3. The primary investigator was not blinded to participant physical activity status.

1.11 Abbreviations

ACL: Anterior Cruciate Ligament

ACLR: Anterior Cruciate Ligament Reconstruction

BREQ-3: Behavioral Regulations for Exercise Questionnaire-3

COH: Cross-over hop for distance

eHEALS: eHealth Literacy Scale

GLTEQ: Godin Leisure-Time Exercise Questionnaire

HBM: Health Belief Model

HRQL: Health Related Quality of Life

IPAQ: International Physical Activity Questionnaire

KOOS: Knee Injury and Osteoarthritis Outcome Score

K-SES: Knee Self-Efficacy Scale

LSI: Limb Symmetry Index
MET: Metabolic Equivalent of Task

MVPA: Moderate-to-Vigorous Physical Activity

PA: Physical Activity

PRO: Patient Reported Outcome

Sallis: Sallis Social Support for Exercise Scale

SDoH: Social Determinants of Health

SDT: Self-Determination Theory

SLH: Single leg hop for distance

TH: Triple hop for distance

TPB: Theory of Planned Behavior

TTM: Transtheoretical Model
CHAPTER 2. LITERATURE REVIEW

2.1 Part I: The Effectiveness of the Transtheoretical Model to Improve Physical Activity in Healthy Adults: A Systematic Review

Acknowledgment: This study was published in the Journal of Physical Activity and Health and was reprinted in this dissertation with permission.

2.1.1 Introduction

The current physical activity (PA) guidelines recommend achieving at least 150 minutes a week of moderate-intensity exercise or 75 minutes a week of vigorous-intensity exercise.\textsuperscript{30} However, the Centers for Disease Control and Prevention (CDC) reports that only 50\% of adults get the amount of exercise needed to prevent chronic illness and disease.\textsuperscript{29} Lack of adequate PA is known to be detrimental to individual health and has been linked to numerous adverse health issues including obesity, type II diabetes, and cardiovascular disease.\textsuperscript{29,30} However, regular PA participation is linked to decreased mortality, improved quality of life, and increased physical and cognitive function.\textsuperscript{29,30} Due to known risks associated with physical inactivity, as well as the known benefits of PA, numerous interventions have been designed to improve PA across the lifespan.\textsuperscript{68-70} These interventions are often grounded in theoretical approaches including Social Cognitive Theory,\textsuperscript{71} Theory of Reasoned Action,\textsuperscript{72} and Theory of Planned Behavior.\textsuperscript{73} These theoretical approaches provide a framework for which the interventions are built and also explain why behavior change may occur.\textsuperscript{74} However, many of the interventions grounded in these theories fail to adequately result in long-term maintenance of behavior change.\textsuperscript{74} Thus, the identification of effective intervention strategies to improve PA in adults, utilizing theory to guide the development, continues.
The Transtheoretical Model\textsuperscript{75} (TTM) synthesizes constructs from various theories into one behavior change model. The TTM was originally developed for smoking cessation but has become widely accepted for exercise improvement interventions as it can be tailored to individuals regardless of their readiness to engage in PA.\textsuperscript{76,77} It includes five stages of behavior change in which individuals utilize up to 10 processes of change, both cognitive and behavioral, to advance to the next stage.\textsuperscript{76} The stages and processes of change are important elements of the TTM because they explain both why and how behavior change occurs within an individual, and allows the intervention to be designed specifically for an individual’s stage of change. Additionally, the TTM states that an individual’s movement between the stages tends to be cyclical rather than linear,\textsuperscript{78} and individuals often move forward and backward within the stages many times while attempting to change their health behaviors.\textsuperscript{74,78} The stages of change include\textsuperscript{76}:

- **Precontemplation:** individuals do not intend to change in the foreseeable future
- **Contemplation:** individuals intend to change within the next 6 months
- **Preparation:** individuals intend to change within the next 30 days
- **Action:** individuals have made an overt change to their behavior and have been performing the health behavior for <6 months
- **Maintenance:** individuals have been performing the health behavior for ≥6 months

Previous systematic reviews\textsuperscript{79-81} have examined the effectiveness of theory-based interventions at improving PA, however, to our knowledge, no reviews have systematically evaluated the literature utilizing TTM interventions to improve PA in adult populations. Given the prior success of theory-based PA interventions, the TTM may provide a superior framework for interventions designed to improve PA behaviors in adults as it draws upon
important constructs from multiple theoretical frameworks. A critical review published by Adams and White\textsuperscript{82} examined the effectiveness of the TTM in promoting PA in 2003. This review supported the use of the TTM-based interventions in the short-term but was unable to determine the effectiveness of interventions in the long-term.\textsuperscript{82} Spencer et al.\textsuperscript{83} expanded on this review in 2006 by providing a comprehensive, qualitative analysis of TTM and exercise-related literature. Overall, this review supported the use of stage-matched interventions, as 17 of 38 studies demonstrated positive results.\textsuperscript{83} However, similar to Adams et al.,\textsuperscript{82} several studies were unable to maintain positive results long-term. While these reviews provide a solid foundation for TTM evaluation, numerous studies have since been published that have included the TTM in various adult populations. Therefore, the purpose of this systematic review is to systematically identify, critically evaluate and synthesize available evidence regarding the effectiveness of TTM interventions to improve PA in healthy adults.

2.1.2 Methods

This systematic review was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.\textsuperscript{84}

2.1.2.1 Search Strategy

A systematic literature search for inclusion was performed from January 2001 through May 20, 2020, by the primary investigator. The authors initiated the systematic search in 2001 to examine evidence published since Adams et al.'s\textsuperscript{82} last known search. Keywords related to physical activity and the TTM were combined using the Boolean operators “OR” and “AND”, and searched in the following electronic databases: CINAHL, MEDline, PubMed, Psychology and Behavioral Sciences Collection, PsycINFO,
Sociological Collection, and SPORTDiscus (Table 2.1). Additional articles were identified through a hand search of the reference lists of articles identified through the database search. After each individual search was complete, duplicates were removed.

2.1.2.2 Eligibility Criteria

The inclusion and exclusion criteria were agreed upon by two authors (RRK, JMH) prior to the search. One author independently reviewed articles retrieved from the systematic search using the inclusion and exclusion criteria listed below. Any articles that remained unclear for inclusion were reviewed by a second author. First, abstracts and titles were screened to determine whether the study met inclusion criteria for this review. Second, for the remaining studies, the full text of articles were reviewed to determine final eligibility for inclusion.

2.1.2.3 Inclusion Criteria

Studies were included in the systematic review if they met the following criteria:

- Utilized a randomized pretest, posttest design\textsuperscript{85} with a minimum of two groups
- Included healthy adults (ages 18+)
- Included an intervention based on the Transtheoretical Model (TTM)
- Included a subjective or objective measurement of physical activity as an outcome measure

2.1.2.4 Exclusions Criteria

Studies were excluded from the systematic review for the following reasons:

- Dissertations, review papers, book chapters, or non-peer reviewed publications
- Study protocols
• Participants with acute or chronic medical conditions, including, but not limited to diabetes, cancer, neurological conditions, stroke, etc.

• Utilized the Stages of Change Questionnaire as the measurement of physical activity

• Included interventions that incorporated additional theories and models such as the Social Cognitive Theory or Theory of Planned Behavior.

• Did not examine the effectiveness of the intervention on physical activity outcomes

• Did not include pre- and post-intervention physical activity outcomes

• Not published in English

2.1.2.5 Quality Assessment

The quality of included studies was determined using the Physiotherapy Evidence Database (PEDro) scale. The PEDro scale was developed to aide individuals in determining the internal validity of clinical trials to guide clinical decision-making. Two investigators (RRK, JMH) independently reviewed and critically appraised each study using the PEDro and came to a consensus over the quality of the study. In the event of disagreement, a third investigator (MCH), who was blind to the individual appraisals, was consulted. Studies were considered high quality if the PEDro score was ≥60%.86

2.1.2.6 Study Characteristics

All studies included interventions based on the TTM with the goal of improving physical activity and health behaviors in healthy adults. The characteristics extracted for each study included: subject demographics, information regarding the TTM intervention, data collection time points, mode of physical activity measurement, and overall study results.
2.1.2.7 Level of evidence and strength of recommendation

The Level of Evidence for each included study was assigned using the Oxford Centre for Evidence Based Medicine (CEBM).\textsuperscript{87,88} According to the CEBM, Level 1 represents well-designed randomized controlled trials and prospective studies; level 2 represents cohort studies; level 3 represents case-control studies; level 4 represents case series or poorly designed cohort or case-control studies; and level 5 represents anecdotal evidence, animal or bench research and clinical observations.\textsuperscript{88} The overall strength of recommendation was assessed with either: Grade A for consistent level 1 studies; grade B for consistent level 2 or 3 studies or extrapolations from level 1 studies; grade C for level 4 studies or extrapolations from level 2 or 3 studies; and grade D for level 5 evidence or inconsistent or inconclusive studies of any level.\textsuperscript{88}

2.1.2.8 Data extraction

A form was developed and piloted to guide data extraction. Three authors (RRK, JMH, MCH) reviewed the form, and reviewed the data from the pilot data extraction. After discussion, modifications were made for the final data extraction form. The primary author extracted data from the individual studies. The data extraction included study sample, subject demographics, TTM intervention details, data collection time points, self-reported and objective measures of physical activity, results, and conclusions (Table 2.2). Extracted data were reviewed for accuracy by a second author once the final inclusion of studies was determined and data extraction was deemed complete.

2.1.2.9 Data Analysis

Means and standard deviations were extracted to calculate Hedges’ $g$ effect sizes.\textsuperscript{89} Effect sizes were only calculated for studies that adequately reported means and standard
deviations for necessary timepoints. Effect sizes were interpreted as small (≤.40), moderate (.41 to .69), or large (≥.70). 

2.1.3 Results

2.1.3.1 Literature Search

The initial search yielded 748 articles (Figure 2.1). One additional article was identified through a hand search of references. Of the 43 articles assessed for eligibility, 11 studies met the inclusion criteria. Seventeen articles were excluded because the intervention was not based on the TTM, or the intervention incorporated additional theoretical models. One study did not include a measurement of PA; three studies used the Stages of Change Questionnaire as the measurement of PA; and one study did not report PA measurement findings. The remaining studies were excluded because they did not utilize a randomized pretest, posttest design, utilized participants under the age of 18, or did not include a healthy population. Characteristics of the included studies are presented in Table 2.2.

2.1.3.2 Methodological quality

The results of the risk of bias assessment of the included studies are presented in Table 2.3. Initially, the investigators (RRK, JMH) agreed upon 82.7% of PEDro items. The investigators resolved 17 of 19 disagreements, while a third reviewer (MCH) was consulted for the remaining two items. Two studies did not utilize a therapist during the intervention as the materials were self-guided. For these studies, PEDro item 6 was omitted from the final score, and were graded on a scale of nine. The average of PEDro scores for the included studies was 51%, with a range from 30% to 77%. Five studies...
scored ≥60% and were classified as high-quality evidence, while six studies\textsuperscript{93-96,98,99} scored <60% and were classified as low-quality evidence.\textsuperscript{86}

2.1.3.3 Outcome measures

All studies included in this review incorporated interventions based on the TTM and examined their effect on physical activity. The outcome of interest in this systematic review was an objective or subjective measurement of physical activity pre- and post-intervention.

\textit{Objective measures of physical activity}

Three studies\textsuperscript{91,93,98} measured PA objectively. The objective measures utilized within the studies included the use of pedometers (Omron HJ-104 Step-O-Meter, Fitbit One, and an unspecified pedometer) to record daily steps. Each study measured step counts at baseline and post-intervention. Dinger et al. and Miragall et al. also measured step counts at additional three\textsuperscript{98} and 12\textsuperscript{91} month follow-ups, respectively.

\textit{Subjective measures of physical activity}

In total, ten\textsuperscript{91-97,99-101} studies utilized subjective measures to measure PA. The self-reported measures included the: Aerobic Center Longitudinal Study Physical Activity Questionnaire,\textsuperscript{134} Auckland Heart Study Physical Activity Questionnaire,\textsuperscript{135} International Physical Activity Questionnaire-Short Form, Paffenbarger Physical Activity Questionnaire,\textsuperscript{136} Patient-Centered Assessment and Counseling walking questions,\textsuperscript{137} Scottish Physical Activity Questionnaire,\textsuperscript{138} Seven-Day Activity Recall, and the Yale Physical Activity Survey.\textsuperscript{139} Subjective measures were obtained at baseline and post-intervention. Individual studies collected data at additional timepoints, both during and
after the interventions, including 4 weeks and up to 24 months after completion of the intervention.

2.1.3.4 Interventions

The goals of the interventions were to identify participants’ current stage of change for exercise readiness and match participants with behavioral-change strategies based on their respective stages. Interventions also utilized many processes of change with consciousness raising, decisional balance, and self-efficacy being the most commonly used. A brief description of each aspect of the intervention pertinent to design and implementation is described below. More information regarding each intervention can be found in Table 2.4.

Mode of Delivery

Interventions based on the TTM were delivered via internet-based sources, print materials, and brief counseling sessions. Internet-based sources included personalized emails and an internet webinar. Print materials included booklets, brochures, manuals, newsletters, and pamphlets. Counselling sessions were conducted via phone calls and in-person sessions. Interventions utilized in the studies also varied by contact time. Self-guided materials were often delivered weekly, bi-weekly, or monthly, while counseling sessions ranged three to eight sessions over the duration of the intervention. On average, counseling sessions ranged from 3-16 minutes while the internet webinar required approximately 45 minutes to complete.
Length of Intervention

The mean intervention length was 4.5 months. The shortest intervention was three weeks while the longest intervention was 12 months. The length of interventions in Marshall et al.\textsuperscript{97} and Mutrie et al.\textsuperscript{99} were unable to be determined, as participants worked through intervention materials at their own pace.

Intervention Delivery

The most common mode of delivery was self-paced, which did not require an outside individual to administer the intervention. When an individual was used to deliver the intervention to the participants, a wide variety of professions were represented. The studies utilized researchers,\textsuperscript{91,93} family practice physicians,\textsuperscript{100} nurse practitioners,\textsuperscript{101} and counselors,\textsuperscript{94,96} to deliver the intervention to the participants. or were self-guided by the participants.\textsuperscript{92-95,97-99}

2.1.3.5 Statistical and clinical significance

Means, standard deviations, and effect sizes are displayed in Table 2.5 and Figure 2.2. Of the 11 included studies, five\textsuperscript{96,98-101} demonstrated statistically significant improvements in the intervention groups compared to the control groups, while six\textsuperscript{91-95,97} studies did not. Two studies\textsuperscript{92,98} included more than one intervention group and a control group, but only Miragall et al.\textsuperscript{98} identified significant differences. The internet-based intervention (IMI) group paired with a pedometer demonstrated significantly higher PA compared to the control group, while IMI alone did not differ from the control group.\textsuperscript{98} A total of 14 effect sizes were calculated for four\textsuperscript{92,94,96,98} included studies. Of the fourteen effect sizes, two\textsuperscript{98} were interpreted as large, six\textsuperscript{96,98} were interpreted as moderate, and
were interpreted as small. However, all small effects and one moderate effect should be interpreted with caution as the CI encompassed zero, indicating no effect may be present.

2.1.3.6 Level of Evidence

The results of this systematic review demonstrate that there is grade D evidence to support the use of interventions based on the TTM to improve physical activity in healthy adults. This grade was given due to the inconsistent results of level 1 and level 2 studies. While five studies supported the use of interventions based on the TTM, six studies demonstrated no differences in physical activity participation between the intervention and control groups post-intervention.

2.1.4 Discussion

2.1.4.1 Summary of Results.

The purpose of this systematic review was to evaluate the effectiveness of interventions based on the TTM to improve physical activity in adults. Five of the 11 included studies demonstrated statistically significant improvements in physical activity levels while six studies demonstrated no differences between intervention and control or comparison groups.

2.1.4.2 Outcome Measures

Subjective measures of physical activity

Of the ten studies that measured PA subjectively, all studies utilized previously validated and/or reliable patient-reported questionnaires. Questionnaires assessed PA
completed over the previous seven days, in these time periods, studies assessed PA in a variety of ways. Several questionnaires quantified PA minutes by subscales (leisure-time, recreational, household, etc.) or activity performed (i.e. walking), while others ask participants to report their engagement in a variety of activities (including frequency, duration, and intensity) to calculate metabolic equivalent values or minutes of moderate-to-vigorous PA. Due to the heterogeneity in assessment measures, it becomes difficult to compare PA participation, and therefore intervention success, between studies.

While each questionnaire utilized in the studies have demonstrated sufficient psychometric properties in their respective patient populations, self-reported measures should be interpreted with caution. When compared to objective measures, participants typically over-estimate their participation in PA on self-reported questionnaires. In part, over-reporting may be attributed to recall bias. While the majority of the subjective measures asked participants to recall PA completed in the previous seven days, one questionnaire asks patients to recall PA from 30 days prior. Recall bias can be greater when participants are asked to recall events from a farther away time period. Self-reported measures are also susceptible to social desirability bias. When participants are aware that the intervention is expected to result in increased PA behavior, participants may be more likely to answer the questionnaire in a manner that will be considered favorable by the researchers.

**Objective measures of physical activity**

Three studies utilized pedometers to objectively measure PA. Baker et al. utilized the Omron HJ-104 Step-O-Meter to track participants’ walking levels. The
pedometer was worn on the right side of the waistband and calibrated to each participant according to the manufacturer’s instructions. At the time of the study, validity and reliability of the model had not been published, but a pilot study published in 2008 found the pedometer to be accurate within 5% of actual steps walked. Dinger et al. did not specify the model of the pedometer used. All participants were instructed on proper pedometer placement and to record steps at the end of the day, and to reset the pedometer each morning. Additionally, participants were encouraged to set daily step goals based on the previous week’s step count. Miragall et al. utilized the Fitbit One, a small pedometer that can be worn in the participant’s pocket, waistband, or bra. The device has demonstrated acceptable reliability for measuring step counts, and can be customized to participant’s sex, age, height and weight. The device also provides just-in-time feedback on the pedometer screen for daily steps, distance travelled, active minutes, floors climbed, and calories burned.

The intervention in Miragall et al.’s trial demonstrated the largest effects: two large effects and three moderate effects. The intervention incorporated both a TTM component and feedback from a pedometer (IMI+PED). The same intervention produced two moderate effect sizes when participants were blinded from pedometer feedback (IMI). While Miragall et al. was the only included study to incorporate the use of both blinded and non-blinded pedometers, it is interesting to note that the pedometer with the highest amount of feedback available to the participants produced the greatest results of all included studies. Participants were able to receive feedback directly from the screen on the pedometer but were also able to view their progress towards their goals (via charts and graphs) on a password-protected website. Previous studies have discussed the
importance of feedback while individuals are attempting to change their behavior. Specifically, feedback that is personalized, action-oriented, and continuously available to participants was present in successful interventions. Therefore, future studies should continue to examine the effect of feedback within TTM interventions and pedometer use against and in conjunction with TTM interventions on exercise motivation and PA participation.

2.1.4.3 Effectiveness of TTM Interventions

A total of five studies identified significant improvements in PA for the TTM intervention group compared to the control group, while six studies did not. Interestingly, there were very few methodological differences between the studies that did identify improvements and those that did not. The length of intervention was similar between study groups. For studies that demonstrated significant improvements, the shortest intervention was 3 weeks, while the longest intervention was 12 months. This was similar to studies with non-significant results where interventions lasted between 4 weeks and 12 months. Both significant and non-significant studies yielded an average PEDro score of 50%, revealing similar levels for risk of bias. Additionally, all studies relied heavily on female populations with two studies recruiting only female participants. Lastly, all studies exhibited similarities between intervention delivery, with a near-equal mix of email, print, or in-person materials. However, of the four studies that utilized counseling as a delivery method, three of the interventions demonstrated significant results. Further, both studies that utilized in-person counseling sessions produced significant results, however the two studies were vastly different in intervention length and delivery details. In Petrella et al.’s trial, counseling and support were delivered by the participants’
family practice physician over the 12-month intervention. Purath et al.\textsuperscript{101} utilized one in-person counseling session which was delivered by a nurse practitioner during the participants’ workplace wellness program health screening and usual care follow up appointments. In this study, the initial counseling discussion lasted between 3-5 minutes, and two weeks following the initial counseling, participants received a booster telephone call to discuss progress, provide additional counseling, and answer questions. Future studies should continue exploring optimal frequency, timing, and length of counseling sessions.

The heterogeneity in intervention characteristics and intervention success is in agreement with the critical review published in 2003.\textsuperscript{82} Here, Adams et al. reviewed 16 TTM interventions while varying intervention design, length, participant recruitment, and outcome measures. In their analysis, the researchers proposed that it may be more important to question “which TTM interventions are effective?” instead of “are TTM interventions effective?”. This question remains evident in the current systematic review as the TTM was interpreted to create 11 different interventions. Therefore, future studies should begin to compare the intervention characteristics to identify the most significant elements.

2.1.4.4 Methodological Considerations

Five\textsuperscript{91,92,97,100,101} studies included in this review were considered high-quality evidence. However, each study was affected by methodological concerns. The ability to blind participants, therapists, and assessors was an issue for all studies. Nine studies did not blind study participants; eight studies did not blind assessors obtaining at least one measurement, and no studies blinded therapists when therapists were utilized. Given the
number of studies that utilized self-guided intervention materials, failure to blind participants can introduce social desirability bias and increase the risk that materials were not utilized as intended. Future studies should continue to examine intervention delivery methods and ways to adequately blind therapists, assessors, and participants. Secondary, nine studies did not conceal allocation of assignment. Lastly, all studies reported dropouts, but only three studies utilized an intention to treat analysis. While participants may drop out of studies for a variety of reasons, excluding them from final analyses can drastically alter intervention results. Additionally, without running such analyses, final results must be interpreted with caution as there is no true way to determine if the effects were a result of the intervention.

2.1.4.5 Practical Considerations

Due to the many similarities between studies regarding intervention characteristics and outcome measures, it is unclear why some interventions led to successful PA adoption while others did not. Participant recruitment may explain some of the variation. While all studies sought to target more sedentary populations, the six studies that demonstrated non-significant results had higher recruitment of individuals in Action and Maintenance stages. The Action and Maintenance stages are the stages upon which individuals are currently engaging in PA. Individuals within the Action stage have been regularly engaging in PA for <6 month, while individuals in the Maintenance stage have been engaging in PA for ≥ 6months. For example, Greaney et al. and Griffin-Blake et al. reported that 58% and 60% of their sample population was in the Action or Maintenance stages at baseline respectively. Higher levels of PA at baseline likely limits the ability of participants to increase PA and/or progress to the next TTM stage post-intervention.
The five\textsuperscript{96,98-101} studies that demonstrated significant results recruited a greater proportion of participants in earlier TTM stages. Mutrie et al.\textsuperscript{99} specifically targeted individuals in the Contemplation and Preparation stages of Change. The remaining studies excluded individuals that exceeded a baseline level of PA specific to each of their studies. Kolt et al.\textsuperscript{96} recruited participants that engaged in <30 minutes of exercise on five days a week. Miragall et al.\textsuperscript{98} only included sedentary participants (exercising <30 minutes of moderate-to-vigorous PA 3 days a week and <7500 steps per day). Petrella et al.\textsuperscript{100} included patients with an inactive lifestyle (based on the seven-day physical activity recall instrument\textsuperscript{144}) while Purath et al.\textsuperscript{101} excluded participants that reported engaging in moderate amounts of PA (>30 minutes of moderate PA a day, 5 days a week or 20 minutes of vigorous PA a day, 3 days a week). Individuals currently participating in lower levels of PA may reap greater benefits from interventions aimed at increasing PA, especially if interventions incorporate strategies to promote behavior change.

2.1.4.6 Review Limitations

This systematic review is not without limitations. First, the investigators sought to identify every relevant article. In order to do so, the authors included multiple databases. However, there is a possibility that additional evidence, such as unpublished null investigations, were inadvertently excluded. In addition, due to the heterogeneous nature of the included outcomes, a publication bias assessment using meta-analysis software was unable to be performed. Additionally, included studies were limited to the English language which may have inadvertently exclude relevant studies. The authors only included studies published in English to limit incorrect translation of studies written in any language other than English. Second, the primary investigator screened all articles for
eligibility and inclusion, which may have increased the risk for bias and/or error. However, two authors agreed upon the identified inclusion and exclusion criteria, and any questions surrounding inclusion of studies were discussed with a second author. It is possible that the authors of the included studies may have had information regarding additional unpublished trials or data which were not included within the published manuscripts. We selected to only include information which has undergone peer review for this systematic review. Third, the included studies examined PA in healthy adults. While many of the studies targeted sedentary populations, a large proportion of participants were classified in the Action or Maintenance stages at baseline, potentially limiting the ability to increase PA. Lastly, the included studies were heterogeneous in their intervention characteristics, limiting their ability to be compared to each other.

2.1.5 Conclusion

After reviewing the literature, our findings suggest that there is a combination of high and low-quality, inconsistent evidence to support the use of interventions based on the TTM when attempting to improve PA in adult populations. Interventions based on the TTM successfully increased PA levels from pre- to post-interventions but were unable to increase levels significantly more than control or comparison groups. However, interventions were more successful when participants were in the Pre-contemplation or Contemplation phase at baseline and when the intervention was delivered via in-person counseling. Further research should focus also on optimal intervention length, timing of therapist-participant interaction, and the use of objective physical activity assessments in conjunction with TTM interventions to improve PA.
## Table 2.1. Search strategy

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<th>Step</th>
<th>Search Terms</th>
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<td>Transtheoretical Model Stages of Change</td>
<td>OR</td>
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<td>2,802</td>
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<td>Physical Activity Exercise</td>
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<td>Intervent* Therapy Education</td>
<td>OR</td>
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<td>Level of evidence</td>
<td>Subject characteristics</td>
<td>Intervention</td>
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<td>Baker et al., 2011</td>
<td>1b</td>
<td>Inclusion: adults (ages 18-65) that were members of the University Exclusion: None reported</td>
<td>A 4-week walking intervention was employed. Initial groups (pedometer-only, minutes-only, control) were stratified to receive email support (ES) or no email support (NS). The ES group received 1 email a month aimed at raising consciousness and/or increasing self-re-evaluation.</td>
<td>SPAQ</td>
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<td>Blissmer et al., 2002</td>
<td>1b</td>
<td>Inclusion: Faculty and staff that completed the informed consent process Exclusion: No contraindications to exercise based on the PARQ</td>
<td>All participants received materials on a monthly basis. Staged Matched Group (SMG): Participants in this group received materials matched to their stage of change. Study materials included personalized letters, and information related to their specific stage of change. Staged Mismatched Group (SMMG): Participants in the stage-mismatched group received the same emails, however, these differed from their current stage. Standard Group (SG): Participants in this group received a generic manual each month developed by the American Heart Association. Participants in the control received a general health pamphlet.</td>
<td>Aerobic Center Longitudinal Study Physical Activity Questionnaire</td>
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<td>Study</td>
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<td>Comparison Group (PED)</td>
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<td>----------------------------------------------------------------------------</td>
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<tr>
<td>Dinger et al., 2007</td>
<td>Adults (ages 25-54) participating in &lt;150 min./week of moderate-intensity PA or &lt;60 min./week of vigorous</td>
<td>No contraindications to exercise based on the PARQ, full-time college students, pregnant or planning to become pregnant during the intervention</td>
<td>Participants received 3 brochures and weekly emails containing TTM-based PA improvement strategies. Brochures providing information regarding &quot;making time to be physically active&quot;, “tips to begin PA”, and “risks/benefits of PA”.</td>
<td>Participants did not receive any additional support.</td>
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<td>Greaney et al., 2008</td>
<td>60 years of age or old, residing in greater East Providence, RI area.</td>
<td>Individuals not living independently in the community.</td>
<td>Participants received a manual that was organized by stages of change and incorporated stage-specific behavioral strategies necessary to advance to the next stage. Participants also received monthly newsletters to address stage-appropriate processes of change, self-efficacy, and decisional balance. Lastly, participants received three 15-min. coaching calls during the 12-month period.</td>
<td>Participants did receive the exercise intervention.</td>
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Table 2.2. Characteristics of included studies (continued)

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</thead>
<tbody>
<tr>
<td>Griffin-Blake et al., 2006</td>
<td>2b</td>
<td>Inclusion: full-time faculty and staff at the University</td>
<td>Exclusion: None listed</td>
<td>Intervention Group: Participants received one of five manuals that focused on SOC and participants received the manual that corresponded to their specific SOC.</td>
<td>Comparison Group: Participants received a single self-help manual focused on Bandura's constructs of self-efficacy, outcome expectancies and expectations, and self-regulation.</td>
<td>Seven-Day Activity Recall</td>
<td>There were no significant differences between groups when comparing minutes of exercise per week, and the interventions were equally effective in moving participants into higher stages of motivational readiness for exercise. Motivational readiness for exercise was significantly and positively correlated with self-report physical activity at baseline ($r &lt; .453$, $p &lt; .001$) and postintervention ($r &lt; .507$, $p &lt; .001$).</td>
</tr>
<tr>
<td>Kolt et al., 2007</td>
<td>1b</td>
<td>Inclusion: Adults (ages 65+) that participate in &lt;30 minutes of activity on 5+ days per week for 6+ months, suitable English, planned on living in the region for the next 12 months</td>
<td>Exclusion: conditions where PA is contraindicated</td>
<td>Intervention Group: Participants received eight telephone counseling sessions aimed at increasing PA over 12 weeks. The participants received the counseling sessions weekly for the first 4 weeks, and then every 2 weeks for the remaining 8 weeks.</td>
<td>Control Group: Participants received usual care.</td>
<td>Auckland Heart Study Physical Activity Questionnaire</td>
<td>For all measures of physical activity, there were greater increases in the intervention group at the conclusion of the intervention period (0–3 months) than in the control group. At the 12-month data collection point, the intervention group spent more time per week on moderate leisure activity ($p = .007$), estimating 86.8 minutes more of moderate leisure-time activity per week.</td>
</tr>
<tr>
<td>Marshall et al., 2004</td>
<td>1b</td>
<td>Inclusion: Respondents from a nationwide survey conducted in 1998</td>
<td>Exclusion: None listed</td>
<td>Intervention Group: The intervention included four booklets regarding stages of motivational readiness. Participants received a personally addressed letter and instructions about how to use the materials. Participants received the booklet that corresponded to their current stage of motivational readiness, and all booklets relevant to the higher stages of motivational readiness. Progression through the intervention materials was self-directed.</td>
<td>Control group: Participants did not receive any informational materials.</td>
<td>Seven-Day Activity Recall</td>
<td>There were no significant differences between groups at any time point (p=.14). The intervention group increased PA by 13 min/week while the control group decreased by 14 min/week at 2 months. At 8 months, the intervention group maintained the PA increase observed at 2 months, but the control group reported a 15-min/week increase from their baseline level. The percentage of participants meeting PA guidelines did not increase at 2-months for either group compared to baseline, but both groups increased this proportion at 8 months.</td>
</tr>
</tbody>
</table>
Table 2.2. Characteristics of included studies (continued)

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Inclusion</th>
<th>Exclusion</th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miragall et al., 2018</td>
<td>2b</td>
<td>Participating in &lt;30 min. of moderate intensity 3x/week, walking &lt;7500 steps per day, ages 18-40</td>
<td>Physical/psychological disorder that would impede PA activity, currently participating in a PA intervention, regular drug or alcohol consumption.</td>
<td>Internet-based Motivational Intervention (IMI) Group: Participants received access to the IMI designed to increase PA motivation and set individualized goals. IMI+PED Group: Participants received the same internet-based materials but also gave participants a pedometer and included information about pedometers, such as their functions (e.g., to count steps), and the website where users can synchronize the pedometer data and check their progress. Control Group: Participants received a blinded pedometer to record daily step count.</td>
<td>Pedometer: Fitbit One</td>
</tr>
<tr>
<td>Mutrie et al., 2002</td>
<td>2b</td>
<td>Employees in the three selected workplaces</td>
<td>None listed</td>
<td>Intervention Group: The intervention was aimed at increasing PA relating to commuting to work. The intervention booklet contained materials based on the transtheoretical model of behavior change, educational, and practical information on choosing routes and maintaining personal safety and an activity diary. Control Group: Participants did not receive any informational materials.</td>
<td>Seven-day recall of physical activity</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>Inclusion</td>
<td>Exclusion</td>
<td>Intervention</td>
<td>Control</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------</td>
<td>-----------</td>
<td>-----------</td>
<td>--------------</td>
<td>---------</td>
</tr>
<tr>
<td>Petrella et al., 2010</td>
<td>1b</td>
<td>Inactive lifestyle (energy expenditure &lt;35kcal/kg/d), readiness to improve PA, able to read/write English</td>
<td>Existence of a condition (MI, stroke, heart failure) or disease that would affect PA participation</td>
<td>Both groups received individualized exercise prescriptions based on submaximal step test results. Intervention Group: Participants received counseling and support based on their stages of exercise behavior. Exercise prescription, given by a physician, for participants in the intervention group were matched to patients’ current SOC for PA. Control Group: Participants only received the exercise prescription.</td>
<td>Seven-day recall of physical activity</td>
</tr>
<tr>
<td>Purath et al., 2004</td>
<td>1b</td>
<td>Sedentary women that attended the university provided health/wellness screenings</td>
<td>Answered yes on the PARQ, engaged in regular PA</td>
<td>Intervention Group: Participants received brief (3-5 minute) counseling sessions based on the participants’ SOC. Participants in precontemplation discussed benefits of PA; participants in contemplation or preparation set PA goals and signed a contract to achieve it. Two weeks into the intervention, a booster phone call to inquire about PA progress and additional counseling was provided. Control Group: Participants received usual care.</td>
<td>Paffenbarger Physical Activity Questionnaire, PACE walking questions</td>
</tr>
</tbody>
</table>

Both groups significantly increased self-reported total energy expenditure (kcal/kg/d); however, the intervention group demonstrated a significantly larger increase compared with the control group (p=.006). Even when mean energy expenditure was adjusted for body weight, a significant increase (p<.001) remained at 12 months in the intervention group while the control group did not change.

At 6 weeks, the intervention group demonstrated significant improvements in 5 of the 10 PA outcome measures compared to controls: SOC, blocks walked per day (p<.05), vigorous and moderate weekend activity (p=.008), minutes walked for exercise (p<.001), and total minutes walked per week (p<.0001). Overall, the intervention group showed significantly more gains compared to the control group.
Table 2.3. Risk of bias of included studies

<table>
<thead>
<tr>
<th>PEDro item</th>
<th>Baker et al., 2011</th>
<th>Blissmer et al., 2002</th>
<th>Dinger et al., 2007</th>
<th>Greaney et al., 2008</th>
<th>Griffin-Blake et al., 2006</th>
<th>Kolt et al., 2007</th>
<th>Marshall et al., 2007</th>
<th>Miragall et al., 2018</th>
<th>Mutrie et al., 2002</th>
<th>Petrella et al., 2010</th>
<th>Purath et al., 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Eligibility criteria were specified</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2 Subjects were randomly allocated to groups</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3 Allocation was concealed</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>4 The groups were similar at baseline regarding the most important prognostic factors</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>5 There was blinding of all subjects</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>6 There was blinding of all therapists who administered the therapy</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>——</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>7 There was blinding of all assessors who measured at least 1 key outcome</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Table 2.3. Risk of bias of included studies (continued)

<table>
<thead>
<tr>
<th></th>
<th>8 Measures of at least 1 key outcome were obtained from &gt;85% of the subjects initially allocated to groups</th>
<th>Yes</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>Yes</th>
<th>Yes</th>
<th>Yes</th>
<th>No</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9 All subjects for whom outcomes were available received the treatment or control condition as allocated or, where this was not the case, data for at least 1 key outcome were analyzed by “intention to treat”</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>10 The results of between-group statistical comparisons are reported for at least 1 key outcome</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>11 The study provides both point measures and measures of variability for at least 1 key outcome</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Table 2.4. Intervention characteristics

<table>
<thead>
<tr>
<th>Study</th>
<th>PA measurement</th>
<th>Mode of Delivery</th>
<th>Who delivered the intervention</th>
<th>Length of intervention</th>
<th>Data collection timepoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baker et al., 2011</td>
<td>SPAQ; pedometer</td>
<td>Email</td>
<td>Researchers</td>
<td>4 months</td>
<td>Baseline, 4 weeks, and 12 months</td>
</tr>
<tr>
<td>Blissmer et al., 2002</td>
<td>Aerobic Center Longitudinal Study Physical Activity Questionnaire</td>
<td>Print materials (manual)</td>
<td>Self-guided by participants</td>
<td>16 weeks</td>
<td>Baseline, 4, 8, 12 and 16 weeks</td>
</tr>
<tr>
<td>Dinger et al., 2007</td>
<td>IPAQ-short form; pedometer</td>
<td>Email and print materials (brochure)</td>
<td>Researchers, self-guided by participants</td>
<td>6 weeks</td>
<td>Baseline, 6 weeks</td>
</tr>
<tr>
<td>Greaney et al., 2008</td>
<td>YPAS</td>
<td>Print materials (manual, newsletters) and counseling sessions (phone calls)</td>
<td>Self-guided by participants, counselor</td>
<td>12 months</td>
<td>Baseline, 12 and 24 months</td>
</tr>
<tr>
<td>Griffin-Blake et al., 2006</td>
<td>Seven-Day Activity Recall</td>
<td>Print materials (booklets)</td>
<td>Self-guided by participants</td>
<td>1 month</td>
<td>Baseline, 1 month</td>
</tr>
<tr>
<td>Kolt et al., 2007</td>
<td>Auckland Heart Study Physical Activity Questionnaire</td>
<td>Counseling sessions (phone calls) and print materials (pamphlets)</td>
<td>Exercise counselors, self-guided by participants</td>
<td>3 months</td>
<td>Baseline, 3, 6, and 12 months</td>
</tr>
<tr>
<td>Marshall et al., 2004</td>
<td>Seven-Day Activity Recall</td>
<td>Print materials (booklets)</td>
<td>Self-guided by participants</td>
<td>unspecified</td>
<td>Baseline, 2 and 8 months</td>
</tr>
<tr>
<td>Miragall et al., 2018</td>
<td>Pedometer</td>
<td>Internet webinar</td>
<td>Self-guided by participants</td>
<td>3 weeks</td>
<td>Baseline, 3 weeks, and 3 months</td>
</tr>
<tr>
<td>Mutrie et al., 2002</td>
<td>Seven-day recall of physical activity</td>
<td>Print materials (booklet)</td>
<td>Self-guided by participants</td>
<td>unspecified</td>
<td>Baseline, 6 and 12 months</td>
</tr>
<tr>
<td>Petrella et al., 2010</td>
<td>Seven-day recall of physical activity</td>
<td>Counseling sessions</td>
<td>Family practice physicians</td>
<td>12 months</td>
<td>Baseline, 3, 6, 9, and 12 months</td>
</tr>
<tr>
<td>Purath et al., 2004</td>
<td>Paffenbarger Physical Activity Questionnaire, PACE walking questions</td>
<td>Counseling sessions</td>
<td>Nurse practitioners</td>
<td>6 weeks</td>
<td>Baseline, 6 weeks</td>
</tr>
</tbody>
</table>

**Abbreviations:** IPAQ, International Physical Activity Questionnaire; PA, Physical Activity; PACE, Patient-Centered Assessment and Counseling; SPAQ, Scottish Physical Activity Questionnaire; YPAS, Yale Physical Activity Survey
Table 2.5. Hedges’ g effect sizes and 95% confidence intervals for time points of included studies

<table>
<thead>
<tr>
<th>Study</th>
<th>PA Measure</th>
<th>Timepoints</th>
<th>Experimental Group</th>
<th>Control Group</th>
<th>Hedge’s g</th>
<th>Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blissmer et al., 2002</td>
<td>Aerobic Center Longitudinal Study Physical Activity Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matched-Mismatched</td>
<td>Post-intervention</td>
<td>65.61±34.44</td>
<td>60.54±34.44</td>
<td>0.15</td>
<td>(-0.32, 0.61)</td>
<td></td>
</tr>
<tr>
<td>Matched-Standard</td>
<td>Post-intervention</td>
<td>65.61±34.44</td>
<td>62.69±34.78</td>
<td>0.08</td>
<td>(-0.35, 0.52)</td>
<td></td>
</tr>
<tr>
<td>Matched-Control</td>
<td>Post-intervention</td>
<td>65.61±34.44</td>
<td>57.95±28.67</td>
<td>0.24</td>
<td>(-0.21, 0.68)</td>
<td></td>
</tr>
<tr>
<td>Greaney et al., 2008</td>
<td>YPAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention-Control</td>
<td>12 months</td>
<td>46±26.02</td>
<td>47±24.50</td>
<td>-0.04</td>
<td>(-0.17, 0.09)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 months</td>
<td>47±28.18</td>
<td>47±26.73</td>
<td>0.0</td>
<td>(-0.13, 0.13)</td>
<td></td>
</tr>
<tr>
<td>Kolt et al., 2007</td>
<td>Auckland Heart Study Physical Activity Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intervention-Control</td>
<td>3 months</td>
<td>184±172.7</td>
<td>116.5±140.1</td>
<td>0.43</td>
<td>(0.14, 0.72)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 months</td>
<td>199.1±211.2</td>
<td>119.2±147.7</td>
<td>0.42</td>
<td>(0.13, 0.71)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 months</td>
<td>244±365.7</td>
<td>117.3±138.8</td>
<td>0.46</td>
<td>(0.17, 0.75)</td>
<td></td>
</tr>
<tr>
<td>Miragall et al., 2018</td>
<td>Fitbit One pedometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IMI-Control</td>
<td>Post-intervention</td>
<td>6837±1424</td>
<td>6251±1484</td>
<td>0.40</td>
<td>(-0.17, 0.96)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 months</td>
<td>7279±2173</td>
<td>5943±1876</td>
<td>0.65</td>
<td>(0.07, 1.23)</td>
<td></td>
</tr>
<tr>
<td>IMI-IMI+PED</td>
<td>Post-intervention</td>
<td>6837±1424</td>
<td>7958±2005</td>
<td>-0.64</td>
<td>(-1.23, -0.04)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 months</td>
<td>7279±2173</td>
<td>8116±2759</td>
<td>-0.33</td>
<td>(-0.92, 0.26)</td>
<td></td>
</tr>
<tr>
<td>IMI+PED-Control</td>
<td>Post-intervention</td>
<td>7958±2005</td>
<td>6251±1484</td>
<td>0.96</td>
<td>(0.36, 1.56)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 months</td>
<td>8116±2759</td>
<td>5943±1876</td>
<td>0.92</td>
<td>(0.32, 1.52)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: IMI, Internet-based Motivational Intervention; IMI+PED, Internet-based Motivational Intervention plus pedometer; PA, Physical Activity; YPAS, Yale Physical Activity Survey
Figure 2.1. Flow chart of literature review
Figure 2.2. Effect sizes forest plots
2.2 Part II: The Utilization of the Theory of Planned Behavior and Self-Determination Theory to Improve Physical Activity Following Anterior Cruciate Ligament Reconstruction

Acknowledgment: This paper was published in the International Journal of Athletic Therapy and Training and was reprinted in this dissertation with permission.

2.2.1 Introduction

Over 3.5 million people report to emergency departments annually for sport- and exercise-related musculoskeletal injuries. Anterior cruciate ligament (ACL) injury is a common musculoskeletal injury that occurs frequently in young individuals. Most often, individuals that injure their ACL undergo ACL reconstruction (ACLR) to restore joint stability, improve knee function, and promote successful return to play and physical activity. However, only 50% of patients return to pre-injury levels of sport participation after ACLR and up to 92% of individuals reduce their physical activity. Further, patients with a history of ACLR participate in less moderate-to-vigorous physical activity and take less daily steps compared to their uninjured peers. Previous investigators have suggested that decreased physical activity participation is likely caused by negative outcomes after ACLR, such as post-traumatic osteoarthritis, pain, and fear of re-injury, and that athletes may experience greater barriers to physical activity participation due to previous injury.

Lack of physical activity participation is especially concerning because physical activity is a crucial component of health and well-being. Engaging in adequate amounts of physical activity can decrease the prevalence of chronic diseases and prevent 1 in 10 premature deaths. Physical activity is also linked to improved cognitive function and mood and decreased levels of stress, anxiety, and depression. Additionally, it is
estimated that inadequate amounts of physical activity result in approximately $117 billion in annual health care costs.\textsuperscript{29} Therefore, it is critical to understand factors that influence physical activity participation so targeted interventions can be identified, validated, and implemented. This is especially true for the post-ACLR population which is already at increased risk for development of post-traumatic osteoarthritis.\textsuperscript{9,153}

Recently, there has been a paradigm shift in ACLR outcomes research, as research has focused more on psychological factors that influence sport and physical activity participation.\textsuperscript{23,55,154-157} These studies identified that psychological factors, particularly self-efficacy and injury-related fear, significantly impact return to sport rates and current physical activity levels.\textsuperscript{23,55} Further, psychosocial factors have been linked to decreases in functional outcomes, such as quadriceps strength and self-reported function,\textsuperscript{156,157} which likely contribute to the observed decrease in physical activity. Despite this progress, current rehabilitation literature has failed to investigate physical activity promotion strategies for the post-ACLR population. Incorporating physical activity promotion into ACLR rehabilitation may increase return to sport rates and improve long-term outcomes.

Various theories and models have been utilized in public health research to explain physical activity participation. Many of these theories have been adapted to create intervention programs aimed at increasing physical activity participation in various populations. Two theories in particular, the Theory of Planned Behavior (TPB) and Self-Determination Theory (SDT), could be applied to improve physical activity participation in the post-ACLR population. The TPB provides a framework for individual and social factors that form intentions to engage in health behaviors, while SDT provides a greater understanding of factors that impact behavioral motivation. Further exploration of these
theories within an orthopaedic population is warranted since participation in physical activity is strongly influenced by intention and motivation. The purpose of this review was to describe the TPB and the SDT, evaluate literature using these theories to promote physical activity and rehabilitation adherence, and integrate constructs from the TPB and SDT to provide targets for increasing physical activity engagement among patients post-ACLR. Implications for clinical practice and research initiatives to further explore this integrated model are also discussed.

2.2.2 Theory of Planned Behavior

Expanded from the Theory of Reasoned Action, the TPB was developed as a universal model to explain why individuals engage or do not engage in a variety of health behaviors. The theory posits that the intention to perform a given behavior is a function of the individual’s attitudes and beliefs, subjective norms, and perceived behavioral control. Attitudes and beliefs refer to the positive or negative thoughts regarding factors that may facilitate or hinder behavior performance. Subjective norms refers to the social influence that important persons (i.e. spouse, parents, friends) have regarding the behavior. Perceived behavioral control refers to an individual’s perception of their ability to successfully perform the given behavior. The theory proposes that a reciprocal relationship exists between the three constructs. Thus, each construct has influence over another. Together, these three constructs shape the individual’s intention, which ultimately has the greatest influence on behavior. Consequently, the theory suggests that stronger intentions to perform a behavior result in a greater likelihood of successfully carrying out the behavior. TPB also suggests that perceived behavioral control can have a direct
influence on the health behavior and that an individual may bypass the process of forming intentions regarding the behavior.  

The TPB has been adapted to explain why individuals participate or do not participate in physical activity. As predicted by the theory, attitudes, subjective norms, and perceived behavioral control are positively correlated to intentions for physical activity, and intention is the main predictor of physical activity engagement. Perceived behavioral control has also been identified as the most significant factor behind the formation of behavioral intentions and thus, physical activity participation.

The TPB has also been utilized to examine post-ACLR rehabilitation adherence. Niven et al. found that intention levels at baseline were the strongest predictor of rehabilitation adherence. However, contrary to the theory, attitudes toward rehabilitation, subjective norms, and perceived behavioral control did not significantly predict intentions to adhere to rehabilitation despite respondents’ high scores on each of these variables. Instead, sport and level of sport were found to be significant predictors of rehabilitation adherence. Given the competitive athlete sample in the study, we hypothesize that additional psychological constructs, such as motivation, need to be considered during the rehabilitation process. Despite Niven et al.’s findings, the use of the TPB is supported for rehabilitation adherence in other patient populations and adherence to injury prevention programs. Additionally, a recent TPB and SDT integrated model revealed that attitudes toward rehabilitation, subjective norms, and perceived behavioral control were significantly associated with intentions for rehabilitation, and that those intentions were significantly related to rehabilitation adherence behaviors. Overall, utilization of the TPB demonstrates promising results for predicting and encouraging physical activity.
engagement\textsuperscript{162,170} and improving rehabilitation adherence.\textsuperscript{167,168} However, we believe the inclusion of concepts from the SDT will strengthen the application of this model to improve physical activity in the post-ACLR population.

2.2.3 Self-Determination Theory

The SDT is a meta-theory that provides an explanation into the inner workings behind human motivation and personality development.\textsuperscript{39,40} This theory posits that motivation exists along a continuum\textsuperscript{40} and that the regulatory processes along this continuum impact individual behavior.\textsuperscript{40,171} Table 2.6 outlines definitions for the types of motivation according to SDT motivation continuum. In brief, motivation shifts from complete lack of motivation (amotivation) to fully internalized motivation (intrinsic motivation) as three basic needs (autonomy, competence, and relatedness) are fulfilled. This shift towards intrinsic motivation is proposed to have a positive influence on behavior and well-being.\textsuperscript{40} Therefore, individuals who are intrinsically motivated ("self-determined") are most likely to engage in the behaviors in both the short- and long-term, while individuals that derive motivation from external sources ("controlled") are more likely to have decreased behavioral engagement.

The SDT also proposes that three basic needs—autonomy, competence, and relatedness—are the key components necessary to foster motivation and provide a framework for understanding why individuals pursue activities and the content behind individual goal pursuits.\textsuperscript{171} Autonomy refers to the level of control the individual feels over their behavior and the environment; competence refers to feelings of capability over the behavior or task at hand; and relatedness refers to a feeling of belonging with others and within their environment. The SDT suggests that an individual is more likely to be
intrinsically motivated when the three basic needs are nurtured. This is critical, as intrinsic motivation improves performance, persistence, creativity, and ultimately behavioral engagement.\textsuperscript{40}

The SDT has been applied extensively to explain, predict, and improve physical activity engagement in a variety of populations.\textsuperscript{172-176} As suggested by the theory, autonomous motivation is associated with increased intention to engage in sport\textsuperscript{173} and greater physical activity participation\textsuperscript{172,174} compared to “controlled” motivation. Further, interventions that support feelings of autonomy demonstrate greater improvements in physical activity engagement in healthy\textsuperscript{175} and rheumatoid arthritis\textsuperscript{172} populations.

The SDT has been applied to investigate adherence to rehabilitation after ACLR. Consistent with SDT, Chan et al.\textsuperscript{177} revealed that autonomous motivation positively predicted adherence to rehabilitation while controlled motivation negatively predicted rehabilitation adherence. Additionally, support from physiotherapists was positively associated with autonomous motivation.\textsuperscript{177} These results are echoed by Lee et al.\textsuperscript{169} where rehabilitation adherence was significantly correlated with autonomous motivation but was not correlated with controlled motivation. Further, this study demonstrated that autonomous motivation can be fostered by physiotherapists.\textsuperscript{169} These studies suggest that patients are more likely to adhere to rehabilitation programs when they believe they have choices regarding aspects of their care and when those choices are supported by the healthcare team. Based on these promising applications, we believe the integration of the SDT and TPB will provide a model that can be applied to increasing physical activity for people after ACLR.
2.2.4 Integrated Physical Activity Model for Musculoskeletal Rehabilitation

Despite strong evidence to support each theory for the promotion of physical activity, the TPB and SDT are not without flaws. The main criticisms for the TPB include its lack of explanation of ‘unconscious influences’, and its inability to adequately address and/or explain individuals that form positive intentions, but ultimately do not engage in the behavior. Further, the original TPB model suggests that motivation is a component of intention but fails to adequately account for the various types of motivation. Similarly, the SDT has received criticism because it does not define the individual’s cognitive appraisals of themselves, their peers, and the environment to the same extent as TPB. Therefore, a combination of TPB and SDT may best account for relevant factors that likely influence return to sport and physical activity engagement following ACLR, and previous research supports the integration of the two theories. A novel theoretical model for the utilization of these combined theories to increase physical activity participation, the Integrated Physical Activity Model, is presented in Figure 2.3.

In the Integrated Physical Activity Model (IPAM), intention and motivation are the most influential constructs that impact physical activity behaviors. In addition, the model suggests that that intention, motivation, and physical activity engagement have a reciprocal relationship, and that positive impacts on one construct will have a subsequent positive effect over the other construct(s). Distal to physical activity behavior are the six constructs that determine the individual’s level of intention and motivation as described in the original theories (Figure 2.3). The combined model suggests that attitudes/beliefs, subjective norms, perceived behavioral control, autonomy, competence, and relatedness serve as the foundation of the approach to physical activity engagement after ACLR. When applying
this model, intention and motivation to return to sport and/or engage in physical activity should be examined during the rehabilitation process and can be used to predict future participation of these activities. If decreased feelings of intention and/or motivation are identified by the clinician, further investigation into the six foundational constructs is warranted. Furthermore, the model suggests that these are the constructs that clinicians should target during injury rehabilitation to increase or maintain intention, motivation, and ultimately physical activity engagement.

2.2.5 Recommendations for Research and Clinical Practice

The TPB and SDT have been used extensively to improve physical activity behaviors, but the applicability of these theories in sports medicine rehabilitation is limited. A recent study investigating the utilization of theory in injury prevention programs reported improvements in attitudes and beliefs and functional performance. Although the intervention was based on the Health Belief Model and not the TPB or SDT, the results provide a promising foundation for the utilization of theory to guide other areas of sports medicine research.

Current literature has explored the relationship between psychosocial factors and objective and self-reported outcome measures. In ACLR populations, self-efficacy and injury-related fear are the most commonly investigated factors and have been linked to functional outcomes in this population. Interventions that incorporate goal-setting have demonstrated improvements in these constructs after sport-related injury. In addition, a recent prospective study incorporated the constructs of both TPB and SDT with the aim to improve rehabilitation adherence in individuals with a history of ACLR. The study found that autonomous motivation was positively associated with attitudes/beliefs,
subjective norms, and perceived behavioral control, and that feelings of autonomy were positively supported by physiotherapists, but were not supported by physicians.\(^{169}\) This suggests that the social source supporting autonomy is an important piece of motivation which is consistent with previously literature.\(^{166,183,190}\) Athletic trainers, like physiotherapists, are able to spend sufficient time with patients throughout the rehabilitation process, and thus, have a unique ability to build relationships and gain patients’ trust. Evidence from Division I athletes demonstrated that an increasing number of athletes turn to athletic trainers for support during the rehabilitation process.\(^{191}\) The study by Yang et al.\(^ {191}\) revealed a perceived increase in support from athletic trainers during the injury rehabilitation process and that athletes were satisfied with the support they received from athletic trainers. Therefore, athletic trainers may be in a position to use the theoretical constructs discussed in this review to improve rehabilitation adherence and promote physical activity engagement.

There is ample opportunity for continued exploration of TPB and SDT utility in ACLR research. Future research should employ quantitative and qualitative methods to investigate the use of these theories within this population. Quantitative studies should continue to explore psychometric properties of self-reported measures used to examine theoretical constructs, such as the Basic Psychological Need Satisfaction Scale\(^ {171}\) or the Motives for Physical Activity Measure.\(^ {192}\) Additionally, studies should examine the relationship between TPB and SDT constructs and the proposed pathways within the IPAM and previous integrated models.\(^ {159,169,182}\) Once these relationships have been confirmed, intervention strategies can be created and implemented to improve return to sport and physical activity engagement after ACLR. Qualitative investigations would provide further
understanding of why and how theory constructs influence physical activity behavior. Researchers should focus on a grounded theory approach to understand these constructs in populations across the lifespan, before, during, and after ACLR and rehabilitation.

Research that has utilized theoretically sound interventions should be considered for use in clinical practice. Clinicians should be aware of contextual factors that influence intention and motivation to return to sport and engage in physical activity. Understanding individual, social, and environmental factors that relate to physical activity engagement will allow clinicians to make more informed decisions throughout the rehabilitation process. The IPAM is designed upon the premise that individual intention and motivation should be examined, and that deficits in any of the six foundational constructs should be targeted during the rehabilitation process. For example, following ACLR, individuals may lack perceived behavioral control to return to sport engagement,23 despite adequate physical function. Individuals may also experience a loss of social support191 and a lack of ‘relatedness’ because they can no longer participate in sport practice due to their injury. Patient-reported outcome measures, such as Knee Self-Efficacy Scale,193 Basic Psychological Need Satisfaction Scale,171 or Motives for Physical Activity Measure,192 may serve as useful tools to identify patient needs. Psychosocial interventions, such as goal setting, imagery, and positive self-talk, can be used during the rehabilitation process to overcome these barriers,189,194 and incorporating these techniques into ACLR protocols will likely improve the quality of care in a more holistic manner leading to greater long-term success. Therefore, the IPAM may provide a useful schema for evaluating intention and motivation for engaging in sport and physical activity in post ACLR patients and designing supplementary interventions to promote physical activity throughout recovery.
However, the aforementioned suggestions should be considered with the following limitations in mind. The use of theoretical models/frameworks within orthopaedic literature is novel, and limited evidence exists utilizing the TPB and SDT specifically in patients post-ACLR. Additionally, the proposed pathways between IPAM constructs have yet to be studied, therefore, the IPAM has not been validated. Despite these limitations, previous evidence has encouraged the utilization of the TPB and SDT together, increasing the viability of the IPAM for future research and clinical applications.

2.2.6 Conclusion

Patients with a history of ACLR demonstrate decreased rates of return to sport and decreased physical activity participation. The TPB and SDT have been independently applied to explain physical activity engagement in a variety of populations. The purpose of this review was to explore how these theories can positively impact return to sport and physical activity engagement after ACLR. We propose that integration of the IPAM into musculoskeletal rehabilitation protocols can increase return to sport participation and improve physical activity participation, even after sport cessation. While utilization of theories within rehabilitation protocols requires further investigation, this novel physical activity model along with previous work provides a promising foundation. We hypothesize that utilization of these theories in clinical practice and research can provide a better framework to better understand why individuals choose to participate in physical activity.
Table 2.6. Types of motivators according to Self-Determination Theory

<table>
<thead>
<tr>
<th>Type of motivators</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic motivation</td>
<td>The most self-determined form of motivation. Refers to the participation in an activity due to innate enjoyment of the behavior.</td>
</tr>
<tr>
<td>Integrated Regulation</td>
<td>The most self-determined form of extrinsic motivation. Refers to behaviors done for personal value.</td>
</tr>
<tr>
<td>Identified Regulation</td>
<td>Refers to a behavioral engagement that is freely chosen due to a desired outcome, not because behavior is enjoyed.</td>
</tr>
<tr>
<td>Introjected Regulation</td>
<td>Refers to behavioral engagement due to controlled personal feelings (i.e., guilt, anxiety).</td>
</tr>
<tr>
<td>External Regulation</td>
<td>The most controlled form of extrinsic motivation. Refers to behavioral engagement motivated by an external force (i.e., to gain prizes or avoid punishment).</td>
</tr>
<tr>
<td>Amotivation</td>
<td>The least self-determined form of motivation. Refers to a complete lack of motivation to engage in the behavior.</td>
</tr>
</tbody>
</table>
Figure 2.3. The Integrated Physical Activity Model.

Physical activity behavior is influenced by intention and motivation. Intention and motivation are influenced by the foundational constructs as described by the original Theory of Planned Behavior and Self-Determination Theory.
CHAPTER 3. PERSONAL AND SOCIAL CORRELATES OF PHYSICAL ACTIVITY IN INDIVIDUALS WITH A HISTORY OF ACL RECONSTRUCTION

3.1 Introduction

Anterior cruciate ligament (ACL) rupture is a common musculoskeletal injury that often occurs during sport and physical activity. After injury, many individuals undergo surgical reconstruction (ACLR) to restore joint stability and function in order to return to previous levels of physical activity.\textsuperscript{13,18} However, only 65% of individuals return to their pre-injury level of sport and up to 92% of patients will alter their physical activity levels after ACLR.\textsuperscript{20,62} Further, it has been demonstrated that individuals with a history of ACLR take fewer daily steps and participate in less moderate-to-vigorous physical activity compared to their uninjured peers.\textsuperscript{20,36,140} This is concerning, as inadequate amounts of physical activity and sedentary lifestyles have been linked to decreased quality of life\textsuperscript{195,196} and increased disability, chronic disease, preventable hospitalization, and premature death.\textsuperscript{29,197} Additionally, it is estimated that physical inactivity results in $117 billion in health care costs annually.\textsuperscript{29} The known benefits of physical activity paired with the economic burden of physical inactivity makes the need for continued investigation into factors that may impact an individual’s ability to meet the recommended physical activity guidelines critical. Specifically, the number of individuals who do not engage in recommended levels of physical activity after ACLR suggests that this population may experience additional barriers to physical activity compared to their uninjured counterparts.

Physical limitations, such as pain, instability, and decreased knee function, have previously been linked to decreased physical activity in the post-ACLR population.\textsuperscript{15,20,198} Recent literature cites psychosocial factors, such as fear of reinjury and decreased self-
efficacy, as additional barriers to return to sport and physical activity in the ACLR population. However, the literature has yet to explore personal, social, and environmental factors that may facilitate physical activity participation in this population. For example, factors such as physical literacy, social support, and health literacy impact physical activity participation in a variety of populations. Physical literacy is the “motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life”. Increased physical literacy has demonstrated significant relationships with physical activity behaviors in adolescent populations and university students. Additionally, qualitative evidence reveals that individual components of confidence and motivation are important for rehabilitation success and return to sport/activity decisions after ACLR. Social support is defined as intentional acts to assist an individual in the development or maintenance of a behavior. Increased social support has been shown to positively influence rehabilitation and recovery after ACLR and physical activity behaviors in healthy adolescent and adult populations. Health literacy is the ability to make everyday decisions that will have a positive impact on health. More specifically, it involves the ability to acquire, evaluate, and comprehend health information in order to make appropriate health-related decisions. Positive associations between health literacy and physical activity have been observed in adults, and increased electronic health literacy has been shown to promote exercise behaviors and overall health status in university students. Finally, interventions aimed at improving these factors have demonstrated improvements in physical activity. For example, improving physical literacy resulted in physical activity behavior improvements in inactive adults and first-year university students, while a
systematic review revealed that community-based health literacy interventions may be most beneficial to improve physical activity behaviors in adult populations.²¹³

Given these findings, it is possible that inadequate physical literacy, health literacy, and social support act as additional barriers to a physically active lifestyle in individuals with a history of ACLR. Understanding how these factors relate to physical activity engagement after ACLR is critical for developing targeted intervention strategies to improve outcomes in this population. Therefore, the purpose of this study was to identify personal and social factors that are related to physical activity in individuals with a history of ACLR. We hypothesize that a combination of physical literacy, health literacy, social support and knee function would explain a significant amount of variance associated with physical activity participation.

3.2 Methods

3.2.1 Design

A cross-sectional study design was used to examine physical literacy, health literacy, social support, knee function, and physical activity in individuals with a history of ACLR. Variables of interest for this study were perceived physical literacy, healthy literacy, and social support scores, self-reported knee function and self-reported physical activity.

3.2.2 Participants

Participants with a history of ACLR were recruited from the general population at a large, research-intensive university and via online sources, including social media platforms and ResearchMatch. ResearchMatch is a national health registry with a large
population of volunteers who have consented to be contacted by researchers about health studies for which they may be eligible. Participants were eligible if they had a history of one or more ACLRs within the last 10 years, were between the ages of 18-40 years, and had been cleared for physical activity by a physician. Participants were excluded if they had ACLR surgery within the last year, reported concomitant ligament reconstruction at the time of ACLR(s), injured their lower extremity within the last six weeks or reported a current injury. Participants were also excluded if they had a history of concussion within the last three months, had been diagnosed with any condition that affected their normal activity patterns, or could not read English. All study procedures were approved by the Institutional Review Board.

3.2.3 Procedures

Individuals who wished to participate received an electronic link to the online survey which was administered via REDCap (Research Electronic Data Capture). After reading and signing an electronic consent form, participants completed an eligibility questionnaire, a demographic and injury history questionnaire, and a series of patient-reported outcome measures (PROs). The PROs included the PLAYself, eHealth Literacy Scale (eHEALS), Sallis Social Support for Exercise Scale, Knee Injury and Osteoarthritis Outcome Score (KOOS), and the Godin Leisure-Time Exercise Questionnaire (GLTEQ). Data collection occurred between September 2020 to March 2021.

3.2.4 Instrumentation

*Demographic and Injury History Questionnaire:* The demographic and injury history questionnaire obtained participant demographic information and orthopaedic injury history, with additional questions regarding ACLR surgery and rehabilitation. These
questions included: the number of surgeries performed and their respective graft types, whether a structured rehabilitation protocol was performed, time since surgery, and the type of physical activity currently performed.

Patient Reported Outcome Measures

PLAYself: The PLAYself questionnaire is a single workbook from the Physical Literacy Assessment for Youth (PLAY) and evaluates self-reported perceptions of physical literacy across four subsections: environment, physical literacy self-description, relative ranking of literacies, and fitness. The environment subsection asks respondents “how good are you at doing sports and activities?” in 6 environments (e.g. gym, water, ice). The 12-question physical literacy self-description subsection is designed to assess respondents’ knowledge, confidence, and motivation toward sports and activity. The relative ranking of literacies subsection asks respondents to rank the importance of reading, math, and movement literacies within three contexts—in school, at home, and with friends. The final fitness subsection is not included in the final score but asks respondents to “agree” or “disagree” with the statement “My fitness is good enough to let me do all the activities I choose”. Therefore, the questionnaire is scored by summing the totals of the environment, physical literacy self-description, and relative ranking of literacies subsections and dividing by 27 to produce a composite score. The composite physical literacy score ranges from 0-100 with higher scores representing greater perceived physical literacy.

Individual subsection scores were used in this study to interpret specific aspects of physical literacy.

For the purposes of this study, the PLAYself questionnaire was altered from the original version. Question 6 within the Environment subsection, how good are you at doing
sports on the playground?, was removed based on the age of the study sample. Therefore, the physical literacy self-description, relative ranking of literacies, and the remainder of the environment subsection scores were summed and divided by 26 to produce the total physical literacy score. Additionally, individual subsection scores will be utilized to interpret physical literacy. Preliminary evidence into the psychometric properties of the PLAYself demonstrated that the use of individual subsections may be more appropriate for an adult population compared to the composite physical literacy score.\textsuperscript{216}

eHealth Literacy Scale: The eHEALS evaluates self-reported perceptions regarding a participant’s ability to find, evaluate, integrate, and apply health information found on the internet.\textsuperscript{217} The eHEALS aims to assess the six core skills that comprise “electronic health literacy” (eHealth literacy): 1) traditional literacy, 2) information literacy 3) media literacy, 4) health literacy, 5) computer literacy, and 6) scientific literacy.\textsuperscript{218} The eHEALS consists of 8-items and is scored on a scale of 8-40, with higher scores representing higher perceived eHealth literacy.\textsuperscript{217}

Sallis Social Support for Exercise Scale: The Sallis Scale is designed to evaluate perceived social support for exercise behaviors.\textsuperscript{219} Specifically, the scale identifies support received from family and friends “over the last three months”. The scale consists of 26 total items that are scored across two separate subscales: 13 questions for perceived family support (Sallis Family) and 13 questions for perceived friend support (Sallis Friend).\textsuperscript{219} Each item is scored on a 5-point Likert scale, with higher scores representing greater perceived social support for exercise.\textsuperscript{219}

Knee Injury and Osteoarthritis Outcome Score: The KOOS evaluates self-reported knee function using five subscales—current symptoms (KOOS-Symptoms), pain (KOOS-Pain),
activities of daily living (KOOS-ADL), sport and recreation (KOOS-Sport), and quality of life (KOOS-QOL). Each subscale of the KOOS is scored individually from 0 to 100, with higher scores representing greater self-reported knee function. The KOOS has demonstrated clinically acceptable validity and reliability in the ACLR population.

*Godin Leisure-Time Exercise Questionnaire:* The GLTEQ was utilized to quantify self-reported physical activity “over the last 7 days”. The questionnaire asks respondents “how many times” they engage in strenuous, moderate, and light physical activity for “more than 15 minutes”. Answers to each question are then multiplied by their corresponding metabolic equivalent of task (MET) values and summed to quantify a physical activity leisure score. For the GLTEQ, MET values of 9, 5, and 3 represent strenuous, moderate, and light intensity activities, respectively. GLTEQ scores ≥24 are interpreted as ‘Active’; scores between 14-23 are interpreted as ‘Moderately Active’; and scores <14 are interpreted as ‘Insufficiently Active/Sedentary’. In accordance with physical activity guidelines, moderate and strenuous leisure scores were summed to create the moderate-to-vigorous physical activity (MVPA) score utilized in the analysis.

### 3.2.5 Statistical Analyses

Descriptive statistics were calculated for all participant demographics (means, standard deviations) and outcome variables (median, interquartile range). A stepwise linear regression model was used to determine if patient reported outcomes scores predicted self-reported physical activity. The PLAYself Environment, PLAYself Physical Literacy Self-description, PLAYself Relative Ranking of Literacies, Sallis Family, Sallis Friend, eHEALS, KOOS-Symptoms, KOOS-Pain, KOOS-ADL, KOOS-Sport, and KOOS-QOL scores served as predictor variables and the GLTEQ MVPA score served as
the dependent variable. Separate Spearman correlations between GLTEQ MVPA and all predictor variables were conducted to reduce the number of predictor variables entered into the regression model. Predictor variables with r>0.20 were eligible for inclusion in the model. Next, the predictor variables were assessed for collinearity. For variables that demonstrated strong collinearity (r>0.70), the variable with the strongest correlation to GLTEQ MVPA was moved forward into the model. Predictor variables that did not significantly contribute to the model’s predictive value (R²) were removed to determine the overall percentage of explained variance. The regression coefficient (β), the constant, and F-statistic for the final regression model was also calculated. Significance was set a priori at p<0.05. All statistical analyses were conducted using SPSS software (v23.0, SPSS, Inc., Chicago, IL, USA).

3.3 Results

A total of 62 participants had complete survey data and were included in the analysis (Figure 3.1). Participants were on average 27.8 ± 4.7 years of age and 6.1 years post-ACLR. Ninety-two percent of participants were classified as ‘Active’ according to GLTEQ scoring guidelines. Additional demographics and ACLR information can be found in Table 3.1. Predictors of self-reported physical activity

Summary scores of predictor variables are displayed in Table 3.2. Bivariate analyses determined that KOOS-QOL, PLAYself Environment, PLAYself Physical Literacy Self-description, and PLAYself Relative Ranking of Literacies were associated with GLETQ MVPA (Table 3.3). Collinearity was not observed between any of the predictor variables, therefore the KOOS-QOL, PLAYself Environment, PLAYself Physical Literacy Self-description, and PLAYself Relative Ranking of Literacies were selected for the model. The
final stepwise linear regression model demonstrated that the PLAYself Physical Literacy Self-description subsection accounted for 12.2% of the variance of self-reported physical activity in individuals with a history of ACLR (Table 3.4).

3.4 Discussion

The purpose of this study was to identify personal and social correlates of physical activity in individuals with a history of ACLR. We hypothesized that a combination of physical literacy, health literacy, social support and knee function would predict current physical activity levels in this population. Overall, our primary hypothesis was not supported as elements of knee function and physical literacy were associated with physical activity, but physical literacy self-description was the only predictor of physical activity levels and explained 12.2% of the variance when the variables were considered together.

Physical literacy is an emerging construct in the literature and is proposed to be critical for long-life physical activity engagement. Often described as the “gateway” to physical activity participation, physical literacy is a multi-dimensional concept and a developmental process that evolves across a lifespan. Recent literature demonstrates significant relationships between physical literacy and physical activity as well as other predictors of health such as cardiorespiratory fitness, body composition, and health-related quality of life. To date, the bulk of physical literacy evidence has been conducted in childhood and adolescent school environments (i.e. physical education) which may not be generalizable to an adult population. However, the results of the present study align with previous evidence supporting the relationship between physical literacy and physical activity. Specifically, the Physical Literacy Self-description subsection demonstrated a
significant relationship with self-reported physical activity in our sample of young adults with a history of ACLR. This subsection is designed to evaluate unique aspects of physical literacy including confidence, motivation, and knowledge toward physical activity. This supports previous literature that identifies confidence/self-efficacy, motivation, and knowledge to be key concepts that influence rehabilitation adherence and treatment success following ACLR and knee injury.\textsuperscript{206,209,223} Therefore, the physical literacy components of confidence, motivation, and knowledge may be especially salient when trying to promote physical activity after ACLR.

While this study examined self-reported physical literacy in individuals after musculoskeletal injury, recent investigations have begun to hypothesize the importance of physical literacy to prevent injury. For example, it is suggested that sport and recreation activities are key avenues to develop fundamental movement patterns in youth and adolescents.\textsuperscript{224} These fundamental movement patterns are essential for developing physical competence\textsuperscript{225} which is a core pillar of physical literacy.\textsuperscript{66} In general, physical competence, also known as movement competence, is a person’s ability to perform movement patterns in multiple environments and their confidence within those abilities.\textsuperscript{66} Interestingly, investigations into movement patterns have raised questions regarding the growing trend of sport specialization in youth sports.\textsuperscript{66,226,227} In line with sports medicine research, Dudley et al. argues that specialization limits an individual’s ability to develop a variety of fundamental movement patterns needed to develop physical literacy.\textsuperscript{66} Further, this specialization has been linked to increases in injury risk\textsuperscript{228} and decreased physical activity participation.\textsuperscript{66,229} While additional research must be conducted to confirm the hypothesized relationships between physical literacy, movement competence, sport
specialization, and injury, it has been demonstrated that disruptions in physical activity due to musculoskeletal injury have detrimental effects on long-term physical activity participation.\textsuperscript{230} We did not identify whether or not the participants in this study specialized in sport, or whether or not they injured their knee playing or training for a specific sport. However, future research should continue to investigate the relationship between sport specialization, musculoskeletal injury history, physical literacy, and physical activity. These factors may be important in understanding the physical inactivity in the post-ACLR population.

Health literacy and social support were not associated with physical activity in our sample. While investigations into these concepts in a post-ACLR population are limited, previous evidence demonstrates that health literacy\textsuperscript{205} and social support\textsuperscript{200,202} impact physical activity in the general population. A systematic review by Buja et al.\textsuperscript{205} revealed positive associations between health literacy and physical activity engagement in adult populations, and increased health literacy in adolescents involved in sports clubs. It is hypothesized that individuals with higher levels health literacy are more likely to participate in activities known to enhance health outcomes, such as physical activity.\textsuperscript{205} Despite this evidence, no relationship between health literacy and physical activity was observed in the present study. We believe the measure of health literacy utilized in this study may have contributed to these findings. Specifically, the eHEALS is designed to evaluate an individual’s ability to utilize the internet for health-related information.\textsuperscript{231} Our sample was on average 28 years old, and recorded a median eHeals score of 32. Therefore, our sample of young adults likely have sufficient computer and web-based skills and may be more confident in their abilities to find and understand health information on the internet.
without participating in physical activity. Utilizing a comprehensive health literacy instrument, such as the Test of Functional Health Literacy in Adults\textsuperscript{212} or All Aspects Health Literacy Scale,\textsuperscript{233} may have uncovered additional information about the relationship between health literacy and physical activity in our sample of young adults.\textsuperscript{203}

Increased perceptions of social support have also been linked to increased physical activity engagement in various populations.\textsuperscript{200-202,234,235} It has been suggested that social connections can model appropriate behaviors and/or enhance confidence for physical activity engagement.\textsuperscript{200} In children and adolescents, support from family and friends are associated with physical activity.\textsuperscript{201,202,234} Similar results have been observed in young-adult and adult populations,\textsuperscript{200,236} while athletic populations appear to receive additional support from coaches and athletic trainers.\textsuperscript{191,237} Despite these findings, this study did not identify significant relationships between social support and physical activity behaviors. Overall, our sample reported low scores for support received from both family and friends related to exercise. These findings may be due to changes in physical activity behaviors and/or social distancing guidelines during the COVID-19 pandemic. A recent qualitative study illustrated new barriers to social support for exercise during the pandemic which may negatively impact an individual’s motivation and self-esteem for physical activity.\textsuperscript{238} Additionally, these findings may be due to the measure of social support utilized in this study. Previous studies have determined that the source of social support may impact physical activity behaviors differently.\textsuperscript{200,201,208} For example, it has been demonstrated that social support from friends is more likely to influence physical activity behaviors in college students and young adults.\textsuperscript{200} The present study only investigated support received from family and friends, and it is possible that subjects receive physical activity support from
sources not identified in the questionnaire such as or coworkers, professors, or personal trainers. Additionally, it is possible that subjects may receive support from family and friends in ways that could not be captured by the questionnaire.

3.4.1 Limitations

This study is not without limitations. First, all data was self-reported by participants and was collected remotely due to COVID-19 restrictions. This limited the ability of participants to ask clarifying questions. Participants may have over-estimated or under-estimated answers to the questionnaires, including the self-reported physical activity assessment. Further, the physical activity results obtained during the COVID-19 pandemic may not accurately represent participant’s normal physical activity engagement. Secondly, physical literacy was measured using a questionnaire that has not yet been validated in an adult population, as no questionnaire designed for an adult population currently exist. Additionally, the questionnaire was altered from its original format. Therefore, the results regarding physical literacy in this study should be interpreted with caution. Finally, the exclusion criteria in this study did not place a limit on the number of ACL injuries/surgeries. While 82% of participants reported only one ACL injury and reconstruction, it is unclear if a history of multiple ACLRs impacted our results.

3.4.2 Future Research

Future studies should consider additional mechanisms to identify how physical literacy, health literacy, and social support impact physical activity behaviors in young adults with a history of ACLR. Specifically, researchers should explore how physical literacy influences physical activity participation in young adults and examine how physical literacy impacts return to sport, long-term physical activity engagement, and other
aspects of health in individuals with a history of ACLR or other musculoskeletal injury. Additionally, future research should identify other personal, social, and environmental factors that impact physical activity in young adults as the factors explored in this study only explained 12% of physical activity behaviors. Finally, future studies should explore how social determinants of health (SDoH) impact the factors explored in this study. SDoH have been demonstrated to be one of the most influential factors regarding overall health status as it includes factors such as socioeconomic status, housing and food security, access to quality education and health care, and racism and discrimination. While many of these factors are beyond the scope of this study, it is likely that SDoH influence perceived physical literacy, health literacy, and social support, and elucidating these relationships may reveal additional factors that impact physical activity participation in a post-ACLR population.

3.5 Conclusion

Aspects of physical literacy and knee function were associated with self-reported physical activity in individuals with a history of ACLR. Physical literacy self-description was the only variable that significantly predicted self-reported physical activity. However, the large unexplained variance indicates that additional factors are contributing to physical activity engagement in our sample of young adults. Future research should strive to create measures that accurately assess physical literacy in adult populations.
Table 3.1. Participant demographics

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>27.8 ± 4.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168.6 ± 10.4</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>69.4 ± 13.7</td>
</tr>
<tr>
<td>BMI</td>
<td>24.3 ± 3.3</td>
</tr>
<tr>
<td>Time Since Surgery (years)</td>
<td>6.1 ± 2.6</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>52 (83.9%)</td>
</tr>
<tr>
<td>Ethnicity (Non-Hispanic White)</td>
<td>57 (91.9%)</td>
</tr>
</tbody>
</table>
Table 3.2. Summary scores of predictor variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median</th>
<th>Interquartile Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOOS-Symptoms</td>
<td>82.14</td>
<td>17.86</td>
</tr>
<tr>
<td>KOOS-Pain</td>
<td>94.44</td>
<td>8.33</td>
</tr>
<tr>
<td>KOOS-ADL</td>
<td>98.53</td>
<td>4.48</td>
</tr>
<tr>
<td>KOOS-Sport</td>
<td>85.00</td>
<td>16.25</td>
</tr>
<tr>
<td>KOOS-QOL</td>
<td>75.00</td>
<td>18.75</td>
</tr>
<tr>
<td>Sallis Family</td>
<td>19.00</td>
<td>12.50</td>
</tr>
<tr>
<td>Sallis Friend</td>
<td>19.50</td>
<td>20.00</td>
</tr>
<tr>
<td>eHeals</td>
<td>32.00</td>
<td>4.00</td>
</tr>
<tr>
<td>PLAYself Environment</td>
<td>262.50</td>
<td>88.00</td>
</tr>
<tr>
<td>PLAYself Physical Literacy Self-description</td>
<td>835.00</td>
<td>218.00</td>
</tr>
<tr>
<td>PLAYself Relative Ranking of Literacies</td>
<td>767.50</td>
<td>241.00</td>
</tr>
</tbody>
</table>

Abbreviations: ADL: Activities of daily living; eHeals: eHealth Literacy Scale; KOOS: Knee Injury and Osteoarthritis Outcome Score; QOL: Quality of life
Table 3.3. Spearman correlations of self-reported physical activity and predictor variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>GLTEQ MVPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>KOOS-Symptoms</td>
<td>.122</td>
</tr>
<tr>
<td>KOOS-Pain</td>
<td>.192</td>
</tr>
<tr>
<td>KOOS-ADL</td>
<td>.136</td>
</tr>
<tr>
<td>KOOS-Sport</td>
<td>-.038</td>
</tr>
<tr>
<td>KOOS-QOL</td>
<td>.322*</td>
</tr>
<tr>
<td>Sallis Family</td>
<td>.087</td>
</tr>
<tr>
<td>Sallis Friend</td>
<td>.040</td>
</tr>
<tr>
<td>eHeals</td>
<td>.121</td>
</tr>
<tr>
<td>PLAYself Environment</td>
<td>.269*</td>
</tr>
<tr>
<td>PLAYself Physical Literacy Self-description</td>
<td>.313*</td>
</tr>
<tr>
<td>PLAYself Relative Ranking of Literacies</td>
<td>.285*</td>
</tr>
</tbody>
</table>

*Significant at p>.05
Table 3.4. Variables identified as significant predictors for MVPA

<table>
<thead>
<tr>
<th>Model</th>
<th>Independent variables</th>
<th>β</th>
<th>R²</th>
<th>Adjusted R²</th>
<th>Constant</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PLAYself Physical Literacy Self-description</td>
<td>.369</td>
<td>.137</td>
<td>.122</td>
<td>5.991</td>
<td>9.486</td>
<td>.003</td>
</tr>
</tbody>
</table>
Figure 3.1. Flowchart describing participant recruitment

n=113
Individuals accessed the survey link

n=112
Participants completed the eligibility questionnaire

n=93
Participants started the survey

n=19
Did not meet inclusion criteria

n=28
Removed due to incomplete survey data

n=65
Participants completed all surveys

n=62
Participants included in quantitative analysis

n=1
Did not consent to participate

n=3
Removed for incomplete GLTEQ data
CHAPTER 4. THE RELATIONSHIP BETWEEN PHYSICAL LITERACY OUTCOMES AND PHYSICAL ACTIVITY IN INDIVIDUALS WITH A HISTORY OF ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

4.1 Introduction

While it is known that regular participation in physical activity is a key component of health and well-being, musculoskeletal injury is an associated risk. Injury to the knee joint is the second-most common musculoskeletal injury observed in emergency departments and acute care settings with adolescents and young adults (ages 13-25 years) sustaining the highest injury rate. Further, sports-related knee injuries account for the largest percentage of severe musculoskeletal injuries which may require surgical intervention. Specifically, injury to the anterior cruciate ligament is common with approximately 250,000 injuries occurring annually. Many individuals opt to undergo reconstructive (ACLR) surgery in order to restore knee joint stability and function to promote successful return to activity. However, decreased sport and physical activity participation have been observed following ACLR. It is estimated that only 65% of patients return to pre-injury levels of sport, while only 55% return to competitive sport after ACLR. Further, it is proposed that the cessation of sport activity due to ACLR may negatively influence physical activity participation long-term. For example, young adults (ages 18-35 years) with a history of ACLR participate in less moderate-to-vigorous physical activity (MVPA) compared to their uninjured peers and do not meet the recommended daily step count of 10,000 steps. Finally, individuals with a history of ACLR are 2.36 less likely to meet physical activity guidelines compared to healthy controls.
Evidence often cites physical and psychological factors as the main barriers impacting sport and physical activity participation post-ACLR,15,23,24,26 but investigations into social and environmental factors are rising. However, a factor that has been largely unexplored in ACLR literature is physical literacy, despite evidence to suggest that it may be an essential element of safe sport and physical activity participation.227,241 Physical literacy is defined as the “motivation, confidence, physical competence, knowledge and understanding to value and take responsibility in physical activities for life.”45 The concept of physical literacy has been proposed as a determinant of health43 and has been linked to increased physical activity participation and greater health-related quality of life.47,49,50 Additionally, individual physical literacy components of motivation, confidence, and physical competence have also been linked to increased physical activity participation in youth and adolescent populations.49,50 Physical competence, also called motor competence, is heavily emphasized in physical literacy intervention programs as a way to improve fundamental movement skills while also increasing individuals’ confidence and motivation for physical activity.224,241,242 This is important as a lack of fundamental movement skills may limit the ability to successfully participate in a variety of activities and may increase an individual’s risk for musculoskeletal injury.227,243

While no studies to date have attempted to assess physical literacy in individuals after musculoskeletal injury, individual components of physical literacy are evident within the literature. Qualitative investigations into experiences after ACLR reveal that confidence, ability to perform sport-specific movements, and motivation are key factors that influence an individual’s willingness and ability to return to sport after injury.55,207,244 Further, it has been demonstrated that fundamental movement patterns, such as running,
jumping, and landing, are significantly altered post-ACLR\textsuperscript{56,60,245} which may further impact confidence and motivation for exercise. These findings suggest that components of physical literacy may not be adequately addressed during the ACLR process and likely impact sport and physical activity participation after medical clearance is obtained. Thus, physical literacy components should be targeted to promote return to sport and physical activity participation after ACLR. Given the lack of explicit physical literacy evidence in sport medicine research, there is a critical need to examine the individual components of physical literacy following musculoskeletal injury and explore their relationship to physical activity participation. Therefore, the primary purpose of this study was to determine if components of physical literacy are predictive of objectively measured physical activity in individuals with a history of ACLR. We hypothesize that objectively measured physical activity will positively correlate to each component of physical literacy. Specifically, we hypothesize that a combination of confidence, motivation, physical competence, and knowledge would explain a significant amount of variance associated with objectively measured physical activity in individuals with a history of ACLR.

4.2 Methods

4.2.1 Design

A modified cross-sectional study design was utilized to examine physical literacy components in a group of adults with a history of ACLR. The predictor variables of interest were motivation, confidence, physical competence, and physical activity knowledge, and the dependent variable was objectively measured physical activity. These variables were chosen to closely align with physical literacy components (Figure 4.1).
4.2.2 Sample Size Calculation

Previous research was utilized to power this study using self-reported physical activity data in individuals with a history of ACLR. The analysis demonstrated that a minimum 45 participants were needed to achieve 80% power (alpha = .05). This calculation was based on a regression analysis utilizing an estimated 4 predictor variables.

4.2.3 Participants

Participants were recruited from the general population at a large, research-intensive university and the surrounding community. Participants were eligible for inclusion if they were between the ages of 18-40, had a history of unilateral or bilateral ACLR within the last 10 years, and had been cleared for physical activity by a physician. Participants were excluded if they reported concomitant ligament repair at the time of ACLR, reported any surgery to the lower extremity within the last year, injured their lower extremity within the last six weeks, sustained a concussion within the last three months, or reported any condition that limits their ability to participate in physical activity.

4.2.4 Procedures

All study procedures were approved by the Institutional Review Board prior to subject recruitment. Participants reported to the laboratory for two testing sessions, separated by one-week of objective physical activity observation. At the first testing session, participants reviewed and completed the informed consent. Once consent was obtained, participants completed a series of patient-reported outcome measures (PROs) and a demographic and injury questionnaire. The PROs included were the Behavioral Regulation in Exercise Questionnaire-3, Knee Self-Efficacy Scale, Self-Efficacy Scale.
for Exercise Scale,249 PLAYself,214 Knee Injury and Osteoarthritis Outcome Score,220 and a physical activity knowledge questionnaire.250 The PROs and demographic and injury questionnaire were administered, stored, and managed utilizing the electronic capture tool REDCap (Research Electronic Data Capture). At the conclusion of the first session, participants were provided an accelerometer to objectively measure physical activity over the next 7 days. Participants were instructed on proper accelerometer wear, were provided with a log to track accelerometer wear time and were encouraged to follow their normal routine throughout the week. After the physical activity observation period, participants returned for the second session where they returned the accelerometer and completed a series of functional tasks that included the Landing Error Scoring System, Single Leg Hop Series, and PLAYbasic. All data was collected by three members of the research team (RRK, JT, DD) who were trained in functional data acquisition. Standard operating procedures were utilized at each data collection session to ensure standardized data collection between research team members.

4.2.5 Instrumentation

Demographic and Injury History Questionnaire: The demographic and injury history questionnaire collected demographic information (age, sex, race, etc.) and orthopaedic injury history. Additional questions collected information regarding ACLR surgery and rehabilitation including: the number of surgeries performed and respective graft types, time since surgery, and dichotomous outcomes related to meniscal procedures, post-operative brace usage, and participation in structured rehabilitation.
Patient Reported Outcome (PRO) Measures

Behavioral Regulations in Exercise Questionnaire-3: The Behavioral Regulations in Exercise Questionnaire-3 (BREQ-3)\textsuperscript{247,248} is self-reported measure designed to assess self-determination (i.e., motivation) for exercise. Adapted from the original BREQ scale,\textsuperscript{251} the BREQ-3 consists of 24-items scored on a 5-Likert scale ranging from 0 (not true for me) to 4 (very true for me). The questionnaire measures each type of regulation described in Deci and Ryan’s motivation continuum;\textsuperscript{39,171} amotivation, external, introjected, identified, integrated, and intrinsic. Regulation subscales are scored separately by calculating the mean scores for each subscale item,\textsuperscript{252} and a relative autonomy index score can then be calculated for the entire questionnaire by weighting each subscale and summing the weighted scores.\textsuperscript{252} Higher positive scores represent greater relative autonomy, while lower and/or negative scores represent controlled regulations. Individual regulation subscales were utilized to represent the motivation component of physical literacy.

Self-Efficacy for Exercise Scale: The Self-Efficacy for Exercise (SEE) Scale\textsuperscript{249} is designed to assess perceived self-efficacy for exercise in an adult population. The scale consists of 9 items, each beginning with “How confident are you right now that you could exercise three times per week for 20 minutes if…” Specifically, the SEE examines perceived barriers for physical activity by examining confidence if “the weather was bothering you”, “you do not enjoy it”, “you felt stressed”, etc. Questions are scored on a scale from 0 (“not confident”) to 10 (“very confident”). Scores are summed and higher scores represent greater self-efficacy for exercise. The SEE has demonstrated acceptable validity and reliability in an adult population ($\alpha=0.92$).\textsuperscript{249} This scale represented the confidence component of physical literacy.
Knee Self-Efficacy Scale: The Knee Self-Efficacy Scale (K-SES) is designed to assess perceived self-efficacy in patients with ACL injury. The 22-item questionnaire is divided into four subscales: Daily Activities, Sport and Leisure Activities, Physical Activities, and Your Knee Function in the Future. Each item is scored on an 11-point Likert scale ranging from 0 (“not certain at all”) to 10 (“very certain”). Scores are then summed and divided by the number of items to allow for scoring of individual subscales and/or the scale as a whole. Higher scores represent greater perceived knee self-efficacy. The questionnaire has demonstrated acceptable validity and reliability in individuals with a history of ACLR ($\alpha = 0.94$, ICC = 0.75). This K-SES total score was utilized to represent the confidence component of physical literacy.

Physical Activity Knowledge Questionnaire: Knowledge for physical activity was assessed using a questionnaire developed by Fredriksson et al. The questionnaire is designed to assess knowledge across four levels. In brief, Level 1 knowledge represents knowing benefits associated with physical activity and risks associated with physical inactivity; Level 2 assesses if respondents understand health conditions that are related to physical inactivity; Level 3a identifies if respondents are familiar with physical activity guidelines (i.e., the frequency, intensity, etc.); and Level 4 knowledge represents the ability of respondents to relate their physical activity knowledge to their own health. The questionnaire was scored utilizing the methods presented in Fredriksson et al. and Levels 2 and 3a were utilized in the data analysis. In brief, Level 2 was scored as the sum of correctly identified health conditions related to physical activity, while Level 3a was dichotomized as ‘correct’ and ‘incorrect’ identification of current physical activity guidelines. This questionnaire represented the knowledge component of physical literacy.
**PLAYself:** The PLAYself\(^{214}\) is a single measurement from the Physical Literacy Assessment for Youth (PLAY) assessment suite and is designed to evaluate self-perceptions of physical literacy. The 22-question questionnaire is divided into four subsections: Environment, Physical Literacy Self-Description, Relative Ranking of Literacies, and Fitness.\(^{215}\) The Environment subsection asks respondents to assess their skills across 6 types of environments. The Physical Literacy Self-Description subsections examines respondents’ motivation, confidence, and knowledge regarding sport and physical activity. The Relative Ranking of Literacies subsection asks respondents to rank the importance of reading/writing, arithmetic, and movement literacies. The Fitness subsection asks respondents to assess whether their fitness is “good enough” to let them participate in all desired activities; however, this subsection is not included in the final score. The PLAYself is scored by summing the totals of the Environment, Physical Literacy Self-Description, and Relative Ranking of Literacies subsections and dividing by 27 to produce a composite physical literacy score. Composite scores range from 0 to 100 with higher scores representing greater perceived physical literacy.\(^{214,215}\) The Physical Literacy Self-Description subsection was utilized to examine individual components of physical literacy. The subsection was chosen based on psychometric property testing conducted in a sample of young adults.\(^{216}\)

**Knee Injury and Osteoarthritis Outcome Score:** The Knee Injury and Osteoarthritis Outcome Score (KOOS)\(^{220}\) is designed to examine self-reported knee function. The 42-item questionnaire is divided into five domains: symptoms (KOOS-Symptoms), pain (KOOS-Pain), activities of daily living (KOOS-ADL), sport and recreation (KOOS-Sport), and quality of life (KOOS-QOL). Items are scored on 5-point Likert scale ranging from 0
(“extreme”/“always”/“constantly”) to 4 (“never”/“none”). Each domain is scored independently from 0 to 100, with higher scores representing greater self-reported knee function. Specifically, a score of 0 represents “extreme knee problems” and a score 100 represents “no knee problems”. Each domain has demonstrated acceptable reliability (ICC ≥ 0.75) in individuals with a history of ACLR.

**Functional Tasks**
Participants completed a series of functional tasks designed to assess physical competence. Functional tasks were chosen based on suggestions for return to sport decision making post-ACLR and current physical literacy evidence.

*Landing Error Scoring System-Real Time:* The Landing Error Scoring System-Real Time (LESS-RT) is a clinical assessment used to identify functional deficits that may predispose individuals to injury and is widely utilized for individuals post-ACLR. Participants were instructed to perform the task as reported by Padua et al. In brief, participants began on a 30 cm platform and jumped over a target line positioned at a distance half of the participant’s height. Upon landing, participants jumped at a maximal height. Participants completed 2 practice trials followed by 4 test trials with 30-seconds rest in between each jump. If participants did not successfully complete the task during the test trials, they were asked to repeat the task. Jump-landing mechanics were assessed and scored based on criteria defined by Padua et al, and the total score (number of errors) was utilized in the analysis.

*Hop-Series Testing:* Participants completed a series of single-leg hop tasks including the single-leg hop for distance (SLH), triple-hop for distance (TH), and cross-over hop distance (COH) to assess single-limb power. Participants performed each test as described by
Gustavsson et al. In brief, participants were instructed to jump as far as possible while maintaining control and landing on the start leg. For the SLH, participants jumped as far forward using one hop. For the TH, participants were instructed to complete three consecutive hops landing on the start leg each time. For the COH, participants were instructed to hop three times while crossing over a 6-cm strip on floor on each jump. For each test, participants completed one practice trial followed by three test trials with 30 seconds rest in between each trial and 1-minute rest in between each hop task. Participants began each test on their uninvolved limb before moving on to the injured limb. All distances were recorded in centimeters, and distances were averaged across the three trials for each testing condition. The average distance for each limb was used to calculate the limb symmetry index (LSI). LSI was calculated as involved limb/uninvolved limb x 100. For individuals with a history of bilateral ACLR, the limb with the most recent ACLR was considered the involved limb.

PLAYbasic: The PLAYbasic is a workbook included in the PLAY tool suite and is designed to be used by coaches, physiotherapist, athletic trainers, and/or other sport and exercise professionals to assess key movement skills across four movement domains: locomotor, upper body object control, lower body control and balance. The PLAYbasic consists of five movement-related tasks: run there and back, single-leg hop, overhand throw, kicking, and backward balance walk. Each task is graded on a 100-mm visual analog scale to represent a maximum score of 100 (i.e., each mm = 1 point). Scores are interpreted as initial (0-24), emerging (25-49), competent (50-74), and proficient (75-100). The maximum proficient score represents “the very best that anyone could be at that skill, regardless of age.”
Accelerometer

An accelerometer (ACTi Graph Link) was utilized to objectively measure physical activity over a period of 7 days. Participants were instructed to put on the accelerometer first thing in the morning, position the device over the right anterior superior iliac spine, and to wear at all times during the week except when bathing, swimming, or sleeping. A valid data collection was defined as at least 10 hours of wear per day, with a minimum wear period of 3 days.\(^\text{260}\) ACTi Life software was utilized to extract and analyze raw physical activity data from the accelerometers. Freedson Adult VM3 cut points were used to categorize physical activity intensity as light, moderate, vigorous, or very vigorous.\(^\text{261}\) Average MVPA (minutes/day) over the 7-day period were used for data analysis.

4.2.6 Statistical Analysis

Statistical analyses were conducted using SPSS software (v23.0, SPSS, Inc., Chicago, IL, USA), and significance was set a priori at \(P<0.05\). Descriptive statistics were calculated for participant demographics (means, standard deviations), PRO measures and functional tasks (median, interquartile range). A stepwise linear regression was utilized to examine if the BREQ-3 regulation scores, SEE, K-SES, PLAYself Physical Literacy Self-Description, Physical Activity Knowledge Questionnaire Levels 2 and 3a, LESS-RT, SLH-LSI, TH-LSI, COH-LSI, and PLAYbasic run, hop, throw, kick, and balance tasks predicted time spent (minutes) in MVPA. Bivariate Spearman correlations between MVPA and predictor variables were conducted to reduce the number of variables entered into the regression model, only those predictor variables with \(r \geq 0.20\) were eligible for inclusion in the model.\(^\text{23}\) Predictor variables were then assessed for collinearity. For variables that demonstrated strong collinearity (\(r \geq 0.70\)), the variable with the strongest correlation to
MVPA was entered into the regression model. The overall percent of the explained variance ($R^2$) for the regression analysis, regression coefficient ($\beta$), the constant, F-statistic, and p-value were identified. Univariate analyses of covariance (ANCOVA) were also utilized to examine the effect of predictor variables that remained in the final model while controlling for confounding demographic variables.

4.3 Results

A total of 47 participants were recruited with 45 of those participants (mean age = 22.8±4.18 years) completing the study and included in the quantitative analysis (Figure 4.2). Participant demographics and ACLR information are presented in Table 4.1. The sample of young adults with a history of ACLR averaged 38.39 (±16.92) daily minutes of MVPA and 64% of participants met the 30 minutes per day guideline. Despite this, the sample averaged approximately 7123 (±2144) daily steps which is less than the recommended 10,000 steps per day. Summary scores for PROs and functional tasks are presented in Table 4.2.

Bivariate analyses determined the BREQ-3 Intrinsic motivation, Integrated motivation, PLAYbasic run, and PLAYbasic hop were positively associated with objectively measured MVPA while the LESS-RT was negatively associated with MVPA (Table 4.3). Collinearity was not observed between any predictor variables, so the five predictors were selected for the model. The final stepwise linear regression model included the PLAYbasic run which accounted for 13.5% of the variance in objectively measured MVPA (Table 4.4). Two demographic variables, age and time since surgery, were moderately, negatively correlated with MVPA. These variables, age and time since
surgery, were entered in to an ANCOVA to further analyze the results of the linear regression with these variables as covariates to the model. After adjusting for age and time since ACLR, the PLAYbasic run remained a significant predictor of MVPA (p=.032) in the adjusted model. The adjusted \( R^2 \) increased from .135 to .272, suggesting that the addition of age and time since surgery, along with the PLAYbasic run accounted for approximately 27.2\% of the variance in objectively measured MVPA.

4.4 Discussion

The purpose of this study was to determine if components of physical literacy predicted physical activity participation in young adults with a history of ACLR. We hypothesized that a combination of motivation, confidence, physical competence, and knowledge would contribute to the variance in objectively measured MVPA. Overall, our hypothesis was not supported as only aspects of motivation and physical competence were associated with physical activity participation, and the PLAYbasic run task was the only variable that significantly predicted MVPA, both with and without controlling for age and time since surgery. Despite our findings, this study adds to the growing body of literature supporting the role of physical literacy for physical activity participation. Specifically, physical competence may be a salient factor to consider when examining MVPA participation after ACLR.

Physical competence is a person’s ability to perform fundamental movement skills in a variety of environments.\(^6\) It is suggested that limited physical competence is detrimental to life-long physical activity participation as it decreases skill and confidence toward physical activities.\(^6\) Dudley et al. suggests that individuals, particularly in youth,
should be exposed to a variety of movement patterns, activities, and environments that are transferable to life-long physical activity participation. While the present study utilized several functional outcomes to quantify physical competence, only three tasks correlated with physical activity. Interestingly, the tasks associated with MVPA are designed to assess the quality of the movement as opposed to outcome-based measurement like hop-testing and subsequent LSI outcomes. Traditionally, hop series testing has been utilized in ACLR research to quantify limb asymmetries, lower extremity power, and quadriceps strength. Despite its widespread use, hop series testing has been called into question in recent literature. Specifically, hop testing LSI may mask asymmetries in strength, joint biomechanics, and movement compensations which could negatively impact the knee joint long-term. Furthermore, these tests do not account for the quality of the hop tests and do not provide an opportunity to assess differences in quality between the surgical and non-surgical limbs. In contrast, the LESS and PLAYbasic task battery assess movement quality and fundamental skills. Within each task, assessors are trained to identify movement pattern qualities and abnormalities that may predispose an individual to injury and/or limit one’s ability to successfully participate in physical activities. Functional tests that evaluate quality over outcome may be more meaningful in individuals with a history of ACLR as they can identify deficits in fundamental movement skills and inefficient movement patterns.

Previous research states that fundamental movement skills are necessary for physical activity participation. The PLAYbasic assesses multiple fundamental movement skills such as running, throwing, kicking, hopping, and balancing. However, the present study demonstrates that not all fundamental movement skills predict physical
activity participation, as only the PLAYbasic run assessment was associated with MVPA in our sample. This could be due to the types of physical activity that participants were currently engaged in. While we did not assess current physical activity engagement (e.g., what types of activities do you perform on a routine basis?), it could be possible that many of our participants participated primarily in running based physical activities. Researchers and clinicians should strive to evaluate a variety of fundamental movement patterns and identify movements that are essential for current and future physical activity needs. Tailoring movement interventions to an individual’s future needs, values, and goals may be more beneficial to increase physical activity engagement instead of focusing solely on current sport-specific demands. For example, fundamental skills of throwing and kicking may be less relevant to young adults that choose to engage in weightlifting, while balancing may be of particular importance to an individual that chooses to engage in yoga or Pilates. However, this assumption cannot be determined from the current study as the researchers did not quantify the types of activities participants engaged in. Additionally, clinicians and researchers must consider the effect of age and time since surgery when planning movement interventions as these factors were negatively associated with MVPA in our sample. Previous research has demonstrated that increasing age and time since surgery are associated with lower return to sport and physical activity participation in individuals with a history of ACLR. Thus, individuals may need additional supports when promoting movement quality and physical activity participation as they age and as time since ACLR increases.

Motivation, confidence, and knowledge did not significantly predict physical activity participation in our sample of young adults. Despite this, previous research
suggests that these variables positively influence physical activity participation in a variety of populations. According to Self-Determination Theory, human motivation exists along a continuum. In brief, amotivation represents a complete lack of motivation; external, introjected, identified, and integrated regulations represent various forms of externally derived motivation; while intrinsic regulation represents fully internalized motivation. Individuals motivated by external regulations are often motivated by rewards or punishments; introjected regulations are often motivated by self-worth or guilt; identified regulations are often motivated by goals related to the activity; integrated regulations are often motivated by feelings of self-identity with the activity (“it’s a part of who I am”); while intrinsic regulations are motivated by pure enjoyment or love of the activity. In the present study, intrinsic and integrated motivation demonstrated weak, positive associations with MVPA. Significant associations between intrinsic and integrated motivation and self-reported physical activity have also been observed in previous college athletes. Based on these results, it is likely that individuals who participate in more physical activity chose activities that they identify with and/or enjoy. Thus, identifying activity preferences of patients may aid researchers, clinicians, and public health experts in physical activity promotion efforts.

Confidence for exercise was not related to MVPA in our sample of young adults with a history of ACLR. Literature identifies that increased confidence/self-efficacy positively influences physical activity participation across a lifespan. Further, ACLR evidence demonstrates that knee self-efficacy impacts return to sport and physical activity. Specifically, individuals that express greater confidence in their knee report greater rehabilitation success, higher return to sport rates, and long-term physical activity
engagement. We believe our lack of findings may be due to the high confidence and physical activity levels observed in our sample. Our sample reported median K-SES and SEE scores of 8.70 and 66.5 respectively while averaging approximately 38 minutes/day of MVPA. The observed ceiling effects in confidence scores may limit the ability to draw conclusions regarding the role of confidence in physical activity participation in our sample. However, it may be logical to infer that higher confidence scores may have contributed to the higher observed physical activity behaviors of the group.

Finally, knowledge toward physical activity was not predictive of MVPA in our sample. Previous research has demonstrated that adults have a basic understanding of the importance of engaging in physical activity, but the majority of adults cannot correctly identify physical activity guidelines or health conditions that are associated and/or exacerbated by inadequate physical activity. This is consistent with evidence that suggests that knowledge is necessary but often not sufficient to translate into behavior change. However, Heinrich et al. revealed that positive outcome expectancy (i.e. the perception of value of the result of a behavior) is positively correlated to self-reported physical activity. Similar results were obtained by Fredricksson et al. who revealed that individuals that possessed greater knowledge regarding the risks of physical inactivity spend more time engaging in physical activity. This suggests that outcome expectancies, both positive and negative, may be more meaningful to encourage physical activity than knowledge alone. Utilizing a theoretical framework, like the Health Belief Model, could uncover variables that influence the formation of outcome expectancies such as perceived severity, susceptibility, benefits, and barriers.
4.4.1 Limitations

This study is not without limitations. First, the research team did not access medical records and all information relating to ACL injury and ACLR were self-reported by the participants. While participants were encouraged to be truthful in the completion of the demographic forms and PROs, our sample was a mean 5 years post-ACLR. It is possible that the information obtained may be subject to recall bias. Second, no measure of physical literacy has been designed for adult populations therefore the research team identified a series of functional assessments and PROs to simulate individual components. However, these methods have not been validated and may not adequately assess all facets of motivation, confidence, physical competence and/or knowledge in young adults. Finally, despite the target population of young adults between ages 18-40, most participants included in our sample were university students with a mean age of approximately 23 years. University students may have greater access to recreation centers, walkable campus, wellness learning opportunities, etc. compared to the general population which may have contributed to the physical activity participation observed in our sample. Additionally, despite efforts to recruit a diverse sample population, the high levels of MVPA observed in this study suggests that self-selection bias may have occurred. Thus, the results of this study are likely not generalizable to all young adults with a history of ACLR.

4.4.2 Future Research

Future research should continue to explore the role of physical literacy and physical activity participation in young adult populations. Specifically, assessing physical literacy in the acute phases of musculoskeletal injury could help researchers and clinicians further elucidate its role on physical activity participation. Additionally, examining exercise-
identity, outcome expectancies, and activity preferences could uncover facets of motivation, confidence, and knowledge that were not investigated in the present study. Qualitative evidence may further elucidate the role of physical literacy, and its individual components, beyond what the PROs selected in this study have provided. Finally, future research should identify differences between individuals that reach physical activity guidelines and individuals that do not. Investigating these differences may provide crucial information to aid in the development of rehabilitation programs that promote long-term MVPA participation.

4.5 Conclusion

Aspects of motivation and physical competence were associated with physical activity in young adults with a history of ACLR, but the PLAYbasic run was the only predictor variable to predict MVPA. This suggests that physical competence should be utilized to improve physical activity participation after ACLR. Future research should continue to explore the role of physical literacy in physical activity participation. Qualitative evidence may provide additional context on motivation, confidence, physical competence, and knowledge to aid in the development of measurement tools designed for young adults.

Acknowledgements

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Statistics Laboratory and the Center for Clinical and Translational Research Grant (NIH CTSA UL1TR001998).
Table 4.1. Participant demographics

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Mean ± Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.80 ± 4.18</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.33 ± 10.10</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>71.72 ± 13.47</td>
</tr>
<tr>
<td>BMI</td>
<td>24.91 ± 3.58</td>
</tr>
<tr>
<td>Time Since Surgery (years)</td>
<td>5.29 ± 2.01</td>
</tr>
<tr>
<td>Average daily MVPA</td>
<td>38.39 ± 16.92</td>
</tr>
<tr>
<td>Average daily steps</td>
<td>7123 ± 2144</td>
</tr>
<tr>
<td>KOOS-Symptoms</td>
<td>80.95 ± 14.25</td>
</tr>
<tr>
<td>KOOS-Pain</td>
<td>91.67 ± 6.83</td>
</tr>
<tr>
<td>KOOS-ADL</td>
<td>97.55 ± 4.63</td>
</tr>
<tr>
<td>KOOS-Sport</td>
<td>84.56 ± 14.30</td>
</tr>
<tr>
<td>KOOS-QOL</td>
<td>76.94 ± 16.36</td>
</tr>
<tr>
<td>Sex (female)</td>
<td>32 (71.7%)</td>
</tr>
<tr>
<td>Ethnicity (Non-Hispanic White)</td>
<td>42 (93.3%)</td>
</tr>
<tr>
<td>Unilateral ACLR</td>
<td>36 (80.0%)</td>
</tr>
<tr>
<td>Concomitant meniscal injury</td>
<td>27 (60.0%)</td>
</tr>
</tbody>
</table>
Table 4.2. Summary scores for PRO and functional variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Median</th>
<th>Interquartile Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSES-Total</td>
<td>8.73</td>
<td>1.18</td>
</tr>
<tr>
<td>SEE</td>
<td>67.00</td>
<td>23</td>
</tr>
<tr>
<td>BREQ-3 Amotivation</td>
<td>.00</td>
<td>0.00</td>
</tr>
<tr>
<td>BREQ-3 External</td>
<td>.75</td>
<td>1.00</td>
</tr>
<tr>
<td>BREQ-3 Introjected</td>
<td>2.25</td>
<td>1.25</td>
</tr>
<tr>
<td>BREQ-3 Identified</td>
<td>3.50</td>
<td>1.00</td>
</tr>
<tr>
<td>BREQ-3 Integrated</td>
<td>2.50</td>
<td>1.63</td>
</tr>
<tr>
<td>BREQ-3 Intrinsic</td>
<td>3.25</td>
<td>0.88</td>
</tr>
<tr>
<td>PLAYself Physical Literacy Self-description</td>
<td>902.0</td>
<td>233</td>
</tr>
<tr>
<td>Knowledge (Level 2)</td>
<td>12.00</td>
<td>6</td>
</tr>
<tr>
<td>SLH</td>
<td>96.15</td>
<td>9.82</td>
</tr>
<tr>
<td>TH</td>
<td>98.65</td>
<td>7.54</td>
</tr>
<tr>
<td>COH</td>
<td>102.50</td>
<td>8.77</td>
</tr>
<tr>
<td>LESS</td>
<td>4.00</td>
<td>3.0</td>
</tr>
<tr>
<td>PLAYbasic run</td>
<td>60.00</td>
<td>16</td>
</tr>
<tr>
<td>PLAYbasic hop</td>
<td>56.00</td>
<td>13</td>
</tr>
<tr>
<td>PLAYbasic throw</td>
<td>52.00</td>
<td>8.5</td>
</tr>
<tr>
<td>PLAYbasic kick</td>
<td>58.00</td>
<td>22</td>
</tr>
<tr>
<td>PLAYbasic balance</td>
<td>59.00</td>
<td>13</td>
</tr>
<tr>
<td>PLAYbasic Total</td>
<td>57.20</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Abbreviations: BREQ-3: Behavioral Regulation for Exercise Questionnaire-3; COH: Cross-over Hop; K-SES: Knee Self-Efficacy Scale; LESS: Landing Error Scoring System; SEE: Self-Efficacy for Exercise Scale; SLH: Single-leg Hop; TH: Triple Hop
Table 4.3 Spearman correlations of objective physical activity and predictor variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Daily MVPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSES-Total</td>
<td>-.046</td>
</tr>
<tr>
<td>SEE</td>
<td>.149</td>
</tr>
<tr>
<td>BREQ-3 Amotivation</td>
<td>.005</td>
</tr>
<tr>
<td>BREQ-3 External</td>
<td>.147</td>
</tr>
<tr>
<td>BREQ-3 Introjected</td>
<td>-.091</td>
</tr>
<tr>
<td>BREQ-3 Identified</td>
<td>.055</td>
</tr>
<tr>
<td>BREQ-3 Integrated</td>
<td>.206</td>
</tr>
<tr>
<td>BREQ-3 Intrinsic</td>
<td>.245</td>
</tr>
<tr>
<td>PLAYself Physical Literacy Self-description</td>
<td>.131</td>
</tr>
<tr>
<td>Knowledge (Level 2)</td>
<td>-.070</td>
</tr>
<tr>
<td>Knowledge (Level 3a)</td>
<td>.037</td>
</tr>
<tr>
<td>SLH</td>
<td>-.160</td>
</tr>
<tr>
<td>TH</td>
<td>-.083</td>
</tr>
<tr>
<td>COH</td>
<td>-.073</td>
</tr>
<tr>
<td>LESS</td>
<td>-.361*</td>
</tr>
<tr>
<td>PLAYbasic run</td>
<td>.437**</td>
</tr>
<tr>
<td>PLAYbasic hop</td>
<td>.269</td>
</tr>
<tr>
<td>PLAYbasic throw</td>
<td>.038</td>
</tr>
<tr>
<td>PLAYbasic kick</td>
<td>-.079</td>
</tr>
<tr>
<td>PLAYbasic balance</td>
<td>-.015</td>
</tr>
<tr>
<td>PLAYbasic Total</td>
<td>.139</td>
</tr>
</tbody>
</table>

*Significant at p>0.05
** Significant at p>0.01
Table 4.4. Variables identified as significant predictors for MVPA

<table>
<thead>
<tr>
<th>Model</th>
<th>Independent variables</th>
<th>$\beta$</th>
<th>$R^2$</th>
<th>Adjusted $R^2$</th>
<th>Constant</th>
<th>$F$</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PLAY basic run</td>
<td>.393</td>
<td>.154</td>
<td>.135</td>
<td>1.493</td>
<td>7.844</td>
<td>.008</td>
</tr>
</tbody>
</table>
Figure 4.1. Physical literacy components

Confidence
• Self-Efficacy for Exercise Scale
• Knee Self-Efficacy Scale

Motivation
• Behavioral Regulation for Exercise Questionnaire-3

Physical Competence
• Landing Error Scoring System
• Hop series testing
• PLAYbasic

Knowledge & Understanding
• Physical activity knowledge questionnaire
Figure 4.2. Flowchart describing participant recruitment

n=78
Screened for inclusion

n=47
Participants consented and completed survey

n=31
Did not meet inclusion criteria or declined participation

n=45
Participants completed data and were included in quantitative analysis

n=2
Lost to follow-up (1), Invalid accelerometer data (1)
CHAPTER 5. THE RELATIONSHIP BETWEEN PHYSICAL LITERACY AND PHYSICAL ACTIVITY IN YOUNG ADULTS WITH A HISTORY OF ACLR: A MIXED-METHODS STUDY

5.1 Introduction

Anterior cruciate ligament injuries are a common musculoskeletal injury in young, active individuals with approximately 250,000 injuries occurring annually.\(^5\) The impetus of anterior cruciate ligament reconstruction (ACLR) is to restore knee joint stability and function to allow patients to return to pre-injury levels of sport and physical activity.\(^{13,18}\) Despite these goals, approximately 50% of patients do not return to competitive levels of sport and many patients fail to meet recommended levels of physical activity.\(^{20,25,33,36,62}\) Specifically, individuals with a history of ACLR participate in less moderate-to-vigorous physical activity (MVPA) and take fewer daily steps compared to healthy counterparts.\(^{7,36,140,147}\) Due to the known benefits associated with physical activity participation and the consequences of physical inactivity,\(^{29,30,195,196}\) investigations into factors that influence physical activity participation in this population have proliferated. Previous studies have identified several physical and psychological factors, such as pain, decreased knee function, fear of reinjury, and decreased self-efficacy,\(^{15,20,23,273,274}\) that limit an individual’s ability to return to sport and/or engage in physical activity after ACLR. However, it is likely that there are additional factors that influence sport and physical activity participation in individuals with a history of ACLR.

Recently, the concept of physical literacy has garnered significant attention in emerging literature.\(^{46,275}\) Physical literacy is the “motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life”,\(^45\) and it is suggested to be a critical component for lifelong
physical activity engagement. Physical literacy has demonstrated significant relationships with physical activity participation and several predictors of health such as body composition, cardiorespiratory fitness, and health-related quality of life in youth and adolescent populations, while interventions have been shown to improve composite physical literacy scores in university students and inactive adults. While results from these studies are promising, existing literature has focused on healthy populations, thus limiting the ability to draw conclusions in persons with a history of musculoskeletal injury. A recent study identified physical literacy as a factor that correlates with physical activity engagement in individuals with a history of ACLR; however, the study utilized methods that have not been validated for an adult population.

While there is a dearth of explicit physical literacy evidence following musculoskeletal injury in adults, individual components of physical literacy are evident in post-ACLR literature. Quantitative evidence has demonstrated relationships between motivation, confidence, and/or movement quality and reinjury rates, return to sport, physical activity participation, and health-related quality of life. Qualitative evidence revealed that motivation, confidence, and knowledge are key factors that influence rehabilitation success, return to sport, and physical activity participation. For example, individuals that returned to sport and physical activity participation described themselves as highly self-motivated while individuals lacking motivation expressed decreased desires to attend and complete rehabilitation sessions. Additionally, increased levels of confidence served as a facilitator for returning to sport and physical activity participation, while a lack of confidence deterred patients from engaging in sport and physical activities. The results from these studies suggest
that individual components of physical literacy impact various aspects of life post-ACLR and warrant further investigation.

It is critical to examine if physical literacy operates as a holistic concept in an adult population and to identify if individual aspects of physical literacy can lead to increased physical activity participation and improved physical and psychological outcomes after ACLR. Identifying individuals that participate in high and low amounts of physical activity could help clinicians understand which factors are most salient in this population to improve practices and treatments post-ACLR. However, physical literacy measurement tools designed for an adult population are lacking, and the tools that exist have limited ability to capture individual adult experiences and expectations for physical activity. A qualitative investigation could enhance the understanding of physical literacy in an adult musculoskeletal injury population, which may offer new insights and opportunities to provide patient-centered care to improve outcomes following ACLR. Therefore, the purpose of this study was to identify individuals participating in greater than expected (over performers) and less than expected (under performers) amounts of physical activity and to gain an understanding of how physical literacy influences physical activity participation in young adults with a history of ACLR.

5.2 Methods

5.2.1 Design

A cross-sectional mixed-methods design was utilized to 1) identify over performers and under performers of physical activity and 2) examine the perceptions and experiences of physical activity and physical literacy in individuals with a history of ACLR. Positive
deviance is a framework used to identify individuals who perform above expected and/or group norms and learn from their behaviors, while negative deviance utilizes individuals who perform under expected and/or group norms. Ethical approval for this study was obtained by the University of Kentucky Institutional Review Board prior to study recruitment.

5.2.2 Participants

Forty-five participants with a history of ACLR were recruited from a large, research-intensive university and the surrounding community. Participants were eligible to be included in the study if they had a history of unilateral or bilateral ACLR within the last 10 years, had been cleared for physical activity by a physician, and were between the ages of 18-40 years. Participants were excluded if they were <1-year post-operative from their most recent ACLR, reported concomitant ligament reconstruction at the time of ACLR, reported lower extremity injury within the last six weeks, reported a concussion in the last 3 months, or had been diagnosed with any condition that affected their normal activity patterns. Participants were also excluded if they could not read and speak English.

5.2.3 Procedures and Credibility

Once participants reviewed and signed the informed consent document, they were provided an accelerometer (ACTi Graph Link) and completed one-week of objective physical activity observation. Participants were instructed to position the device over the right anterior superior iliac spine first thing in the morning, to always wear the device unless bathing, swimming, or sleeping, and to follow their normal routine during the observation period. Average daily minutes of MVPA were used to identify over and under performers. Over performers were defined as individuals engaging in the most MVPA (top
10% of the sample, n=5), while under performers were defined as individuals engaging in the least MVPA (bottom 10% of the sample n=5). Once the over and under performers were identified, individuals were invited to participate in a one-on-one semi-structured qualitative interview conducted by the first author (RRK).

Prior to study recruitment, two pilot interviews were conducted to refine the interview protocol and methodology. The Consolidated Criteria for Reporting Qualitative research (COREQ) checklist was used to design the interview protocol and guide the reporting of the qualitative methods and results. Prior to data collection, participants were provided with a brief introduction of the study purposes and definitions of key words/phrases related to physical literacy that were utilized throughout the interview. A standard interview protocol (Appendix A) served as a tentative framework and covered three broad areas: physical activity before ACLR, ACLR rehabilitation/recovery, physical activity after ACLR. Participants were asked open-ended questions about physical activity and components of physical literacy (e.g., confidence, motivation, physical competence, and knowledge and understanding). While the interview protocol was designed to guide the data collection process, the semi-structured interviews were participant driven, meaning that participants were given the opportunity to contribute additional information and/or explore additional topic areas as they saw fit. Interviews took place in a laboratory setting and each interview was audio recorded. Field notes were kept during and after each interview to capture non-verbal cues. After the interviews, two authors (RRK, AGD) transcribed interview audio files verbatim and reviewed the transcriptions against the original audio file to ensure accuracy. Participant interviews occurred between March 2022 and April 2022 and ranged from 28 to 56 minutes.
Prior to data collection, the first author (RRK) engaged in bracketing and reflexive journaling to set aside preconceived notions about the research questions. The primary author identified that her knowledge of the subject matter and her personal experience with ACLR could influence the interpretation of data. Therefore, researcher triangulation was utilized to ensure researcher bias did not impact data analysis and study results. Credibility and trustworthiness were further established through the use of ongoing reflexive journaling, prolonged engagement with the data, frequent research team meetings, and maintenance of a detailed audit trail.281

Data analysis followed the methods outlined by Strauss and Corbin282 in which three phases of constant comparison coding (open, axial, and selective coding) were employed. Two authors (RRK, JT) performed two rounds of line-by-line coding to develop higher-order themes and sub-themes. The first round was used to identify patterns in the data and develop higher-order themes. During the first round of coding, one author (JT) was blinded to group allocation to further establish credibility. The second round of coding was used to confirm the higher-order themes and identify sub-themes. After the second round of coding, the high-order themes and sub-themes were cross-referenced with the original transcriptions to ensure that the codes/themes accurately represented the perceptions and experiences of the participants. Next, the higher-order themes and sub-themes were discussed amongst the entire research team. Finally, excerpts that illustrated themes were selected and reported. All qualitative analysis decisions were made through discussion until consensus was reached.
5.2.4 Quantitative Data Analysis

Raw physical activity data was extracted from the accelerometers and analyzed using ACTi Life software. Freedson Adult VM3 cut points were used to categorize physical activity intensity as light, moderate, vigorous, or very vigorous.\textsuperscript{261} Average MVPA (minutes/day) were utilized to identify the over and under performers. SPSS software (v23.0, SPSS, Inc., Chicago, IL, USA) was used to calculate descriptive statistics for participant demographics and physical activity and independent t-tests to assess differences in participant demographics and physical activity between over and under performers.

5.3 Results

Five over performers and five under performers were identified from the larger sample. One under performer was lost to follow up, so the next available participant was interviewed. All participants were students in academic programs. However, under performers were significantly older and had greater time since surgery (Table 5.1). Additional participant demographics are available in Table 5.1.

Over and under performers described several similarities and differences that influence physical activity participation. Four higher-order themes and 12 sub-themes were identified from the semi-structured interviews (Table 5.2). In general, participants described the roles of motivation, confidence, and knowledge for physical activity participation after ACLR. Specifically, participants discussed barriers and facilitators to physical activity participation, how knowledge impacts recovery and physical activity after surgery, and the importance of establishing a routine for physical activity.
Theme 1: Barriers to Physical Activity

Over and under performers described similar barriers to current physical activity participation. The most common barriers to physical activity participation amongst all participants included school responsibilities and negative emotions related to exercise (e.g., judgement, guilt). Participants described how these perceived barriers negatively impacted confidence and motivation for physical activity. Specifically, several participants noted that increased responsibilities for school (e.g., homework, studying, clinical rotations) limited the time and energy available to engage in physical activity. As one under performer noted, “I’m very passionate about physical activity. If I wasn’t a student and having to study so much, I would definitely be more active now too” (under performer).

Several participants also described how negative emotions, such as guilt and fear of judgement from others, led to decreased confidence in exercise-related environments and decreased motivation for physical activity. One participant stated, “I think this is a very common answer, but the gym really shoots it [motivation] down because you got people like they, like you’re looking, like you got people there that clearly have been going every day for the last 10 years, and you’re like ‘I look nothing like that. I have no idea what I’m doing’” (under performer). Additionally, many female participants described how negative emotions were further exacerbated in the presence of the opposite sex. One participant said, “When the gym is really busy, it’s easy to feel a little unconfident taking up the space that you need to do what you want to do because there’s just a lot of people. Especially because there’s like large, strong men, like they’re kind of scary sometimes” (over performer). These comments were echoed by other participant stating, “I feel like there’s this gym culture outside of the military where guys at the gym are there to work out, but also like
may see a female, especially a small female, and they want to come over and teach her how to do stuff, or hit on her, or make her uncomfortable” (under performer). Finally, a few participants described how self-judgement also negatively impacted confidence and motivation for physical activity. One participant said, “I take a lot of pride in myself and then sometimes I feel like if I’m not as active as I was, then I just, it’s just kind of like you’re your biggest enemy, so I feel like I’m looking at myself in a negative way” (over performer).

While many similarities between over and under performers were observed, under performers described decreased accessibility and limited resources as an additional barrier to physical activity. They described how limited access to facilities and/or desired activities decreased motivations to engage in physical activity. Specifically, one under performer said, “I don’t have a gym membership. I have a gym in my apartment building, and it’s really small and most of the machines don’t necessarily work, and half the time there’s some big bulky men in there, so I think those are probably some areas where I just get nervous going to the gym and then maybe couldn’t do everything that I wanted to do” (under performers).

Theme 2: Facilitators to Physical Activity

Over and under performers also described similar facilitators to physical activity including enjoyment for physical activity, positive social influences, satisfaction in physical abilities, and physical and mental health benefits. Participants noted that these factors often reinforced motivation and increased confidence for physical activity.
Nearly every participant described how enjoyment for physical activity was a key facilitator for engaging in physical activity. Specifically, participants noted that they were more motivated to exercise when they identified and participated in activities they genuinely enjoyed. One participant stated, “It’s [weightlifting] something I crave. It’s something that I really look forward to going to the gym and pushing myself with weights and going out and getting walks in” (over performer). Additionally, under performers noted that finding activities they enjoyed would likely help them increase their physical activity in the future. For example, one under performer described excitement for joining a recreational league in the future by saying, “I haven’t played soccer since high school, so I’m really excited to do something that I used to really enjoy and hopefully will still enjoy” (under performer).

Participants also reported a wide range of positive social influences that helped facilitate physical activity participation. While support from family and friends were commonly reported, participants also identified positive social influences from pets, fitness instructors, and even other exercisers unknown to the participant. Participants described how social influences serve as positive role models for exercise, accountability partners, and extrinsic motivators. One participant stated, “Definitely the organizational part of [an exercise/fitness focused campus group], and with that is a big social component because you’re with a lot of girls who prioritize the same things, being active, enjoying exercise, um, it encourages me” (over performer). These statements were echoed by another participant who said, “I think it’s great to have either a role model or someone who you can be a role model for, just so you can push each other and find growth in different ways,
either emotionally or physically or just in general. I think that helps a lot” (under performer).

Satisfaction in physical abilities was a facilitator that related to confidence and motivation for physical activity for many participants. Specifically, numerous participants revealed that seeing progress, challenging themselves, and/or achieving goals increased their confidence which further reinforced their motivation to participate in physical activity. One participant stated, “I want to push my limits. I want to see how strong I can get with certain exercises, how much weight I can pull. For me, it’s almost like I want that challenge for myself. I want to push myself. I want to grow” (over performer). Interestingly, several participants reflected on their ACLR experience when describing satisfaction with their current physical abilities. For example, one participant stated, “There’s something really enjoyable about knowing what your body is capable of and doing it. Especially after you had like an ACL injury, and you weren’t allowed to walk without crutches and do things like go on hikes. And then you go on a hike for the first time, it’s like ‘I did that. I can do this.” And it just, it makes you feel really empowered, I guess. It’s good for your confidence” (under performer).

Benefits to physical and mental health was another theme that was mentioned by every participant. Over and under performers described how these benefits were often a key motivator that facilitated physical activity participation. Specifically, most participants focused on mental health benefits such as feeling happier, feeling confident, and decreased stressed; however, physical health benefits such as feeling stronger and improved sleep were also commonly reported. One participant described physical and mental health benefits by stating, “I know that it’s more than just a physical component. I know that it
feels with anxiety and stress. I feel like it makes me sleep better. It impacts so many other things, so I think it’s important for overall well-being” (under performer). Interestingly, over and under performers often focused on the immediate effects on mental health, while physical health effects were often discussed as a long-term or futuristic benefit (e.g., “physical activity will make me healthier”).

Finally, many over performers described aspects of accessibility and resources that facilitated physical activity which contrasts with statement from the under performers. Specifically, these participants described how living in close proximity to gyms and/or recreation centers increased motivation to participate in physical activity, while one participant described satisfaction in the variety of resources and activities available at their local recreation center. The participant noted, “I definitely would say one [factor] is like being in a close proximity to the gym. That’s like also like very good, and like there’s plenty of things to do” (over performer).

Theme 3: Knowledge Influences Recovery and Physical Activity after Sport

Knowledge was identified as a factor that related to aspects of ACLR recovery, transitioning out of organized sport, and current physical activity, and these experiences were similar between over and under performers. In general, participants described an overall lack of knowledge regarding ACLR, and nearly every participant stated that they wished that had more knowledge about the surgery and recovery process. One participant stated, “I wish I would have known more about what, like what does it entail. Because for me, I was going in blind basically to my ACL rehab. It was more so just like ‘okay, I gotta get the reconstruction surgery’, and then I went to rehab, and I nothing, I had no…. I did not know what to expect at all. So that would be something I really wish I knew more
about” (over performer). Due to the perceived lack of knowledge, several participants described how their injury experiences influenced their career path and how they hope to educate future patients. One participant stated, “I will want to give the people the information that I didn’t have” (under performer). Another said, “I feel like I can empathize with my patients because I have been there. […] I think just kind of meeting them where they are and explaining to them that no two journeys look the same. Like, ‘I know your teammate had this kind of recovery, but that may not be the case for you, and that’s okay” (under performer).

Similarly, patients described that a lack of knowledge on how to transition out of sport contributed to decreased confidence for physical activity and negative perceptions of current physical activity engagement. One participant stated, “[the transition out of football] just wasn't really clear cut. It's like, I feel like I've always had everything kind of like cut-paste for me and then like when you’re transitioning out of sport, and out of high school, it's like ‘here's the world, go find it’. And it was just, it was just kind of that perspective kind of like scared, like decreased [my] confidence a little bit” (over performer). While discussing the transition out of organized sport participation, several over performers noted that their current physical activity levels were significantly decreased despite engaging in adequate amounts of physical activity. It appears that the perception of decreased physical activity negatively impacted physical activity participation after sport. One participant stated, “I wish that people had talked to me about physical activity not needing to be like a competition or high stress every time, like it can be something very small that you incorporate into your day. It doesn't have to be an hour long, intense practice every single day, it can be really small, just intentional movements.
And I think that that shift in my mindset allowed me to not just be quote-unquote guilty for not participating exercise because I realized that, like all the small things that I was doing, just setting aside a little time for myself was enough...it didn't have to be this big intense like regimented sort of structure. [...] I think that I would’ve incorporated a lot more [physical activity] freshman year. I think I was going through that transition during that time, and I just didn't know how to deal with the fact that I wasn't doing that competitive, long, daily intense exercise that was required for sports, so I think that I would have prioritized that sort of new mental, new outlook on physical activity earlier” (over performer).

Participants also described that knowledge of physical activity guidelines did not influence their current physical activity participation. In general, participants had adequate knowledge of how much physical activity is recommended to achieve health benefits, but they didn’t feel that these guidelines were particularly relevant in their own lives. One participant stated, “In the back of my mind, I know I should get moving a couple times a week, but I’m not mentally checking ‘oh, I’ve met 150 minutes; I met three days a week; I strength trained twice a week; cardio once a week; like I’m not really checking that. It's more just what [activity] I want, when I want” (over performer). Instead, a few participants described how knowledge of physical activity guidelines might be more helpful for individuals with health issues or concerns or individuals just starting their physical activity journey. In contrast, one participant described how knowledge of physical activity guidelines could decrease confidence for physical activity. The under performer stated, “If I let myself get bothered by the numbers, I feel like that would make me less confident,
and then [I’d] be like ‘okay, well what's the point if I'm not hitting it [the physical activity guidelines]?’. So, I try to just do what I can”.

**Theme 4: Establishing a Routine for Physical Activity**

While over and under performers described similarities in barriers and facilitators to physical activity and the role of knowledge, distinct differences were observed in the ability to integrate physical activity into their daily routine and lifestyle. Under performers described difficulties in incorporating physical activity as a part of their routine and lifestyle. This inability to create a routine for physical activity was often rooted in the barriers previously discussed. Several participants described how school and lifestyle responsibilities limited their ability to prioritize physical activity. For example, one participant said, “I know it's important. I will preach on and on about how important it is, although I am not the best role model, I guess. Just because, like I said I'm a student, our curriculum is very difficult, and it's just with our schedule not being set schedule every week, it's hard to you know, find a time. […] I knew the importance of it, I just never could get in a routine. So, it wasn't like I wasn't doing anything, it was just not at the top of my priority list” (under performer). Another participant added, “School takes up a lot of my time. So, right now I’m on rotations. I switch locations every four weeks. […] but it’s hard to have a routine right now with all of the uncertainty and change that happens” (under performer).

On the contrary, over performers discussed their ability to establish a routine and incorporate physical activity as a part of their lifestyle. The reasons for creating and maintaining a physical activity routine were highly individualized for over performers but often related to aforementioned facilitators. For example, several over performers
described how the facilitators of enjoyment and mental and health benefits encouraged them to create a physical activity routine. One participant said, “I think that this last year, I kind of developed my own physical activity habits, and I have a feeling that they're going to stay established in the way that they are, which is, you know, exercising what I want, when I can, for longevity health purposes and mental health purposes” (over performer). Additionally, a couple participants revealed that physical activity had become an integral part of their self-identity. One over performer stated, “It’s just part of who I am basically. It’s part of what I want for my daily lifestyle.”

5.4 Discussion

The purpose of this study was to examine perceptions of physical literacy and experiences with physical activity in individuals with a history of ACLR that participate in greater than and less than expected amounts of physical activity. Specifically, we sought to uncover factors related to physical literacy that may influence participation in physical activity after ACLR. Understanding physical literacy and physical activity from the patient perspective may provide important context needed to develop post-surgical return to sport and physical activity promotion interventions. We identified four higher-order themes relating to physical activity participation: 1) barriers to physical activity, 2) facilitators to physical activity, 3) knowledge influences recovery and physical activity after sport, and 4) establishing a routine for physical activity. Our findings suggest that a combination of barriers and facilitators to physical activity and aspects of knowledge shape one’s ability to establish a routine for physical activity participation (Figure 5.1). Additionally, the results of this study support the use of physical literacy as a holistic concept. Participants consistently described how motivation, confidence, and knowledge interact with and
influenced one another. For example, participants discussed how confidence and motivation are related, how knowledge and lack of knowledge can increase and decrease confidence respectively, and how satisfaction in physical abilities (e.g., physical competence) often reinforced confidence and motivation for physical activity.

The qualitative interviews uncovered numerous barriers and facilitators to physical activity participation that are consistent with previous literature. Specifically, facilitators such as social support and enjoyment, and barriers like lifestyle transitions and negative emotions have been identified in both individuals with and without history of ACLR. The experiences with barriers and facilitators were nearly identical between over and under performers except for perceived accessibility to resources. Over performers in our sample identified accessibility/availability of resources as a facilitator to physical activity, while under performers identified accessibility as a barrier. Investigations into social determinants of health have demonstrated that limited access to resources, including those built for physical activity, contribute to decreased levels of health. The perceptions of decreased availability of physical activity resources negatively impacted physical activity engagement in the under performers despite positive feelings and social supports for exercise. While social determinants of health were not explored in this study, further exploration into feelings of perceived accessibility for physical activity warrants future research in individuals with a history of ACLR. Overall, the lack of observed differences between over and under performers suggest that barriers and facilitators may not be the only key to promoting physical activity participation.

Similarities between over and under performers were also observed in experiences with knowledge of physical activity guidelines and knowledge related aspects of recovery.
and physical activity. While participants revealed that knowledge of physical activity guidelines did not influence current physical activity participation, aspects of knowledge were salient during ACLR recovery and transitioning out of sport. Nearly all participants described a lack of knowledge regarding surgical and recovery processes and how to successfully transition out of organized sport. Participants spend considerable time reflecting on the consequences of being unprepared for “normal” physical activity which often resulted in temporary cessation of all physical activity. Reifsteck & Brooks revealed that student-athletes are often accustomed to structured exercise regimens and the support from various coaches who are responsible for programming such workouts.\textsuperscript{285} However, many individuals struggle to maintain regular physical activity once these supports are no longer available.\textsuperscript{285} Further, it has been documented that former athletes experience greater difficulties and may experience limitations in physical activity and activities of daily living compared to non-athletes, potentially due to history of musculoskeletal injuries.\textsuperscript{230} While our participants did not report physical limitations, they did discuss how sport participation caused them to negatively view their physical activity after sport and/or current physical activity. Several over and under performers expressed that they currently participate in less physical activity compared to their organized sport days, and a couple over performers revealed that this caused them to question if they were “doing enough”. This suggests that individuals may have unrealistic expectations for exercise after sport and may need to undergo a psychological shift in priorities when adjusting to physical activity outside of sport.\textsuperscript{286}

The final theme derived from our qualitative interview was the ability of participants to establish a routine for physical activity. Distinct differences were observed between over
and under performers. Simply put, over performers were able to establish a routine for physical activity, while under performers were not. While the exact mechanisms for establishing a routine for physical activity remain unclear, it appears that our over performers were able to shift their mindset away from sport and identify new forms of physical activity that were enjoyable and meaningful to them. Over performers also described how these strategies helped them overcome barriers to continue to prioritize physical activity. However, over performers revealed that this process took time and did not happen immediately upon their transition out of sport. Additionally, several over performers posited that increased knowledge on how to successfully transition out of sport would have helped them develop their physical activity routine more quickly. Interestingly, one over performer credited her ability to establish a routine to her physical therapist who used ACLR rehabilitation session to change her mindset about exercise and to prepare her for physical therapy outside of sport. Similarly, previous evidence has supported the use of transition from sport intervention programs to aid in the promotion lifelong physical activity.\textsuperscript{230,285,287} One program, the Moving On! program, sought to introduce former athletes to various types of activities while connecting with peers in a fun environment.\textsuperscript{285} An overarching goal of the program was to reframe what physical activity looks like outside of competition-based activities to promote lifelong activity engagement.\textsuperscript{285} The intervention pilot demonstrated positive results and acceptance amongst participants\textsuperscript{287} suggesting that similar programs may help individuals with a history of ACLR successfully establish routines for physical activity. Thus, future research should investigate the utility of transition programs specifically designed for individuals with a history of ACLR as they may need different supports compared to other populations.
5.4.1 Limitations

The results of this study should be interpreted with the following limitations in mind. Firstly, participants were purposely sampled from a larger cross-sectional study examining the relationship between physical literacy and physical activity. While our study identified individuals participating in high and low levels of physical activity, self-selection bias may be present in our sample to include individuals with positive attitudes toward physical activity. Additionally, our participants were mean 3 and 6 years post-ACLR, meaning that their thoughts and feelings relating to their ACLR surgery/recovery and transition out of sport may have been subject to recall bias. Finally, our sample included university undergraduate and graduate students which may not be representative of all patients after ACLR. Due to their connection with university resources, our participants might experience unique barriers and facilitators to physical activity that differ from the general population. Additionally, nine of our ten participants were female which limits the generalizability of our results to males with a history ACLR.

5.5 Conclusion

Despite participating in significantly different levels of physical activity, over and under performers described similar barriers and facilitators for physical activity and experiences with knowledge relating to surgery, recovery, transition of sport, and physical activity guidelines. Additionally, participants described how physical literacy components of motivation, confidence, and knowledge influence one another. However, distinct differences in the ability to establish a routine for physical activity were observed. The ability to establish routines seemed to be a function of barriers, facilitators, and aspects of knowledge. Our data highlight the importance of educating patients throughout the surgery
and rehabilitation process and supporting patients as they transition out of organized sport and into lifelong physical activity engagement.

Acknowledgement

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Table 5.1. Participants demographics

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Positive deviants</th>
<th>Negative deviants</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (female, male)</td>
<td>4, 1</td>
<td>5, 0</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>19.20 ± .84</td>
<td>24.80 ± 4.82</td>
<td>.03*</td>
</tr>
<tr>
<td>BMI</td>
<td>25.90 ± 3.85</td>
<td>23.86 ± 2.63</td>
<td>.36</td>
</tr>
<tr>
<td>Time Since Surgery (years)</td>
<td>3.40 ± 1.14</td>
<td>6.20 ± 2.49</td>
<td>.05*</td>
</tr>
<tr>
<td>Average daily MVPA</td>
<td>70.97 ± 10.03</td>
<td>14.38 ± 4.11</td>
<td>&lt;.001**</td>
</tr>
<tr>
<td>Average daily steps</td>
<td>10525 ± 500</td>
<td>4503 ± 358</td>
<td>&lt;.001**</td>
</tr>
</tbody>
</table>

*Significant at p>0.05
** Significant at p>0.01
Table 5.2. Higher-order themes and subthemes

<table>
<thead>
<tr>
<th>Barriers to physical activity</th>
<th>Facilitators to physical activity</th>
<th>Knowledge influences recovery and physical activity after sport</th>
<th>Establishing a routine for physical activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>School responsibilities</td>
<td>Enjoyment for activity</td>
<td>ACLR recovery</td>
<td>Difficulties in establishing a physical activity routine*</td>
</tr>
<tr>
<td>Negative emotions</td>
<td>Positive social influences</td>
<td>Transitioning out of organized sport</td>
<td>Ability to establish a physical activity*</td>
</tr>
<tr>
<td>Accessibility to resources*</td>
<td>Satisfaction in physical abilities</td>
<td>Current physical activity</td>
<td></td>
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<tr>
<td></td>
<td>Physical and mental health benefits</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accessibility to resources*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Differences observed in experiences between over and under performers
Figure 5.1. A conceptual model of the interactions between higher-order themes.

Establishing a Routine
6.1 Purposes, Aims, and Hypothesis

The purposes of this dissertation were to examine theoretical models and constructs relevant to physical activity participation; to examine personal and social correlates of self-reported physical activity in individuals with a history of ACLR; to examine the relationship between physical literacy and physical activity in individuals with a history of ACLR; and to explore perceptions of physical literacy and experiences with physical activity. This dissertation and the included studies were designed to address the following aims and hypothesis:

1. To identify personal and social factors that were predictive of self-reported physical activity in individuals with a history of ACLR.

   Hypothesis: A combination of physical literacy, health literacy, social support and knee function would explain a significant amount of variance associated with self-reported physical activity participation.

2. To determine if components of physical literacy were predictive of objectively measured physical activity in individuals with a history of ACLR.

   Hypothesis: A combination of confidence, motivation, physical competence, and knowledge would explain a significant amount of variance associated with objectively measured physical activity.

3. To identify individuals that participate in greater than expected and less than expected amounts of physical activity and to gain an understanding of how physical activity is associated with physical literacy and health literacy.
literacy influences physical activity participation in young adults with a history of ACLR.

6.2 Summary of Findings

The summary of findings for each specific aim are presented below. The findings include:

1. To identify personal and social factors that were predictive of self-reported physical activity in individuals with a history of ACLR.

   Findings: Our hypothesis was unsupported as aspects of knee function and physical literacy were associated with self-reported MVPA, but only the PLAYself Physical Literacy Self-description subsection explained a significant amount of variance associated with self-reported MVPA. Specifically, the PLAYself Physical Literacy Self-description explained 12.2% of the variance observed in physical activity levels.

2. To determine if components of physical literacy were predictive of objectively measured physical activity in individuals with a history of ACLR.

   Findings: Our hypothesis was unsupported as aspects of motivation and physical competence were associated with MVPA, but only the PLAYbasic run task explained a significant amount of variance (R²=13.5%) in objectively measured MVPA. After controlling for age and time since surgery, the PLAYbasic run remained a significant predictor of MVPA, while these variables in combination explained 27.2% of the variance observed in MVPA.
3. To identify individuals that participate in greater than expected and less than expected amounts of physical activity and to gain an understanding of how physical literacy influences physical activity participation in young adults with a history of ACLR.

Findings: Five individuals participating in greater than expected amounts of MVPA and five individuals participating in less than expected amounts of MVPA were identified. Four higher-order themes were identified in which participants discussed 1) barriers to physical activity participation, 2) facilitators to physical activity participation, 3) how knowledge impacts recovery and physical activity after surgery, and 4) the importance of establishing a routine for physical activity. Within these higher-order themes, participants described the roles of motivation, confidence, and knowledge for physical activity participation after ACLR.

6.3 Synthesis of Results and Future Research Implication

In combination, our studies demonstrate that physical literacy may be a salient factor that should be addressed to promote physical activity after ACLR. Our quantitative findings revealed that individual components of physical literacy explain 12.2% and 13.5% of the variance associated with self-reported and objectively measured MVPA respectively. Specifically, our quantitative results demonstrated that aspects of confidence, motivation, and physical competence related to MVPA in participants that were 1-10 years post-ACLR. Our qualitative findings uncovered factors that influenced physical activity from the participant perspective. Individuals that participated in greater than and less than expected amounts of physical activity described similar facilitators and barriers for
physical activity and perceptions of knowledge after ACLR. However, distinct differences were noted in perceptions of accessibility to resources and the ability to establish a routine for physical activity between high activity and low activity groups. Thus, our qualitative findings suggest that a combination of barriers and facilitators to physical activity and aspects of knowledge shape one’s ability to establish a routine for physical activity after ACLR.

Future research should continue to explore the role of physical literacy and physical activity after ACLR and examine factors that contribute to motivation and confidence for physical activity. While factors like motivation, confidence, knowledge, and social support have been shown to positively correlated to physical activity participation in a variety of populations, the results of this dissertation were conflicting. Our qualitative evidence demonstrated that motivation and confidence helped facilitate physical activity participation, but our quantitative evidence did not identify these factors as a predictive factor for MVPA. Additionally, our qualitative study identified social influence/support and knowledge about ACLR and transitioning from organized sport as factors that relate to motivation and confidence which differed from our quantitative results. This demonstrates that currently validated patient reported outcome measures and surveys that assess these factors may not be valid for this patient population. Thus, future research should utilize a combination of quantitative and qualitative methods to identify factors (e.g., motivation, confidence, etc.) that may positively or negatively impact physical activity for people with a history of ACLR that are relevant to this patient population.

Additionally, future research should consider the relationship between physical activity and social determinants of health (SDoH). While not a focus of this dissertation,
our qualitative study identified aspects of SDoH that serve as facilitators and barriers to physical activity in individuals with a history of ACLR. SDoH are the complex conditions in which people are born, grow, live, work, and age and they influence an individual’s ability to make lifestyle choices and maintain healthy behaviors that promote (or do not promote) improvements in health status and overall well-being. While a direct link between musculoskeletal injury outcomes and SDoH has yet to be established, sports medicine professionals, such as athletic trainers, are encouraged to recognize SDoH within their settings and utilize strategies to account for and improve SDoH within their patient populations. Examining SDoH in post-ACLR care will allow healthcare professionals to care plans for patients in a holistic manner and may improve physical activity participation and long-term health outcomes.

6.4 Conclusion

This dissertation examined the relationship between physical literacy and physical activity in individuals with a history of ACLR. Previous research has demonstrated that physical literacy is related to physical activity participation in childhood and adolescent populations, but the role of physical literacy has been largely unexplored in young adults. Our research indicates that individual components of physical literacy are associated with self-reported and objectively measured physical activity in young adults 1-10 years post-ACLR. Additionally, individuals with a history of ACLR described how the components of motivation, confidence, and knowledge are related to one another and how these factors influence physical activity participation after ACLR. Specifically, enjoyment, social influences, physical abilities, and perceptions of physical/mental health benefits positively influence motivation and confidence for physical activity while school responsibilities and
negative emotions toward exercise (e.g., judgement, guilt) negatively influence motivation and confidence for physical activity. In summary, physical literacy is a promising avenue for understanding and promoting physical activity participation in individuals with a history of ACLR.
APPENDIX

Semi-Structured Interview Protocol

Opening Statement: The purpose of this interview is to explore your perceptions of physical literacy and experiences with physical activity. By doing this study, I hope to gain an in-depth understanding of how physical literacy influences physical activity participation in individuals with a history of anterior cruciate ligament reconstruction. Before we start the interview, are you okay with this interview being audio/video recorded? [Get consent] I’m going to ask you a series of questions. Remember, there are no right or wrong answers to any questions. I want to know what you really think. Also, you may choose not to answer any question, or you may choose to end the interview at any time. Do you have any questions before we start?

Interview Questions:

Section 1: Key questions about physical activity and physical literacy before injury

1) Before your injury, what role did physical activity have in your life?
   b. Prompt: What sorts of physical activity did you participate in?

2) Before your injury, what motivated you to participate in physical activity?

3) Before your injury, what made you feel confident during physical activity?

Section 2: General information about injury and rehabilitation

4) Please tell me about your ACL injury and your rehabilitation process.
   a. Prompt: Why did you decide to have reconstructive surgery?
   b. What sorts of activities did you do during your recovery to prepare for your return to sport/physical activity?
      i. Prompt: Did you work with any sort of medical or exercise personnel? (i.e., athletic trainer, physical therapist, personal trainer, strength coach)
      ii. Prompt: What difficulties did you have, if any, returning to activity?
      iii. Prompt: How did the rehabilitation process facilitate or hinder your return to activity?

Section 3: Key questions about physical activity and physical literacy after injury

5) Thinking about the first 1-2 years after your injury, what role did physical activity have in your life?
a. Were you able to return to your desired level of sport and/or physical activity following your surgery? Why or why not?
   i. Prompt: What was your desired level of sport/physical activity?
   ii. Prompt: Did you want to return to sport and/or physical activity? Why or why not?
6) How did your feelings towards physical activity change after your injury (if at all)?
   a. Prompt: In what ways did your confidence in physical activity change? In what ways did your motivation for physical activity change?
7) How did your physical activity behaviors change since your injury (if at all)?
8) Thinking about your life currently, what role does physical activity have in your life?
   a. Prompt: How important is physical activity to you currently?
9) Tell me about the types of physical activity you currently participate in.
   a. Prompt: In the next 6 months, what would your ideal physical activity participation look like? Is this more or less active than you currently are?
      i. Are you satisfied with your current level of physical activity? Why or why not?
   b. Prompt: Does your knee limit your ability to participate in any activities? If so, how, and what activities?
   c. How has COVID-19 been a facilitator and/or barrier your physical activity participation?
10) What factors encourage you to participate in physical activity?
   a. Prompt: Friends/family/social connections? Weather?
   b. What factors hinder your ability to participate in physical activity?
11) Please describe what motivates you to participate in physical activity.
   a. What decreases your motivation to participate in physical activity?
12) Please describe what makes you feel confident during physical activity?
   a. How does the environment influence your confidence? Environments can include places, like the gym, or outdoor conditions like snow or water. If so, how?
      i. Rephrase: Do you feel more confident in certain environments over others?
   b. Please describe what hinders your confidence during physical activity?
      i. Are there activities that you don’t feel confident participating in? If so, what?
13) What do you know how physical activity recommendations/guidelines?
   a. Rephrase if needed: Do you know how often adults are encouraged to be physically active and/or the types of activities that are recommended?
   b. Do these recommendations influence your participation in physical activity?
   c. Do you (or have you) search for or seek out any information related physical activity? If yes, what types of resources do you search for?
14) How do you see the role of physical activity in your future?

Section 4: Closing

15) What do you wish you would have known before your injury?
   a. Prompt: This could be about the recovery process, about physical activity, or anything else.

16) What else would you like to tell me about your experiences with physical activity or your ACL injury/recovery that we have not already discussed?

17) Thank you for your participation in this interview. Would you be willing to be contacted again should I have any further questions?
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Peer Reviewed Published Abstracts


4. Kleis RR, Dlugonski D, Hoch MC, Ireland ML, Hoch JM. Differences in current self-reported physical activity among females with varying previous


**Manuscripts Submitted for Publication**

