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Impact of Psychological Factors on Adolescents with Anterior Knee Pain

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The Impact of Psychological Factors on Adolescents with Anterior Knee Pain

by

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Approval/Signature Page

We hereby certify that this dissertation, submitted by Mitchell Selhorst, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirement for the degree of Doctor of Philosophy in Physical Therapy.

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Abstract

Problem and purpose: Psychological factors impact self-report measures of pain and function among adults with anterior knee pain (AKP), but we do not know (1) if psychological factors also impact pain, self-reported function, and objective measures of function among adolescents with AKP and (2) if a psychological intervention would affect function. The *purpose of this dissertation* is to determine the impact of psychological factors on pain, self-reported function, and objective measures of function in adolescents with AKP.

Methods: This dissertation was prospective, with three separate studies. Two were cross-sectional observational studies, and the third was a randomized-controlled trial. Patient questionnaires were used to describe psychological beliefs, including fear avoidance (fear avoidance beliefs questionnaire-physical activity), kinesiophobia (Tampa scale for kinesiophobia-11), and pain catastrophizing (pain catastrophizing scale-child) in adolescents with AKP aged 12-17 years. In research study #1, self-reported function, pain, and clinical measures of function were assessed. In research study #2, three-dimensional motion analysis was used to assess movement patterns during a single leg hop for distance in a subset of the participants (n=30). In research study #3, participants were randomly assigned to a psychologically-informed education group or a control group. Change in self-reported function was assessed over six weeks.

Results: Adolescents with AKP (n=87, 62% female, age 14.6 ±1.7 years) and healthy controls (research study #2 only, n=10, 60% female, age 15.5 ±1.8 years) were recruited for participation. Research study #1 identified a significant mild-moderate adverse association between psychological beliefs, self-reported function (r = -0.59), pain (r = 0.34), hip abductor strength (r = -0.41), and single leg hop distance (r = -0.38). Research study #2 found no

significant between-group differences in movement patterns in adolescents with elevated or low maladaptive psychological beliefs. Research study #3 found that adolescents who received a brief psychologically-informed educational intervention had significantly greater short-term improvements in function compared to controls (mean difference of 8.0 points, 95% CI 2.4, 13.5; $p = 0.01$).

Conclusion: Maladaptive psychological beliefs were adversely associated with self-reported function, pain, and certain aspects of objective function. Providing a brief psychologically-informed intervention significantly improved maladaptive beliefs and self-reported function among adolescents with AKP.

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CHAPTER 1

Background

Anterior knee pain (AKP) is one of the most common musculoskeletal complaints reported among adolescents, affecting 6-10% of all adolescents.(1-5) AKP results in decreased ability to participate in sports, recreation, and even work activities.(6, 7) A common misconception is that AKP is benign and self-limiting, particularly in adolescence. Several studies have shown that this is not the case, as even after receiving treatment, many adolescents continue to have pain and disability,(1, 2, 8-10) and up to 91% of patients with AKP report persistent or recurring pain that lasts for years despite intervention.(6, 7)

Psychological beliefs have recently been shown to impact self-report measures of pain and function among adults with AKP.(11) Adults with AKP may have elevated anxiety, depression, pain catastrophizing, and pain-related fear, which correlate with increased pain and reduced function.(12-16) In a recent systematic review, Maclachlan et al.(11) reported that pain catastrophizing and pain-related fear were the psychological factors which demonstrated the strongest and most consistent correlation with pain and dysfunction among adults with AKP. Pain catastrophizing describes a maladaptive cognitive style with an irrational negative forecast of future events regarding pain, originally observed in patients with anxiety and depressive disorders.(17) Pain-related fear can be assessed by measuring fear-avoidance beliefs and kinesiophobia. Individuals are motivated to avoid activities in which they have experienced pain in order to reduce the likelihood of re-experiencing pain or causing further physical damage. (18) This fear is an adaptive behavioral strategy for dealing with situations involving acute pain, but pain-related fear can become maladaptive.(18)

Psychological beliefs have been found to be associated with self-reports of pain and function, however, the association between psychological beliefs and objective measures of

functional ability in individuals with AKP is unclear. Self-report measures of functional ability in AKP are based upon the individual's self-perception of what physical activity they can or cannot perform. Psychological beliefs, such as high levels of pain-related fear, are associated with an individual's self-perception of their physical capabilities and may not be associated with their actual physical capability. Two studies(19, 20) found a relationship between psychological beliefs and objective measures of function, while a third study(21) found no relationship.

Although AKP is most prevalent in the adolescent population,(4) 95% of the research is done in the adult population.(9) Of the studies assessing psychological beliefs and AKP, all were performed in the adult population.(11) Adolescents likely have different psychological factors which impact them compared to adults, with their daily life being composed of school, sport, friends, and family. A pediatric psychological model has been proposed wherein parents play a significant influential role.(22) The influential force of parents may be an important factor which is not observed in adults with AKP, therefore the association between psychological beliefs and AKP observed in adults should not be generalized to adolescents with AKP.

Additionally, based on the current evidence regarding psychological factors and AKP, it is unknown whether pain and the associated decreased function lead to the development of maladaptive psychological beliefs, or if elevated maladaptive beliefs lead to greater levels of pain and dysfunction. Change in fear-avoidance beliefs has been reported as the strongest predictor of function and pain outcomes in AKP.(14) Similarly, changes in pain and function were found to coincide with changes in individuals' pain catastrophizing and kinesiophobia beliefs.(12) These studies were observational and could not determine a causal relationship between psychological factors, pain, and functional ability. This chapter will provide a brief overview of some of the psychological factors associated with AKP and outline a proposed

research study in order to improve our understanding of the impact of psychological beliefs in adolescents with AKP.

Problem Statement

Psychological factors impact self-report measures of pain and function among adults with Anterior Knee Pain (AKP), but we do not know (1) if psychological factors also impact pain, self-reported function, and objective measures of function among adolescents with AKP; and (2) if a psychological intervention would affect function.

Considering the suboptimal clinical outcomes following treatment of AKP, more effective interventions are needed. Psychologically-informed education including pain neuroscience education is an intervention designed to target multiple factors, including pain-related fear. Pain neuroscience education has been shown to result in immediate improvement in physical impairments in adults with chronic low back pain.(23) In a recent systematic review of adults with low back pain, pain neuroscience education was found to reduce short-term self-reports of physical disability.(24) In a group of adolescents with neck pain, pain neuroscience education resulted in both improvements in self-reports of function as well as improvements in physical impairments.(25) To date, no study has assessed the efficacy of any psychologically-informed intervention for the treatment of AKP.

The primary psychological variable of interest in this dissertation will be fear-avoidance beliefs, as measured by the Fear-Avoidance Beliefs Questionnaire-Physical Activity subscale. As other psychological factors may also be associated with physical performance, we will also assess pain catastrophizing (Pain Catastrophizing Scale), fear of movement (Tampa Scale for Kinesiophobia-11), stress (Perceived Stress Scale-Child), anxiety (PROMIS Anxiety), and depression (PROMIS Depression) as secondary variables of interest.

Goal

The *dissertation goal* is to determine the impact of psychological factors on pain, self-reported function, and objective measures of function in adolescents with Anterior Knee Pain. We will accomplish this goal by first assessing the association between psychological factors, pain, self-reported function, and measures of functional ability. Second, we will assess the cause-and-effect relationship of psychological beliefs on function and pain through a randomized controlled trial.

Research Questions/Hypotheses

Psychological beliefs have been found to be significantly associated with self-reported function and pain in adults with AKP.(11) Additionally, there is conflicting evidence regarding the association of psychological beliefs on objective measures of function in adults with AKP, with two studies finding a significant association and one finding no association.(19-21) No study has assessed the cause-and-effect relationship of psychological beliefs on function and pain among individuals with AKP. Adolescents likely have different psychological factors which impact them compared to adults, with their daily life being composed of school, sport, friends, and family. A pediatric psychological model has been proposed wherein parents play a significant influential role.(22) The influential force of parents may be an important factor which is not observed in adults with AKP, therefore the association between psychological beliefs and AKP observed in adults should not be generalized to adolescents with AKP. The primary purpose of this study is to investigate the influence of psychological factors on self-reported function, pain, and objective measures of function among adolescents with AKP.

Research Question 1:

Do psychological factors influence pain, function and level of performance on clinical tests of physical impairment and performance in adolescents with AKP?

a. Measured constructs: Self-reported functional ability, pain, objective measures of function
b. Measured constructs: Parent psychological beliefs, and adolescent beliefs, pain, and function

Hypothesis 1a: Adolescent psychological factors will be associated with the adolescent's self-reported function, pain, and objective functional ability. Additionally, psychological beliefs will provide further information on self-reported function after accounting for demographic and physical factors associated with AKP.

Hypothesis 1b: Parental beliefs will be associated with the participant's psychological beliefs, self-reported functional ability, and pain.

Research Question 2

Are psychological factors associated with differences in frontal-plane biomechanics during a single leg hop task?

a. Measurements: Peak hip and knee moments during single leg landing.

Hypothesis 2: Participants in the elevated fear-avoidance group will have greater peak external hip adduction and knee abduction moments during a single leg landing, compared to participants in both the low fear-avoidance and healthy control groups.

Research Question 3:

Does providing brief psychologically-informed education improve immediate (same session) and short-term (2 week and 6 week) outcomes in individuals with anterior knee pain?

c. Primary outcome- Function as measured by the Anterior Knee Pain Scale

d. Secondary outcome- Pain as measured by the Numeric Pain Rating Scale

e. Secondary outcome- Psychological beliefs as measured by the Fear Avoidance Beliefs Questionnaire, Tampa Scale for Kinesiophobia-11, and Pain Catastrophizing Scale-Child

Hypothesis 3a: Adolescents who view the brief psychologically-informed video will demonstrate significantly greater improvements in functional ability when compared to those who view the control video;

Hypothesis 3b: Adolescents will demonstrate greater reductions in pain, but to a lesser extent than function, when compared to those who view the control video.

Hypothesis 3c: Adolescents who view the psychologically-informed video will demonstrate significant and immediate reductions in maladaptive psychological beliefs.

Relevance and Significance

AKP is quite common in the adolescent population and can have a significant impact on their quality of life. This proposed project will add to our knowledge of how psychological factors are associated with pain and function in adolescents with AKP, and whether a psychologically-informed intervention can improve function in this population. In particular, this study will improve our understanding of the potential cause-and-effect relationship between psychological factors and function, and the extent psychological factors influence objective measures of function. In a recent systematic review, Maclachlan(11) states that it remains unknown whether the experience of AKP and inability to perform physical tasks lead to the development of psychological problems, or whether psychological features influence pain and function through mechanisms such as effects on endogenous pain modulation, individual resilience, and the

motivation to cope with the symptoms of AKP. Specifically targeting psychological features, by performing a psychologically-informed intervention with the intent to affect pain-related fear and observing the effect on function, will help fill this knowledge gap. If the psychologically-informed intervention group shows greater improvements in function compared to the control group, this would indicate that to some extent psychological features influence function in those with AKP.

Practical Application of the Findings

- *Research Question #1 Do psychological factors influence pain, function and level of performance on clinical tests of physical impairment and performance in adolescents with AKP?*

Psychological factors are associated with self-report measures of function and pain in adults with AKP,(11) but it is not known if these psychological factors are associated with self-reported function, pain, and objective measurements of function in adolescents with AKP. Self-report measures are assessments of an individual's self-perception of their disability, and this self-perception may or may not actually reflect objective measures of physical impairment and performance. This research question aims to answer if psychological factors are associated with self-reported function, pain, and objective measures of function on common clinical tests. The results of this study will increase our understanding of the influence of psychological factors in adolescents with AKP.

- *Research Question #2 Are psychological factors associated with differences in frontal-plane biomechanics during a single leg hop task?*

Although the etiology of AKP remains unknown, the most commonly accepted cause is alterations in lower limb biomechanics resulting in abnormal tracking of the patella within the

trochlear groove.(8) As elevated pain-related fear, pain catastrophizing, anxiety, and depression are associated with higher reports of AKP, psychological factors may be associated with altered biomechanics. The results of this study will improve our understanding of the association between psychological factors and altered movement patterns.

- *Research Question #3 Does providing brief psychologically-informed education improve immediate (same session) and short-term (2 week and 6 week) outcomes in individuals with anterior knee pain?*

Piva et al(14) stated that pain-related fear, as measured by the FABQ-PA, should be specifically targeted during treatment for AKP, as reduction in fear was the strongest predictor of improvement in pain and function outcomes in their observational study. This proposed interventional study intends to establish whether psychologically-informed education, which intends to alleviate pain-related fear and pain catastrophizing, results in improved function and pain. Psychologically-informed education, an intervention intended to address pain-related fear, has been shown to improve functional ability and reduce healthcare utilization in adults with low back pain.(26) Psychologically-informed education was also shown to produce immediate changes in physical performance for patients with low back pain.(23) Being able to make immediate improvements in physical performance by alleviating patients' fear would be an invaluable tool for physical therapists, by removing barriers to clinical improvement. Psychologically-informed interventions are typically intensive,(27) which potentially poses an issue when treating AKP because current evidence demonstrates that exercise should be the primary focus of a treatment approach.(28) Therefore, there is a need for a concomitant intervention that can efficiently and effectively address maladaptive psychological beliefs.

LIST OF ABBREVIATIONS

Anterior Knee Pain	AKP

SUMMARY

Psychological beliefs have a consistent association with pain and function among adults with anterior knee pain (AKP). It is currently not clear if these same psychological beliefs are associated with pain and function in adolescents with AKP, as they experience different psychological factors. Additionally, the cause-and-effect relationship between psychological beliefs and function is unknown among individuals with AKP. The intent throughout the remainder of this document will be to add to the body of literature for adolescents with AKP and improve our understanding of the influence of psychological beliefs in this population.

CHAPTER 2: REVIEW OF THE LITERATURE

INTRODUCTION

This chapter will serve as a comprehensive review of the literature surrounding all aspects of the proposed research process. The initial section of chapter 2 will focus on the description of AKP and current treatment interventions. After describing the current treatment approaches, this chapter will explore the psychological impact on AKP. We will explore and analyze the current literature on the relationship between multiple psychological variables and several domains associated with AKP. Additionally, this chapter will review methods of assessing these psychological variables. Finally, the chapter will end with an explanation of identifiable gaps in the literature that remain to be explored.

Description of Anterior Knee Pain

Anterior knee pain (AKP) is characterized by pain in or around the patellofemoral joint without observable cartilage damage.(29) There are many diagnoses involving the patellofemoral joint including patellofemoral pain, apophyseal injuries (Osgood-Schlatter's disease and Sinding-Larsen-Johansson's disease), soft tissue injuries (iliotibial band syndrome, bursitis), and tendinous injuries (patellar tendinopathy, quadriceps tendinopathy).(30) Frequently, patients present with symptoms consistent with multiple diagnoses of the patellofemoral joint, and the etiology of each condition is often vague and similar. Therefore, the umbrella term of AKP is a useful method for categorizing individuals who report pain in and/or around the patellofemoral joint.

Incidence and Etiology

AKP represents the most common complaint of the knee, and is one of the most frequently reported musculoskeletal complaints in pediatric patients.(30, 31) AKP is reported

more often by females than males.(3) Although prevalent among young adults who are between the ages of 18 and 35,(32) AKP is most common among adolescents, affecting 6-10% of this age group.(1-3, 9) AKP is even more common in active adolescents who participate in sport, with a prevalence rate reaching 22%.(10) Additionally, sport specialization has been found to increase the risk of AKP by 1.5 fold.(33)

A common misconception is that AKP is benign and self-limiting, particularly in adolescence. Several studies have shown that this is not the case, as even after treatment most individuals still reported AKP. (6, 7, 34, 35) Rathleff et al(7) found that 65% of adolescents reported AKP two years later, while Stathopulu and Baildam(6) found that 91% reported AKP 4 to 18 years after initial diagnosis. AKP can have a pronounced functional impact, reducing an individual's ability to participate in sports, recreation, and even daily activities.(6, 7) Additionally, 71% of patients reported that they needed to stop or reduce their sports participation due to the continued pain.(7)

The etiology of AKP is multifactorial, and the underlying cause remains unknown.(8, 36) The intensity of AKP is not related to the presence or severity of any patellofemoral lesion. (37) Common explanations include abnormal tracking of the patella, impaired lower extremity mechanics, decreased flexibility, and weakness of the hip abductors/external rotators and quadriceps muscles. (38-43) The high prevalence of AKP in the athletic population suggests that repetitive and/or excessive specific loading contributes to the pathogenesis of AKP in adolescents. (9) However, there is also a subgroup of adolescents with AKP (~33%) who do not participate in sport at all, which likely eliminates excessive loading as the sole cause of AKP in adolescents. (44)

Physical interventions for AKP

There are multiple physical interventions that clinicians may use when treating AKP. The primary interventions include muscle strengthening, stretching, and taping.(29) Quadriceps and hip strengthening are mainstay treatments for AKP, and are shown to be effective at reducing pain and improving activity.(45) Many other physical interventions have been proposed to treat AKP, including dry needling, (46, 47) manual therapy, (48-50) foot orthoses, (51, 52) electrotherapies, (53) and vastus medialis obliquus training,(54, 55) but current evidence does not support their use. Despite the fact that some physical interventions are efficacious, the continued pain and high recurrence rate of AKP suggest that these physical interventions are insufficient to resolve AKP.(9, 34)

Strengthening

The strongest evidence for improvement in self-reported function and pain among individuals with AKP results from strengthening interventions. In a Cochrane review,(56) consistent evidence stemming from low-quality studies suggests that the use of strengthening exercises results in mild to moderate improvements in AKP. The studies were considered by the review to be low quality due to design flaws and small sample sizes.(56) The researchers found improvements in both pain and function in the short term, as well as enhanced long-term outcomes. Quadriceps strengthening has long been recommended for individuals with AKP.(57) Strengthening exercises typically include both open and closed chain strengthening exercises, with a systematic review finding no significant differences in outcomes between closed chain versus open chain exercises.(58) More recently, strengthening of other areas such as the hip, core, and foot have been advocated for AKP.(38, 59-61) There is limited evidence suggesting that adding a foot strengthening program may improve pain and function in a subgroup of

individuals with AKP who demonstrated impaired foot posture. (61) In a recent systematic review,(62) the pooled results of hip and knee strengthening were shown to have a large effect size for improved function, and significantly reduced pain. Interestingly though, this same systematic review showed that hip and knee strengthening resulted in no significant improvements in actual hip or quadriceps strength. The improvement in self-reported functional ability and pain, without a concurrent improvement in strength, suggests that the mechanism behind the improvement noted with strengthening exercises is something other than a resultant effect of stronger muscles.

Flexibility

Individuals with AKP have been found to have significantly less quadriceps and gastrocnemius flexibility compared to a healthy population. (63) Conflicting reports exist on whether hamstring, hip flexor, and iliotibial band flexibility limitations are associated with AKP.(3, 63, 64) Quadriceps muscle tightness is thought to increase patellar compression forces during motion.(65) Reduced gastrocnemius flexibility has been found to be associated with altered mechanics, as noted with increased peak knee abduction during squatting and jumping activities.(66-69) Flexibility exercises have been shown to improve pain and function when added to a strengthening program,(70, 71) but stretching alone has not been found to be an effective treatment for AKP.(72)

Patellar Taping

Patellar taping, primarily using McConnell tape, has been suggested as a means to improve patellofemoral joint mechanics. McConnell taping techniques attempt to reduce the lateral glide theorized to increase AKP by providing a medial taping force to the patella. However, results from a dynamic magnetic resonance imaging study suggests that patellar taping

actually shifts the patella inferiorly and not medially.(73) Regardless of the exact mechanism, there is moderate evidence that suggests that patellar taping can provide immediate and short-term reductions in AKP.(74, 75) The addition of patellar taping was found to provide no additional benefit in longer-term data (12-52 weeks).(76)

Psychological Factors and AKP

Non-physical, psychological factors have been found to influence AKP and other persistent musculoskeletal conditions.(11-14, 23, 26, 77-79) However, current clinical management of AKP is largely based off a biomedical structural paradigm.(8, 80, 81) Adults with AKP may have elevated anxiety, depression, pain catastrophizing, and pain-related fear, which correlate with pain and reduced physical activity.(11) Change in fear-avoidance beliefs has been reported as the strongest predictor of function and pain outcomes in AKP.(14) Similarly, changes in pain and function were found to coincide with changes in individuals' pain catastrophizing and kinesiophobia beliefs.(12) These results indicate that clinicians treating adults with AKP should consider possible psychological factors.

Maclachlan(11) performed a systematic review assessing the psychological features associated with AKP. Eighteen different psychological instruments were used to measure psychological constructs and their relationship to AKP. Elevated levels of anxiety, depression, pain catastrophizing, and pain-related fear (fear-avoidance and kinesiophobia) are reported in adults with AKP.(11) These psychological factors have been found to influence pain and self-reports of function.(11) Anxiety and depression have been found to have a moderate-to-large correlation with pain and function.(12-15) Pain catastrophizing and pain-related fear demonstrated the strongest and most consistent correlation with pain and function among individuals with AKP.(11)

Piva et al (15) measured common physical impairments (iliotibial band length, quadriceps strength, lateral step down test, etc.), as well as anxiety and fear-avoidance beliefs, in a sample of 74 individuals (29 ±9 years old) with AKP. They planned to control for psychological factors to determine which physical impairment was most associated with pain and function. The results indicated that physical impairments were not strongly associated with individual self-reports of pain and function, but there was a moderate correlation between anxiety and fear-avoidance beliefs and pain and function. Piva et al(14) then followed these same individuals for 2 months to assess if change in physical impairments, anxiety, and fear-avoidance beliefs predicted change in pain and self-reports of function. Change in prone gastrocnemius flexibility was the only physical impairment associated with change in pain ($r = -0.25$) and function ($r = 0.43$). Change in fear-avoidance beliefs (FABQ-PA) was more predictive of change in pain ($r = 0.51$) and function ($r = -0.57$) than physical impairments. There was no mention of change in anxiety in the follow-up study. The study design used by Piva et al(14, 15) could not establish a cause-and-effect relationship between psychological variables and pain and function.

Domenech et al(13) recruited 97 individuals with chronic AKP (32 ± 10 years, 83% female) to assess the relationship between psychological factors (kinesiophobia, anxiety, depression and pain catastrophizing) with pain and self-reports of physical function. Anxiety and kinesiophobia were significantly correlated with function, but only pain catastrophizing and depression were significant predictors of functional ability, explaining 56% of the variance. In this sample of adults with AKP, 36% (n=35) demonstrated high levels of pain catastrophizing (PCS ≥ 24), 11% (n=11) had a high depression score (HAD ≥ 11), 30% (n=29) had high levels of anxiety (HAD ≥ 11) and 82% (n=80) had high levels of kinesiophobia (TSK ≥ 40). Domenech et

al(12) then followed a sample of 50 adults with AKP (32 ± 11 years, 89% female) to assess how these same psychological measures would predict changes in pain and function following biomedical treatment. Change in pain catastrophizing significantly predicted change in pain, explaining 49% of the variance. Change in pain catastrophizing and anxiety significantly predicted change in function, explaining 58% of the variance. No psychological intervention was performed in this study. Domenech et al theorized that catastrophizing modulates the perception of pain and this relationship is bidirectional and dynamic.

Selhorst et al(82, 83) found that using a treatment approach which included a psychological intervention resulted in clinically significant improvements in short-term pain and function among adolescents with AKP, compared to a traditional physical treatment approach. A cognitive behavioral approach was applied for individuals who demonstrated high fear-avoidance beliefs (FABQ-PA >14). Although a psychological intervention was included as a part of the treatment algorithm, the study design could not determine to what degree the psychological intervention was responsible for the differences observed in the treatment effects.

In a cohort of 496 adolescents with AKP, Mansfield and Selhorst(84) found the median FABQ-PA score to be 14/24. Adults with low back pain are considered to have elevated fear-avoidance beliefs if they score ≥15/24 on the FABQ-PA, the cutoff of 15 or greater was determined by using the median of a sample of adults with low back pain.(85) These finding suggest that a cutoff for elevated fear-avoidance beliefs in adolescents with AKP may be ≥14/24, and ≤10/24 which represents the first quartile (Q1) may serve as the cutoff for low fear-avoidance beliefs.

Psychological Assessment

Psychological factors are assessed primarily through interviews or by using patient/family self-report surveys. Assessment of psychological factors through interview requires specialized training and is outside the scope of practice for physical therapists; therefore patient/family self-report surveys will be used to assess psychological factors. The primary psychological variable of interest in this dissertation will be fear-avoidance beliefs, as measured by the Fear-Avoidance Beliefs Questionnaire-Physical Activity subscale (FABQ-PA). Since other psychological factors may also be associated with physical impairment, we will also assess pain catastrophizing (Pain Catastrophizing Scale-PCS), fear of movement (Tampa Scale for Kinesiophobia-11), stress (Perceived Stress Scale-10), anxiety (PROMIS Anxiety) and depression (PROMIS Depression) as secondary variables of interest.

Fear-Avoidance Beliefs

Individuals are motivated to avoid activities in which they have experienced pain in order to reduce the likelihood of re-experiencing pain or causing further physical damage. This is an adaptive behavioral strategy for dealing with situations involving acute pain, but fear-avoidance can become maladaptive.(18) Fear-avoidance beliefs are moderately positively correlated with AKP ($r = 0.31$) and negatively correlated with physical function ($r = -0.32$).(86) Fear-avoidance beliefs are strongly negatively correlated with functional improvement in patients with AKP ($r = -0.57$) and are more predictive of functional improvement (beta = -0.45) than any physical impairment.(11, 14, 87) Additionally, elevated fear-avoidance beliefs have been associated with greater activity limitation in the adolescent population.(88)

Modified Fear-Avoidance Beliefs Questionnaire-Physical Activity (FABQ-PA) subscale:

The fear-avoidance beliefs questionnaire is a two-part questionnaire consisting of a work subscale and physical activity subscale. The work subscale was not included because many adolescents do not participate in regular work activity, so the score would likely not be valid.(1, 2, 8-10) The FABQ-PA subscale quantified the patient's fear of pain and beliefs about avoiding activity. (89) The FABQ-PA is a 5-item self-report measure which assesses an individual's fear-avoidance of painful activity and was modified for the knee.(14) The FABQ-PA was modified by changing the word "back" to "knee" on the questionnaire.(14) Each item is scored on a 0-6 scale, with 0 indicating completely disagree and 6 indicating completely agree. Questions 2-5 are summed to create a final score of 0-24, with high scores indicating higher pain-related fear. The reliability and validity for the FABQ-PA has never been assessed in the knee, but the FABQ-PA has a test-retest reliability of r = 0.59-0.64, and an internal consistency of alpha = 0.72-0.78 for other musculoskeletal conditions.(90, 91)

Kinesiophobia

Kinesiophobia refers to the maladaptive pain-related fear associated with avoidance behaviors, and the avoidance of movement and physical activity. Kinesiophobia has been shown to predict the likelihood that a patient is likely to avoid exercise, and exercise is a predictor of recovery in adolescents with AKP.(2, 92) Kinesiophobia is moderately correlated with pain (r = 0.26) and strongly correlated with function (r = -0.53) in individuals with AKP.(13) Additionally, kinesiophobia is predictive of post-treatment pain (r = 0.35) and function (r = -0.41) in individuals with AKP.(12) The Tampa Scale for Kinesiophobia-11 (TSK-11) is an 11-item questionnaire that will be used to assess fear of injury due to movement.

Tampa Scale for Kinesiophobia-11 (TSK-11): The TSK-11 is an 11-item questionnaire that assesses fear of injury due to movement. Patients are asked to make ratings of their degree of

agreement with each of the 11 statements, for instance, 'Pain lets me know when to stop exercising so that I don't injure myself'. Ratings range from 1 (strongly disagree) to 4 (strongly agree). The responses are summed to yield a total score where higher values reflect higher pain-related fear.(93) The TSK-11 has been shown to predict the likelihood that a patient is likely to avoid exercise and exercise is a predictor of recovery in adolescents with AKP. (2, 92) The test-retest reliability of the TSK-11 is r = 0.81, and an internal consistency of alpha = 0.79,(94, 95) the standard error of measurement was 2.41-2.54 and has a minimal detectable change score of 4-5.6.(94, 95)

Pain Catastrophizing

Pain catastrophizing describes a maladaptive cognitive style with an irrational negative forecast of future events, which was originally observed in patients with anxiety and depressive disorders.(17) The Pain Catastrophizing Scale (PCS) is a 13-item self-report measure designed to assess an individual's catastrophizing. Each item is rated on a 5-point scale, ranging from 0 (not at all) to 4 (all the time). The PCS has previously been used to assess pain catastrophizing in individuals with AKP and is moderate to strongly correlated with pain (r = 0.43) and function (r = -0.53). (11, 78, 96) The PCS-child (PCS-C) and PCS parent (PCS-P) are variations of the original PCS measure designed to assess pain catastrophizing among children and their parents. The PCS-C demonstrated acceptable goodness of fit in a community sample of children 8-17 years, with an internal consistency ranging from an alpha of 0.84 to 0.89.(97) The PCS-C is predictive of chronic or recurring pain in adolescents, and has moderate-strong correlations with pain intensity (r = 0.49) and disability (0.50).(97) The PCS-P has high internal consistency ranging from alpha = 0.81-0.93.(98) In a sample of adolescent outpatients, the PCS-P predicted

22% of the child's pain intensity.(98) The PCS-P demonstrates moderate correlation with the child's function (r = 0.36), parental anxiety (r = 0.31), and parental depression (r = 0.26).(98)

Anxiety

Anxiety is a common psychological response to injury.(99) A distinction is made between state anxiety and trait anxiety.(100) State anxiety is defined as an unpleasant emotional arousal in the face of threats, such as a physical injury.(101) Trait anxiety, on the other hand, reflects the existence of stable individual differences in the tendency to respond to various situations.(101) Individuals with high trait anxiety have been found to have higher state anxiety post-injury.(102) Individuals with chronic AKP have been found to have higher levels of anxiety than matched controls.(103) Piva et al(15) believed that prior to recommending the inclusion of anxiety measures in clinical practice for AKP, further studies should be done using performance-based measures of physical function. There are several self-report surveys designed to assess anxiety including the Beck Anxiety Inventory, the Hospital Anxiety and Depression Scale, and the PROMIS pediatric anxiety item bank. Because of the ease of administration, similar psychometrics and the additional benefit of the parent-proxy report, the PROMIS pediatric anxiety item bank short form was used.

Beck Anxiety Inventory

The Beck Anxiety Inventory (BAI) is a 21-item measure of anxiety. Each item is scored 0 to 3 for a total possible range of 0-63, with higher scores indicating higher levels of anxiety.(104) The BAI demonstrates high internal consistency (alpha = 0.92) and good test-retest reliability (r = 0.75).(104) Additionally, the BAI was able to discriminate between anxious groups and non-anxious diagnostic groups (depression, dysthymic disorders, etc.).(104) The

BAI has been used in one study to assess the anxiety levels in individuals with AKP, with moderate correlation to AKP (r = 0.34) and function (r = -0.45).(15)

Hospital Anxiety and Depression Scale

The hospital anxiety and depression scale (HADS) is a 14-item measure of anxiety and depression in clinical populations with symptoms of physical disease.(105) Each item is answered on a 4-point scale (0-3), with 7 items being scored for anxiety and 7 items score for depression. The HADS was designed to avoid questions which might be endorsed due to physical rather than psychological state.(106) The HADS has been found to have moderate to high convergent validity (r = 0.54 - 0.79) with interview ratings.(105) The internal consistency of the HADS has been reported as alpha = 0.83-0.84 in adults with musculoskeletal injuries.(107) In the adolescent population (12-17 years), the HADS has adequate test-retest reliability and was able to discriminate between known groups of adolescents diagnosed with depressive or anxiety disorders and those without these diagnoses.(108) The HADS has been used twice to assess the anxiety and depression levels of individuals with anterior knee pain.

PROMIS pediatric anxiety item bank

The Patient-Reported Outcomes Measurement Information System (PROMIS) project has many patient-reported outcomes, including the PROMIS pediatric anxiety item bank. The PROMIS pediatric anxiety item bank focuses on fear, worry and nervousness specific to the environment of home, school, and social activities.(109) There are 2 forms of the PROMIS pediatric anxiety item bank, the 8-item static short form and a computer adaptive test (CAT). The CAT administers a minimum of 5 and a maximum of 12 items, but studies have found the CAT to be less precise than the static form.(110) All items used a 7-day recall period and one of

two sets of standardized 5-point response options: never, almost never, sometimes, often, and almost always. In a sample of pediatric individuals 8-17 years old, the PROMIS pediatric anxiety item bank demonstrated good test-retest reliability (r = 0.75) and an internal consistency of alpha = 0.84.(110) Using IRT analysis, the PROMIS pediatric anxiety item bank demonstrated satisfactory goodness of fit in the pediatric population.(109) The root mean squared error was 4.09.(110) An additional advantage to the PROMIS item banks that allow for answering secondary questions is the parent-proxy report, where we can also gather information from the patient's parent or guardian.

Depression

Symptoms of depression are reported in more than 20% of young athletes.(111) Injured athletes have reported higher depression symptoms than non-injured athletes for up to 2 months following injury.(102) Depression has been found to be strongly correlated with function (r = 0.57-0.59) and moderately correlated with pain (r = 0.30-0.44) among individuals with AKP.(12, 13) Although there are many surveys assessing depression, due to the nature of this study a brief survey that does not assess suicidal ideation is required. Common depression screens, including the Beck Depression Inventory and the Patient Health Questionnaire-adolescent (PHQ-A), were not considered as they assess suicidal ideation. The Hospital Anxiety and Depression Scale, and the PROMIS pediatric depressive symptoms item bank are both brief and assess depression symptoms, without specific questions regarding suicidal ideation. Because of the ease of administration, and the additional benefit of the parent-proxy report, the PROMIS pediatric depressive symptoms item bank short form was used.

Hospital Anxiety and Depression Scale: Psychometric properties presented in anxiety section.

PROMIS pediatric depressive symptoms item bank:

The PROMIS pediatric depressive symptoms item bank focuses on negative mood, loss of interest, worthlessness and loneliness.(109) This item bank is best described as a measure of depressive symptoms rather than a diagnostic test for depression. There are 2 forms of the PROMIS pediatric depressive symptoms item bank, the 8-item static short form and a computer adaptive test (CAT). The CAT administers a minimum of 5 and a maximum of 12 items, but studies have found the CAT to be less precise than the static form.(110) All items used a 7-day recall period and one of two sets of standardized 5-point response options: never, almost never, sometimes, often, and almost always. In a sample of pediatric individuals 8-17 years old the PROMIS pediatric depressive symptoms item bank demonstrated good test-retest reliability ($r = 0.76$) and an internal consistency of alpha = 0.86.(110) Using IRT analysis, the PROMIS pediatric depressive symptoms item bank demonstrated satisfactory goodness of fit in the pediatric population.(109) The root mean squared error was 3.96.(110) An additional advantage to the PROMIS item banks that allow for answering secondary questions is the parent-proxy report, where we can also gather information from the patient's parent or guardian.

Stress

Stress has been defined as the state of mental or emotional strain resulting from adverse or demanding circumstances. Chronic stress has been strongly and negatively associated with health and performance.(112-115) Adults with AKP had significantly higher levels of stress than matched controls.(103) Stress of the adolescents with AKP was assessed using the Perceived Stress Scale-10 (PSS-10) in this study. The PSS-10 is a brief screening tool for measuring perceived stress and has been found to have superior psychometric properties to the PSS-14.(116) The PSS is rated on a 5-point scale from 0: Never to 4: Very often; scores can range

from 0-40 and higher scores indicate higher stress. In a sample of children 5-18 years, it was able to discriminate between children with known stress disorders and controls.(117) In a sample of adolescents, the PSS-10 demonstrated a Cronbach alpha of 0.87.(118) In the general population, the PSS-10 has a test-retest reliability of r = 0.77 and has a moderate correlation (r = 0.45 - 0.60) with other measures of stress.(116)

Pain Neuroscience Education

Pain was originally thought to have a direct corresponding link to tissue damage as described in the biomedical model. This model assumed that pain was in response to injury or tissue damage, and did not account for the influence of psychological factors.(119) In the latter half of the 20th century there was a shift away from this paradigm,(120) and over the past few decades research has demonstrated that cognitive processes modulate pain.(121-124) The biopsychosocial model has now largely replaced the biomedical model as the theoretical framework for explaining the pain experience. The biopsychosocial model incorporates all aspects in a patient's life as potential modulators of pain, not just tissue damage.(125) The biopsychosocial model puts an emphasis on the fact that pain is modulated by beliefs, and therefore pain can be improved by modifying inaccurate beliefs.(126) Pain neuroscience education attempts to help patients reevaluate their pain by modifying inaccurate beliefs and assisting them in developing more effective coping skills.(119)

One of the psychological factors in the biopsychosocial model is fear. Individuals are motivated to avoid activities in which they have experienced pain, in order to reduce the likelihood of re-experiencing pain or causing further physical damage. Fear-avoidance is a protective behavioral strategy, but fear-avoidance can become maladaptive.(18) The Fear Avoidance Model describes how fear modulates pain (Figure 2.1).(127) Clinicians who treat

pediatric patients have recognized that different factors affect children and have proposed a pediatric model (Figure 2.2). (22) Both the adult and the pediatric Fear Avoidance Models depict a circular nature of the fear, disuse, and pain. However, this nature seems to be more appropriately described as a descending spiral (Figure 2.3), where every revolution in the cycle may result in increasing avoidance, fear, and dysfunction.(128) Pain neuroscience education attempts to address maladaptive behaviors to break the cycle of pain and achieve positive outcomes.

Pain neuroscience education has most extensively been studied in adults with chronic spinal pain. In a recent systematic review,(27) 13 randomized trials were identified which examined the effectiveness of pain neuroscience education in adults. The pain neuroscience education interventions spanned from educational pamphlets to 4 hour in-person sessions. Nine of the studies assessed individuals with spinal pain, three of the studies assessed individuals with fibromyalgia, and one study assessed individuals with generalized chronic pain. In all of the reviewed studies, physical therapists delivered the pain neuroscience education. Strong evidence was found for pain neuroscience education reducing pain intensity, and limited evidence to support short-term improvement in physical performance. Louw et al.(23) found that a one-time pain neuroscience education session resulted in immediate significant improvements in forward flexion motion of the lumbar spine and the straight leg raise test in individuals with lumbar radiculopathy.

Pain neuroscience education has not been extensively studied in the pediatric population. Following a 30-minute pain neuroscience lecture, a group of healthy middle school students had significant improvements in their knowledge of pain as measured by the Neurophysiology of Pain Questionnaire.(129) In a small randomized sample of adolescents with neck pain,

immediate significant improvements in neck extensor endurance were noted in the group that received pain neuroscience education.(25) However, no significant improvements were noted in cervical flexor strength, scapular strength or pain levels.(25)

FIGURE 2.1 Graphical Display of the Fear-Avoidance Model. (Vlaeyen and Linton, 2000)

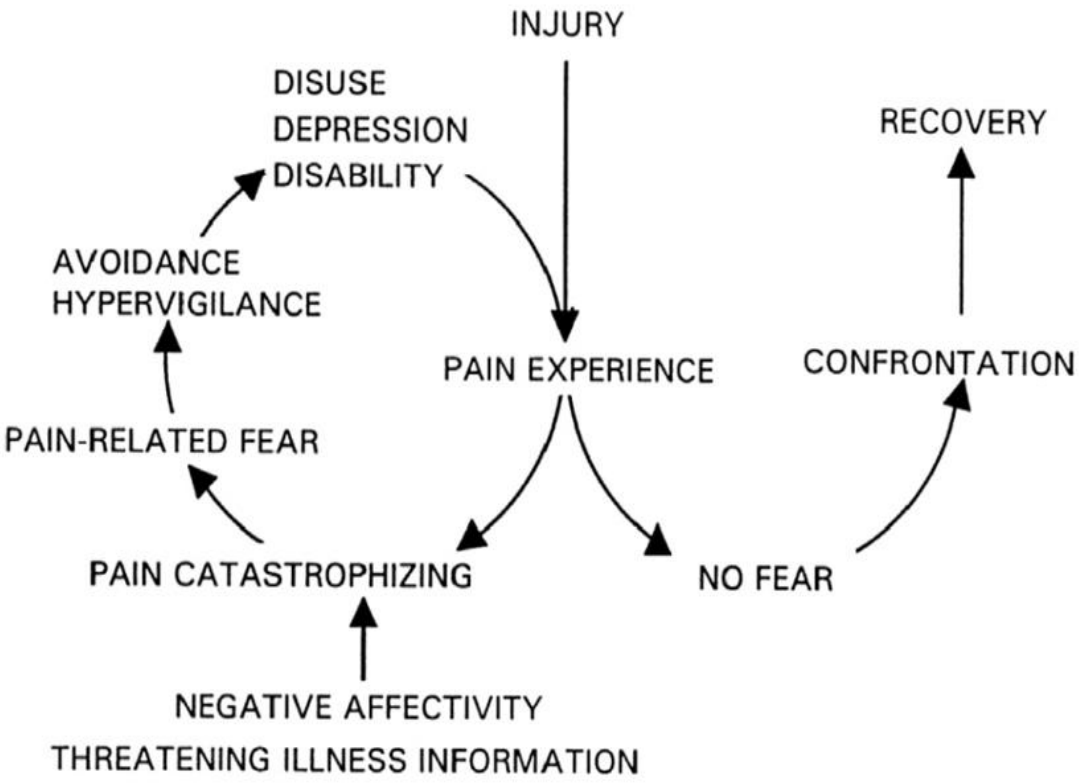


FIGURE 2.2 The Interpersonal Fear-Avoidance Model. (Simmons et al, 2015)

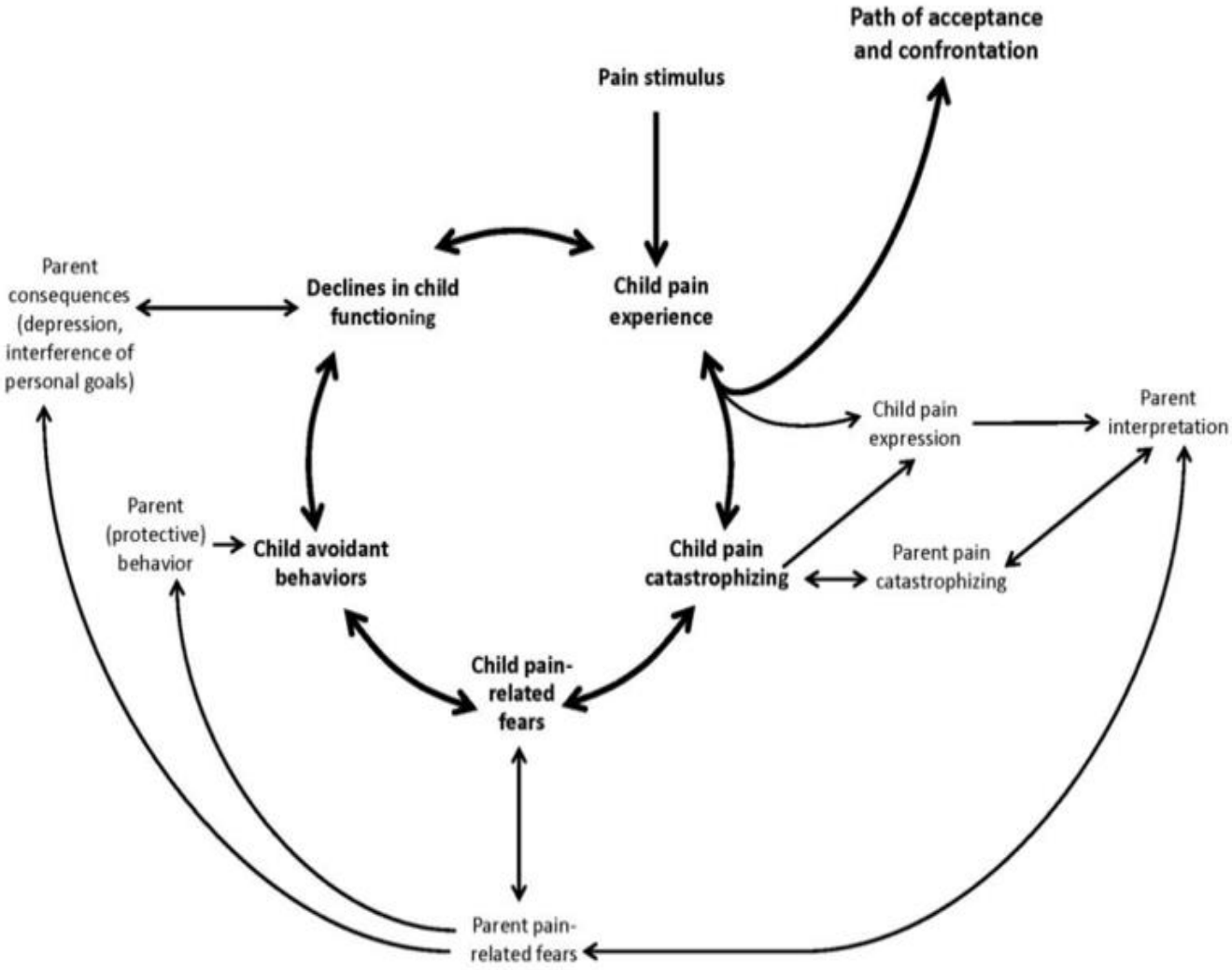
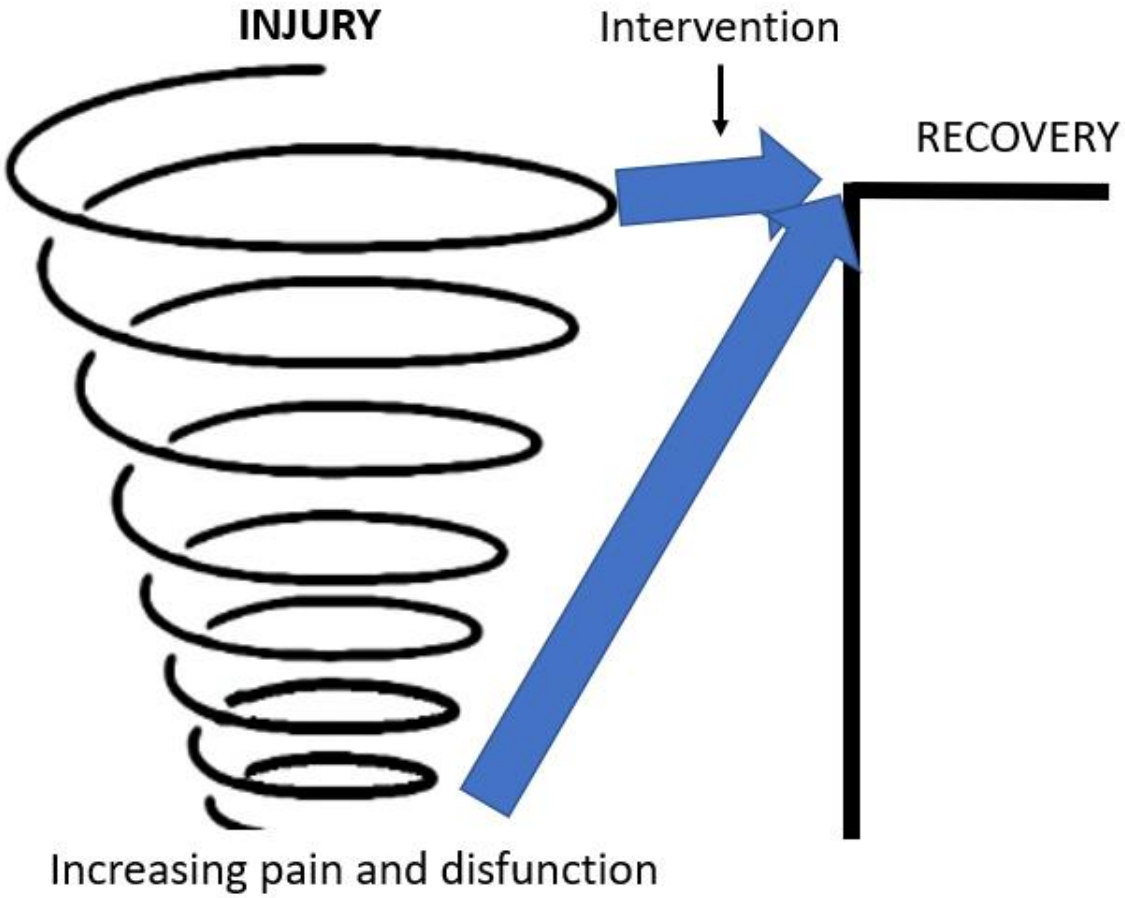


FIGURE 2.3 Spiral of Fear, Pain and Disfunction



Gaps in the Literature and Contributions of this Study.

Although AKP is most prevalent in the adolescent population, 95% of the research is done in the adult population.(9) Of the studies assessing how psychological symptoms are associated with AKP, all were performed in the adult population.(11) Adult research may not be generalizable to adolescents, as there are significant differences between these populations. Not only are adolescents not skeletally mature, but they also participate in stressful physical activities, such as organized sport, on a frequent basis. The psychological factors experienced by adolescents are also potentially different from adults, as adolescents may be heavily influenced by their parents and school environment. This study will contribute to the field by providing evidence of how psychological factors affect adolescents with AKP. Moreover, as adolescents may be significantly affected by the psychological beliefs of their parents, this study will also assess how parental beliefs affect pain and function. With adolescents being the largest population of individuals experiencing AKP, this information is a needed contribution to the literature base.

Psychological factors have been found to be significantly associated with self-reports of functional ability, but it is not known if psychological factors affect actual physical performance in adolescents with AKP.(11) Self-report measures of functional ability in AKP are based upon the individual's self-perception of what physical activity they can or cannot perform. Psychological factors, such as high levels of pain-related fear, may affect an individual's self-perception of their physical capabilities and not their actual physical capabilities. This study will help fill this knowledge gap by assessing the association of psychological factors with actual physical performance. Research question 1 will assess the association between adolescent and parent psychological beliefs, self-reported function, pain and objective function on common

clinical tests in adolescents with AKP. Research question 2 will explore the relationship of psychological factors and lower extremity biomechanics in adolescents with AKP.

Psychological factors, particularly elevated pain-related fear and pain catastrophizing are associated with self-reports of both pain and decreased function in adults with AKP.(11) Selhorst et al(83) found that a treatment approach which included interventions to address psychological beliefs resulted in clinically significantly better reports of pain and function at 6-weeks among adolescents with AKP. However, the study design by Selhorst et al.(83) was insufficient to determine the isolated effect of psychological interventions on patient outcomes. Psychologically-informed education, including pain neuroscience education, has been proposed as an intervention to improve maladaptive beliefs. Pain neuroscience education has been found to provide immediate changes in straight leg raise motion among individuals with chronic low back pain,(23) and has resulted in significantly improved reports of pain and function at 3-year follow-up.(26) Research question #3 will assess the immediate and short-term effects of psychologically-informed education on patient outcomes among adolescents with AKP.

CHAPTER 3: METHODOLOGY

INTRODUCTION

This chapter will serve as a complete outline of the methodology employed in this research study, including a detailed description of measurement tools, data collection procedures, and data analysis plan.

Research Methods

Setting

The research was performed at Nationwide Children's Hospital Sports and Orthopedic Physical Therapy clinics, where adolescents are treated for orthopedic conditions. All study protocols followed the regulations of the Institutional Review Boards at Nationwide Children's Hospital and Nova Southeastern University. Parental consent and child assent were obtained prior to the collection of any data.

Participants

The population of interest was adolescents with AKP presenting to Nationwide Children's Hospital Sports Medicine and Sports and Orthopedic Physical Therapy clinics, as well as a small group of healthy adolescents without AKP. Study staff screened and recruited adolescents until 97 participants were enrolled in total. Nationwide Children's Hospital electronic documentation system and treating clinicians in these departments helped identify potential participants with AKP. Study staff recruited participants being seen by Nationwide Children's Hospital Sports and Orthopedic Physical Therapy clinics. Recruitment was based on a sample of convenience, with all individuals who had a primary complaint of AKP being eligible. Patients who met the following criteria were offered the opportunity to participate in the research study.

Inclusion Criteria

Anterior Knee Pain Cohort

Specific inclusion criteria

1. Age between 12 and 17 years.
2. Having AKP as defined as: Pain around or behind the patella, which is aggravated by at least one activity that loads the patellofemoral joint during weight bearing on a flexed knee (e.g., squatting, stair ambulation, jogging/running, hopping/jumping)

Specific exclusion criteria

1. Prior history of patellar dislocation.
2. Suspicion of other diagnosis of the knee by evaluating physical therapist or principal investigator.
3. Other concomitant injury of the leg.
4. Prior history of knee surgery.
5. Red flags present for non-musculoskeletal involvement (bowel/bladder problems, saddle anesthesia, progressive neurological deficits, recent fever or infection, unexplained weight loss, unable to change symptoms with mechanical testing).
6. Numbness and tingling in any lumbar dermatome.

Healthy Cohort

Specific inclusion criteria

1. Age between 12 and 17 years.
2. No history of lower quarter injury in the past 12 months.

Specific exclusion criteria

1. Prior history of surgery in the lower extremity.
2. Neurologic or developmental disorder which alters lower extremity function.
3. Red flags present (bowel/bladder problems, saddle anesthesia, progressive neurological deficits, recent fever or infection, unexplained weight loss, unable to change symptoms with mechanical testing).
4. Numbness and tingling in any lumbar dermatome

Screening of Pain-Related Fear

All patients treated at Nationwide Children's Hospital Sports and Orthopedic Physical Therapy clinics complete intake questionnaires when treatment begins. The FABQ-PA was given to all patients who reported AKP symptoms. This intake FABQ-PA score was used to determine the participant's eligibility for Research Question 2. Individuals with elevated fear avoidance beliefs ($\geq$14/24), and those with low fear avoidance beliefs ($\leq$10/24), were offered the opportunity to also participate in research question 2 (3-dimensional biomechanical analysis of movement). Participants could still participate in research questions 1 and 3 if they declined to participate in the biomechanical analysis. Individuals who met the elevated or low fear avoidance criteria were offered the opportunity to participate in research question 2, until 10 participants in each group were recruited.

Data Collection with REDcap Software and iPad interface

Demographic, psychological beliefs, pain, and self-reported function data were collected using Research Electronic Data Capture (REDcap) on an iPad. Electronic survey collection ensured protection of personal health information (PHI) while traveling between clinics, as well as legibility of answers, and that all answers were reported prior to completion. This data was

used in research question 1, 2, and 3. The same REDcap system was also used to email the family follow-up surveys for research question 3.

Variables

Participant Demographic and Pain/Function/Physical Activity Profile

Demographic data were collected on each participant including their age, sex, and body mass index (BMI). For the AKP cohort we collected the duration of knee pain, and knee injured (R, L, Bilateral). Additionally, a physical activity profile was created for each participant, and the Tegner Activity Scale and the Marx Activity Rating Scale were used to provide a standardized method of grading the participant's level of work and sporting activities.(130, 131) Furthermore, we asked the participant if they participate in organized sport (If so, which sport/s)?

Participants answered questions about their current pain and functional ability. Pain was assessed using the Numeric Pain Rating Scale (NPRS). The NPRS is an 11-point pain-rating scale ranging from 0 (no pain) to 10 (worst imaginable pain) used to assess the patient's highest knee pain in the past 24 hours.(132) The NPRS has a minimal clinically important difference of 1.2 points among individuals 12-50 years with AKP.(133) The participant's functional ability was assessed using the Anterior Knee Pain Scale (AKPS). The Anterior Knee Pain Scale, a 13-item self-report questionnaire assessing current knee function and symptoms. The AKPS is scored 0-100, with 100 representing no disability. The AKPS has a minimal clinically important difference of 10 points and has been found to have excellent validity and reliability among individuals 12-50 years with AKP.(134, 135)

Psychological Variables

The primary psychological variable of interest in this dissertation was fear-avoidance beliefs, as measured by the Fear-Avoidance Beliefs Questionnaire-Physical Activity subscale (FABQ-PA). Use of the FABQ-PA subscale quantified the patient's fear of pain and beliefs about avoiding activity. (89) The FABQ-PA is a 5-item self-report questionnaire. Items 2-5 are scored 0-6, with higher scores representing higher levels of fear-avoidance beliefs (0-24). As other psychological factors may also be associated with pain and function, we also assessed pain catastrophizing (Pain Catastrophizing Scale-Child), fear of movement (Tampa Scale for Kinesiophobia), stress (Perceived Stress Scale-10), anxiety (PROMIS Anxiety), and depression (PROMIS Depression) as secondary variables of interest. The participant's parent or guardian completed the parental equivalent of each of the above psychological measures. For a detailed description of these measures, please refer to the Psychological Assessment section in Chapter 2.

Research Question 1 Specific Procedures and Variables

Research question 1 assessed if psychological factors are associated with pain, self-reported function, and clinical measures of physical impairment and performance. Measures of physical impairment and performance were chosen for their applicability to AKP and their ability to be used in most clinic situations.

Flexibility

Flexibility testing assessed the quadriceps muscle and weight-bearing dorsiflexion. Quadriceps flexibility and weight-bearing dorsiflexion motion were assessed using an Accumar digital inclinometer. The average measurement of two trials with a 5-second pause between trials was recorded.

Quadriceps flexibility testing (FIGURE 3.1): Quadriceps muscle length was assessed with the participant lying in prone on the table while the investigator locked the hips into place by pushing down on the PSIS region. The investigator passively flexed the participant's knee to end range and recorded the measurement. The inclinometer was placed over the distal tibia. The intra-rater reliability of this measurement is excellent with a reliability coefficient of 0.91 (95% CI 0.80, 0.96) in individuals with AKP.(136)

FIGURE 3.1 Quadriceps Flexibility Testing

Weight-bearing dorsiflexion testing (FIGURE 3.2): Weight-bearing dorsiflexion was measured using the lunge test.(137) The participant lunged with the tested lower extremity in front, bringing the affected patella as close to a wall as possible without either heel coming up off the floor. The digital inclinometer was placed 1 cm distal to the tibial tuberosity. The measurement was taken once maximum dorsiflexion was reached. The intra-rater reliability of this measurement is excellent, with a reliability coefficient of 0.96 (95% CI 0.89, 0.98) and a minimal detectable change of 3.8 degrees.(137)

FIGURE 3.2 Weight-bearing dorsiflexion testing

Strength

Muscle strength was quantified for hip abduction and knee extension with hand-held dynamometry. The participant exerted a maximal isometric contraction against the padded buttress of the dynamometer. The average force of 2 trials with a 30 second rest was recorded. If there was a greater than 10% difference between the two trials, a third trial was performed with the lowest value dropped. The average maximal contraction was expressed as a percentage of the participant's body weight.

$$\frac{\text{Average maximal contraction (Kg)}}{\text{Body weight (Kg)}} = \text{Weight adjusted force}$$

Hip abduction setup: Hip abduction strength was tested with the participant side-lying with the tested side up. The contralateral hip and knee joints were positioned at approximately 30 degrees

of flexion for stability and comfort. The knee of the tested limb was fully extended and the hip was positioned in approximately 10º of abduction. The dynamometer pad was located proximal (~5 cm) to the lateral malleolus.(15) The examiner inspected the whole body position during the maximal voluntary contraction trials, in order to ensure minimal compensation from pelvic rotation and flexion and rotation about the hip. If the examiner judged there was too much compensation, that test was not recorded, and the participant was reinstructed in proper testing form.

Seated quadriceps setup: To assess knee extensor strength, participants were seated with their knee positioned at 90º of flexion. The dynamometer pad was positioned perpendicular to the anterior aspect of the tibia, 5 cm proximal of the medial malleolus. As the examiner's strength can adversely affect the accuracy of handheld dynamometry, the dynamometer was held in place with straps affixed to the treatment table.(138)

Performance

Lateral-step-down test (FIGURE 3.3): The lateral-step-down test was performed by having the participant stand on a 20cm (8 inch) step with one leg and perform a squat to approximately 60º of knee flexion. The participant was instructed to keep their hands on their waist and keep their knee over the second toe while squatting.

Participants repeated the lateral step down five times. Quality of movement of the lateral step-down test was scored based on criteria previously reported in literature (Table 3.1).(66, 136) The lateral-step-down test using this scoring system demonstrates an acceptable intra-rater reliability (Kappa 0.67) among individuals with AKP.(136)

FIGURE 3.3 Lateral Step Down Test

TABLE 3.1 Alignment testing scoring

Criterion Interpretation		**Score**
Arm strategy	Removal of a hand off the waist	1
Trunk alignment	Leaning in any direction	1
Pelvis plane	Loss of horizontal plane	1
Knee position	Tibial tuberosity medial to second toe Tibial tuberosity medial to medial border of foot	1 2
Steady stance	Subject stepped down on non-tested limb, or foot wavered from side-to-side	1
Total Score: 0-6		/6

Single Leg Hop for Distance: The participant was instructed to perform a single leg hop as far as possible while landing safely on the same limb and stabilizing for 1 second. Distance was measured to the nearest centimeter on a standard measuring tape affixed to the floor. Two trials were performed on each leg with the longest distance used.(139)

Sample Size Estimation

Sample size estimates were based on correlation statistical tests using alpha=0.05. A sample size of 85 participants was calculated to provide sufficient statistical power (80%) to detect a mild correlation between psychological factors and clinical tests of physical impairment ($r = 0.3$).

Data Analysis

Statistical analyses were made using IBM® SPSS® (Statistical Package for the Social Sciences) 24.0 software (IBM Corporation, Armonk, NY). Descriptive statistics were calculated for demographic and baseline variables. There were no missing data that needed to be accounted for among the participants. To test the hypothesis of the primary aim, Spearman's correlation coefficients were used to describe the association between psychological variables and measures of pain and function. Statistical significance was established *a priori* ($\alpha < 0.05$) with a Holm's Sequential Bonferroni correction (24 comparisons) utilized to account for multiplicity of tests as necessary.(140) The adjusted statistical significance ranged from $\alpha \leq 0.0021$ to $\alpha \leq 0.0028$. To test the hypothesis that these psychological characteristics provide further information about the participant's function after demographic and physical factors associated with AKP are accounted for, a two-stage hierarchical regression analysis was performed. Self-reported function was the dependent variable. In the first block, factors commonly associated with AKP were entered, including sex, pain, quadriceps strength, quadriceps flexibility, and hip abduction strength. In the second block the participant's FABQ-PA, TSK-11 and PCS-c scores were entered. The secondary aim was assessed using Spearman's correlation coefficients to describe the association between parent psychological beliefs, participant psychological beliefs, pain, and function.

Research Question 2 Specific Procedures and Variables

Group Allocation

We recruited 30 participants in total. Potential participants completed self-report psychological questionnaires on pain-related fear at baseline. Participants who had elevated pain-related fear (FABQ-PA $\geq$ 14) were placed into the elevated maladaptive beliefs group. Another group (low maladaptive beliefs group) were comprised of participants with low activity-related fear (FABQ-PA $\leq$ 10).(84) Ten healthy adolescent participants were recruited to serve as a control group completing the biomechanical analysis.

Motion Analysis Testing

Three-dimensional motion analysis was used to quantify each participant's movement patterns and knee biomechanics during dynamic activities. Kinematic data were collected using 22 OptiTrack cameras (NaturalPoint, Inc., Corvallis OR) and ground reaction forces were collected using 4 AMTI force plates (Advanced Mechanical Technology Inc., Watertown, MA). Motion capture and force plate data were synchronized. The motion analysis data was exported for subsequent analysis in Visual3D software (C-Motion, Germantown, MD). Knee joint moments were calculated using standard inverse dynamics equations and were reported as raw (Nm) and normalized to mass × height (Nm / (kg × m)) data. Peak knee abduction moment was the primary biomechanical variable of interest as it has been demonstrated as a risk factor for AKP and adolescents with greater knee abduction moments during landing are at increased risk.(141, 142)

Marker Setup

Individual retro-reflective spherical markers (61 markers) were attached to the trunk and pelvis and bilaterally over the upper and lower extremities. (Figure 3.4, and 3.5) Anatomical and

tracking markers were used to calculate lower extremity joint centers and track segment motion during the single leg hop task. The hip joint centers were determined functionally with the star-arc method.(143) The knee joint centers were calculated as the midpoint between the medial and lateral femoral condyles, and ankle joint centers were calculated at the midpoint between the medial and lateral malleolus. A static model was created based on anatomical marker placements, with the long axis of the thigh determined as the line from the knee joint center to hip joint center, medio-lateral axis as the line perpendicular to the long axis along the line between medial and lateral femoral condyles, and the antero-posterior axis normal to the long and medio-lateral axes. The shank was defined in a similar manner, with the long axis as the line from ankle joint center to knee joint center, medio-lateral axis defined as the line from the medial and lateral malleoli and perpendicular to the long axis, and the antero-posterior axis normal to the long and medio-lateral axes.

FIGURE 3.4. Marker Setup on a participant

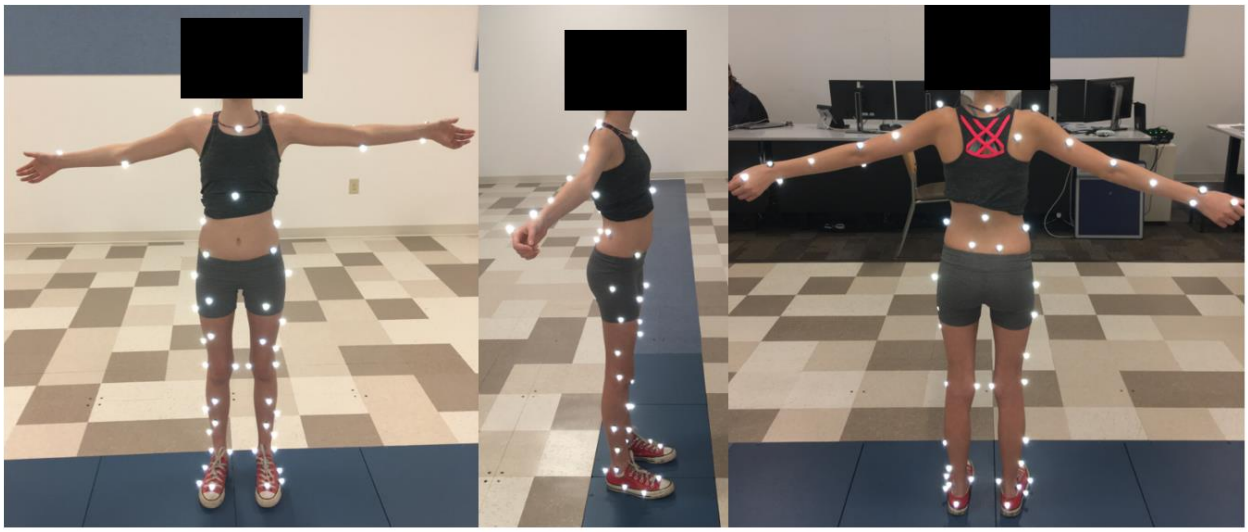
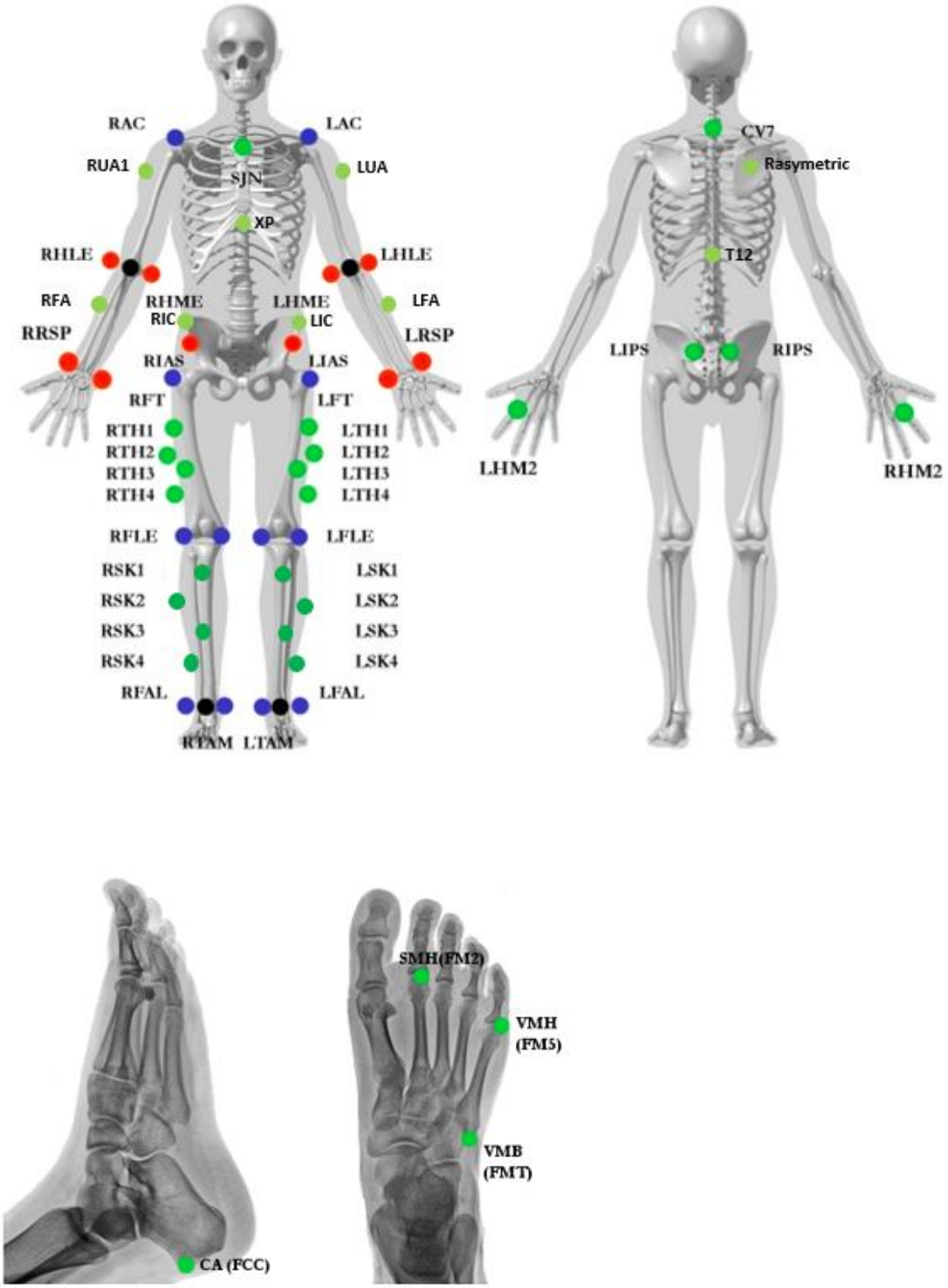


FIGURE 3.5. Marker placement



Motion Analysis Activities

Participants performed a single-leg hop for distance task. Single-leg hop for distance: The participant was instructed to perform a single leg hop as far as possible while being able to land safely on the same limb and stabilizing for 1 second. Peak knee abduction moments were quantified during the deceleration phase of landing. The deceleration phase was operationally defined from initial contact to the lowest vertical position of the body's center of mass.

Sample Size Estimation

Research question #2 was an exploratory analysis with the goal to detect trends and areas for future research. We recruited injured and healthy participants into 3 groups (elevated psychological beliefs, low psychological beliefs, healthy controls) with 10 participants in each group for a total of 30 participants.(144)

Data Analysis

All statistical analyses were performed with IBM SPSS (v 24, SPSS Inc., Chicago, IL). Descriptive statistics were used to describe the participants baseline demographics and characteristics. To test the hypothesis that adolescents with elevated maladaptive beliefs demonstrate greater peak knee abduction moments during a single leg hop task compared with the low maladaptive beliefs and healthy control groups, a Kruskal-Wallis test was performed. Additional Kruskal-Wallis tests were performed to assess between group differences in the secondary variables of interest. Post-hoc Mann-Whitney U tests were performed to determine specific between-group differences.

Research Question 3 Specific Procedures and Variables

Design

We assessed research question 3 using a prospective randomized controlled trial design. Participants completed the randomized intervention immediately after completing research question 1. Post-intervention testing was also completed in the same session. A follow-up REDcap survey was sent by email to assess function, and pain 2 weeks and 6 weeks later.

Intervention

Psychologically Informed Education Medium

There are many ways to provide psychologically-informed education, but we believed that adolescents would respond well to video education on an iPad. Adolescents are extremely comfortable with this technology, and the video allowed for standardized education among all participants.

Intervention: Psychologically-Informed Video

The psychologically-informed video was created through collaboration with a physical therapist and clinical psychologist. The physical therapist had 10 years' experience treating adolescents with AKP and has training and experience addressing psychological beliefs in this population. The clinical psychologist had advanced training and expertise in non-pharmacological interventions for pain management. In addition to completing a pain-focused postdoctoral fellowship in pediatric psychology, the psychologist has over ten years of experience working in pain research. To ensure that the information was provided at a level that was understandable for all adolescent participants, the narrator's script was written at a 6th grade reading level. Four physical therapists with experience in treating AKP (2) and specific training in pain neuroscience education (2) reviewed the video and provided feedback. Additional

feedback on the video was provided from the first five participants and minor modifications were made to remove confusing transitions, but there were no changes in content. The resulting psychologically-informed video was 8 minutes and 30 seconds long.

The psychologically-informed video addressed pain-related fear and pain catastrophizing using the "Common Sense Model of Self-Regulation" framework. This framework advocates for information to address five cognitive dimensions: (1) identity (the effort to evaluate symptoms and label the illness); (2) cause (the subjectively formulated belief of what is causing the symptoms); (3) time-line (the patient's perception of how long the problem will last); (4) consequences (the patient's predictions of how the illness will affect them in different areas of their life); and (5) controllability (the patient's belief regarding their outcome and personal ability to change it).(145) Additionally, the video provided participants components of pain neuroscience education, with information on how their body processes nociception, experiences pain, and the concept that pain does not always mean tissues are being damaged. Recommended adult pain neuroscience education was modified using published recommendations for the adolescent population and tailored to AKP.(119)

Key information provided in the psychologically-informed video addressed each part of the five cognitive dimensions listed above as follows. 1) First, the video explained that although their diagnosis may sound complicated, it should not be scary, and provided an overview of AKP in easy to understand terms. 2) The video explained that AKP can be from too much stress, both from patellofemoral joint stressors and psychological stressors. 3) It then provided a timeline, telling participants that through exercise and by modifying activity many adolescents can greatly reduce their pain and improve function within a month.(82-84) 4) However, if left unaddressed, the pain for some can last for months or even years. 5) Finally, the video related that many of

the stressors which contribute to AKP can be controlled by the adolescent and ends by providing a few simple tips to help reduce these stressors.

Control Group

Participants in the control group watched a video on the iPad equal in length to the psychologically-informed education video. The control video discussed basic anatomy of the knee and provided no psychological education or positive reinforcement about their condition.

Outcomes

The primary outcome measure used in this research question was change in Anterior Knee Pain Scale (AKPS). Secondary outcomes included change in the Numeric Pain Rating Scale (NPRS). Each measure was collected at baseline, 2 weeks, and at 6 weeks.

Randomization and Blinding

Research question 3 was a double-blinded randomized controlled trial. The participants knew they were watching an educational video, but were not made aware if it was the control or experimental video. The study staff and treating physical therapists were blinded to group allocation until all measurements were completed. Randomization was performed using a computer-generated list, which was created by an individual not involved in the study using the website www.randomizer.org. The computer-generated list was uploaded to the REDcap system, which allowed participants to watch the allocated video while keeping the study staff blinded.

Sample Size Estimation

Sample size estimates were based on anticipated differences necessary to detect clinically important change using the Anterior Knee Pain Scale. Sample size calculations were made using alpha=0.05, a minimal clinically important difference of 10, and a within-group standard deviation (SD) of 12.4.(135, 146) Assuming a dropout rate of 10%, a sample size of 28

participants in each group was calculated to provide sufficient statistical power (80%) to detect a meaningful between-group difference.

Data Analysis

Statistical analyses were made using IBM® SPSS® (Statistical Package for the Social Sciences) 24.0 software (IBM Corporation, Armonk, NY). An intent-to-treat design with the multiple-imputation model was used for any missing values due to patient drop-out.(147) Descriptive statistics were calculated for demographic and baseline variables. To ensure the intervention worked as anticipated, change in psychological beliefs (FABQ-PA, TSK-11, and PCS-c) were assessed with a two-way multivariate analysis of variance (MANOVA). The test the hypothesis of study's primary aim a two-way mixed analysis of variance (ANOVA) was performed, with the treatment group as the between-subject variable and time as the within-subject variable. The dependent variable for the primary objective was the Anterior Knee Pain Scale score. Effect size for the Anterior Knee Pain Scale was assessed using partial η^2. A partial $\eta^2 = 0.01$ is considered small, 0.1 is medium, and 0.25 is a large treatment effect.(148) Post-hoc univariate testing was performed to assess the interaction and between group differences at 2 weeks and 6 weeks, as well as the change in function over the 6 weeks. To test the hypothesis of the study's secondary aim, a two-way mixed ANOVA was performed to assess between group differences in pain over time.

Resource Requirements

The major resource requirements to complete this dissertation were as follows: iPads, digital inclinometer, dynamometer, motion analysis lab, and patient honorarium. Nationwide Children's Hospital supported this study by providing all resources not supplied through external grant funding. iPads were used to collect participant

information and self-report measures. Using electronic methods of data collection helped decrease transcription errors, avoid lost surveys, and protect participant information. Additionally, research question 3 required an iPad for participants to watch the psychologically-informed education video or control video. Clinical testing of physical impairments were performed using an Accumar digital inclinometer, tape measure, and MicroFET2™ hand-held dynamometer. Research question 2 required access and use of a motion analysis lab to complete. Nationwide Children's Hospital had a motion analysis lab and the PI was able to access the lab to perform the proposed research. The lab had 22 OptiTrack cameras (20 infrared motion capture cameras and 2 color cameras), and 4 AMTI force plates. Processing of motion capture data was performed using Motive and Visual 3d software. A biomechanical engineer assisted to ensure proper data collection. In addition, this study received grant funding from the Ohio Physical Therapy Association Research Grant and internal funding from Nationwide Children's Hospital. This funding was used to provide participants an honorarium to help facilitate effective recruitment and retention of participants and to help cover the lab cost for motion analysis testing.

CHAPTER FOUR

This chapter presents the first of the four manuscripts that were prepared based on the results of this dissertation study. The status of the manuscript is published. The full citation is:

Selhorst M, Hoehn J, Degenhart T, Schmitt L, Fernandez-Fernandez A. Psychologically-informed video reduces maladaptive beliefs in adolescents with patellofemoral pain. Phys Ther Sport. 2019; 41:23-8.

Psychologically-Informed Video Reduces Maladaptive Beliefs in Adolescents with Patellofemoral Pain.

Contribution of Authors and Co-Authors

Author: Mitchell Selhorst

Contributions: Conceived and implemented the study design. Collected and analyzed data. Wrote first draft of the manuscript.

Co-Author: Jessica Hoehn

Contributions: Helped conceive study design and study intervention. Provided feedback on statistical analyses and early drafts of the manuscript.

Co-Author: Todd Degenhart

Contributions: Provided expert feedback on study intervention and relationship in context to larger field of pain science. Provided feedback on early drafts of the manuscript.

Co-Author: Laura Schmitt

Contributions: Helped conceive study design. Provided feedback on early drafts of the manuscript.

Co-Author: Alicia Fernandez-Fernandez

Contributions: Helped conceive study design. Provided feedback on statistical analyses and early drafts of the manuscript.

*Published here with permission from Physical Therapy in Sport. At the request of Physical Therapy in Sport which published this manuscript, Anterior Knee Pain (AKP) has been replaced with Patellofemoral Pain (PFP).

INTRODUCTION

Patellofemoral Pain (PFP) represents the most common complaint of the knee, and is one of the most frequently reported musculoskeletal complaints in adolescent patients.(4) PFP is characterized by pain in or around the patellofemoral joint during weight bearing on a flexed knee without observable cartilage damage.(29, 149) Although prevalent among young adults who are between the ages of 18 and 35 years,(32) PFP is most common among adolescents, affecting 6-7% of adolescents.(1-5)

A common misconception is that PFP is benign and self-limiting, particularly in adolescence.(34) PFP has a pronounced functional impact, reducing an individual's ability to participate in sports, recreation, and even daily activities.(6, 7) Rathleff et al(7) found that 65% of adolescents reported pain and dysfunction two years later, while Stathopulu and Baildam(6) found that 91% reported patellofemoral symptoms 4 to 18 years after initial diagnosis. Moreover, several studies (6, 7, 34, 35) have shown that even after treatment, most individuals still report pain and functional limitations.

The etiology of PFP is multifactorial, and the interactions of the proposed risk factors and PFP remain unclear.(150) The most commonly accepted theoretical model is that abnormal loading of the patellofemoral joint results in elevated stress through the patellofemoral joint.(150) There is however, a distinct psychological component to PFP. Maladaptive psychological beliefs are associated with increased pain and reduced self-reported function among individuals with PFP.(11-14) The relationship between maladaptive beliefs and objective functional ability in individuals with PFP is unclear, with two studies(19, 20) finding a relationship between maladaptive beliefs and objective function and a third study(21) finding no relationship. Common maladaptive psychological beliefs include pain-related fear and pain

catastrophizing.(11, 84) Successfully addressing these maladaptive beliefs may be an important facet of treating adolescents with PFP. Currently, there is no randomized controlled trial that investigated psychological factors as a primary outcome in PFP population.(151)

As PFP is largely treated with physical interventions that may not address maladaptive psychological beliefs, there is a need for a concomitant intervention that can effectively and efficiently do so. Education has been shown to effectively reduce maladaptive psychological beliefs in other patient populations.(27) There are several challenges to creating a psychologically-informed intervention for adolescents with PFP. Firstly, the information must be provided at a level which is easily understood by this young population.(119) Secondly, the psychologically-informed intervention should be brief to keep the young patient's attention as well as leave sufficient time for important physical interventions. Finally, the intervention would ideally be one that can be implemented by all clinicians, not just those with advanced training.

The purpose of this study was to test the hypothesis that a brief psychologically-informed video can reduce maladaptive psychological beliefs in adolescents with PFP.

METHODS

Design

This study was a prospective case series performed in the outpatient physical therapy clinics of a pediatric hospital. Adolescents who reported pain in their anterior knee from March 2019 through April 2019 were considered for participation. The institutional review board approved this study prior to recruitment and data collection. All patients and guardians provided written informed consent prior to participation. Participants completed a research study session and then continued with traditional physical therapy focusing on exercises to improve flexibility, strength and neuromuscular control two sessions per week.

Participants

Patients were included if they were an adolescent (aged 12- 17 years) who reported pain around or behind the patella, which was aggravated by at least one activity that loads the patellofemoral joint during weight bearing on a flexed knee (e.g., squatting, stair ambulation, jogging/running, hopping/jumping).(149) Patients were excluded if there was a 1) prior patellar dislocation, 2) suspicion of other diagnosis of the knee, 3) other concomitant injury of the lower quarter, 4) previous surgery in the lower quarter, 5) neurologic or developmental disorder which alters lower extremity function.

Intervention-Psychologically-Informed Video

The psychologically-informed video was created through collaboration with a physical therapist and clinical psychologist. The physical therapist had 10 years' experience treating adolescents with PFP and has training and experience addressing psychological beliefs in this population. The clinical psychologist had advanced training and expertise in non-pharmacological interventions for pain management. In addition to completing a pain-focused postdoctoral fellowship in pediatric psychology, the psychologist has over ten years of experience working in pain research. To ensure that the information was provided at a level that was understandable for all adolescent participants, the narrator's script was written at a 6^{th} grade reading level. Four physical therapists with experience in treating PFP (2) and specific training in pain neuroscience education (2) reviewed the video and provided feedback. Additional feedback on the video was provided from the first five participants and minor modifications were made to remove confusing transitions, but there were no changes in content. The resulting psychologically-informed video was 8 minutes and 30 seconds long.

The psychologically-informed video addressed pain-related fear and pain catastrophizing using the "Common Sense Model of Self-Regulation" framework. This framework advocates for information to address five cognitive dimensions: (1) identity (the effort to evaluate symptoms and label the illness); (2) cause (the subjectively formulated belief of what is causing the symptoms); (3) time-line (the patient's perception of how long the problem will last); (4) consequences (the patient's predictions of how the illness will affect them in different areas of their life); and (5) controllability (the patient's belief regarding their outcome and personal ability to change it).(145) Additionally, the video provided participants components of pain neuroscience education, with information on how their body processes nociception, experiences pain, and the concept that pain does not always mean tissues are being damaged. Recommended adult pain neuroscience education was modified using published recommendations for the adolescent population and tailored to patellofemoral pain.(119)

Key information provided in the psychologically-informed video addressed each part of the five cognitive dimensions listed above as follows. 1) First, the video explains that although their diagnosis may sound complicated, it should not be scary, and provides an overview of PFP in easy to understand terms. 2) The video explains that PFP can be from too much stress, both from patellofemoral joint stressors and psychological stressors. 3) It then provides a timeline, telling participants that through exercise and by modifying activity many adolescents can greatly reduce their pain and improve function within a month.(82-84) 4) However, if left unaddressed, the pain for some can last for months or even years. 5) Finally, the video relates that many of the stressors which contribute to PFP can be controlled by the adolescent and ends by providing a few simple tips to help reduce these stressors.

Self-report measures

The outcomes used in this study were self-report measures which were completed using an electronic data capture system (REDcap). The self-report measures were completed at baseline (pre-video intervention), immediately following the psychologically-informed video, and at a 2-week follow-up.

Participant Demographics

Demographic data was collected on each participant including their age, sex, and body mass index (BMI). Participants were asked the duration of their knee pain, and the knee injured (R, L, Bilateral). The participants were asked if they participate in organized sport. Additionally, the Tegner Activity Scale was used to provide a standardized method of grading the participant level of work and sporting activities.(130)

Function

The Anterior Knee Pain Scale, a 13-item self-report questionnaire, was used to assess participant's knee function and symptoms. The Anterior Knee Pain Scale is scored 0-100, with 100 representing no disability. The Anterior Knee Pain Scale has a minimal clinically important difference of 10 points and has been found to have excellent validity and reliability among individuals 12-50 years with patellofemoral joint dysfunction.(134, 135)

Pain

The Numeric Pain Rating Scale (NRPS), an 11-point pain-rating scale ranging from 0 (no pain) to 10 (worst imaginable pain), was used to assess the patient's highest knee pain in the past 24 hours.(132) The NRPS has a minimal clinically important difference of 1.2 points in this population.(133)

Psychological Beliefs

Pain catastrophizing and pain-related fear demonstrate the strongest and most consistent correlation with both pain and physical function among individuals with PFP.(11) Pain catastrophizing was assessed using the Pain Catastrophizing Scale-Child (PCS-c), while pain-related fear was assessed using the Modified Fear-Avoidance Beliefs Questionnaire-Physical Activity (FABQ-PA) subscale and the Tampa Scale for Kinesiophobia-11 (TSK-11). Significant change in these measures of maladaptive beliefs has yet to be established for this population, but based on other populations a 25% reduction on each scale was considered clinically meaningful improvement.(152)

The PCS-c is a 13-item self-report measure used to assess pain catastrophizing and has a test-retest reliability of r = 0.88 (95% CI 0.83 - 0.93).(153) Each item was rated on a 5-point scale, ranging from 0 (not at all) to 4 (all the time) and was summed to create a final score of 0-52, with higher scores indicating greater pain catastrophizing.(97) The FABQ-PA subscale quantified the patient's fear of pain and beliefs about avoiding activity.(89) The FABQ-PA is a 5-item self-report measure which assesses an individual's fear-avoidance of painful activity and was modified for the knee.(14) The FABQ-PA was modified by changing the word "back" to "knee" on the questionnaire.(14) Each item was scored on a 0-6 scale, with 0 indicating completely disagree and 6 indicating completely agree. Questions 2-5 were summed to create a final score of 0-24, with higher scores indicating greater pain-related fear. This measure has a test-retest reliability of r = 0.59-0.64 for individuals with musculoskeletal conditions.(90, 91) Elevated FABQ-PA scores in this population has been reported as $\geq$14.(84) The TSK-11 is an 11-item questionnaire that assessed fear of movement and re-injury. Patients were asked to make ratings of their degree of agreement with each of the 11 statements. Ratings range from 1

(strongly disagree) to 4 (strongly agree). The responses are summed to yield a total score of 44, where higher values reflect greater fear of injury due to movement.(93) The test-retest reliability of the TSK-11 has been reported as r = 0.81 (95% CI, 0.58-0.93).(94)

Sample Size

Sample size estimates were based on the anticipated differences necessary to detect a 25% reduction in maladaptive psychological beliefs. The FABQ-PA was used to determine the sample size for this study. Sample size calculations were made using alpha= 0.05, an anticipated initial group mean of 13.2 and a standard deviation of 5.8 on the FABQ-PA.(84) A sample size of 20 participants was calculated to provide sufficient statistical power (80%) to detect meaningful within-group difference.

Data Analysis

Statistical analyses were made using IBM® SPSS® (Statistical Package for the Social Sciences) Statistics 24.0 software (IBM Corporation, Armonk, NY), and statistical significance was established *a priori* ($\alpha \leq 0.05$). Descriptive statistics were calculated for demographic and baseline variables. Repeated-Measures Analysis of Variance (ANOVA) evaluated change in the PCS-c, FABQ-PA and TSK-11 over time (baseline, immediately post-intervention, and 2 weeks). To account for the multiple comparisons performed Bonferroni correction was used ($p < 0.05/3$). When the test statistic was significant, Bonferroni post-hoc pairwise comparisons were performed.

RESULTS

Twenty adolescent participants with PFP enrolled in this study. Post-intervention data was gathered immediately after the psychologically-informed video, as well as 2 weeks later. Three participants did not complete the 2-week assessment (FIGURE 4.1). Participant

demographics are presented in **TABLE 4.1**. Half of the participants (n=10) were considered to have chronic PFP, reporting symptoms duration longer than 3 months.

FIGURE 4.1. Participant Flow Diagram

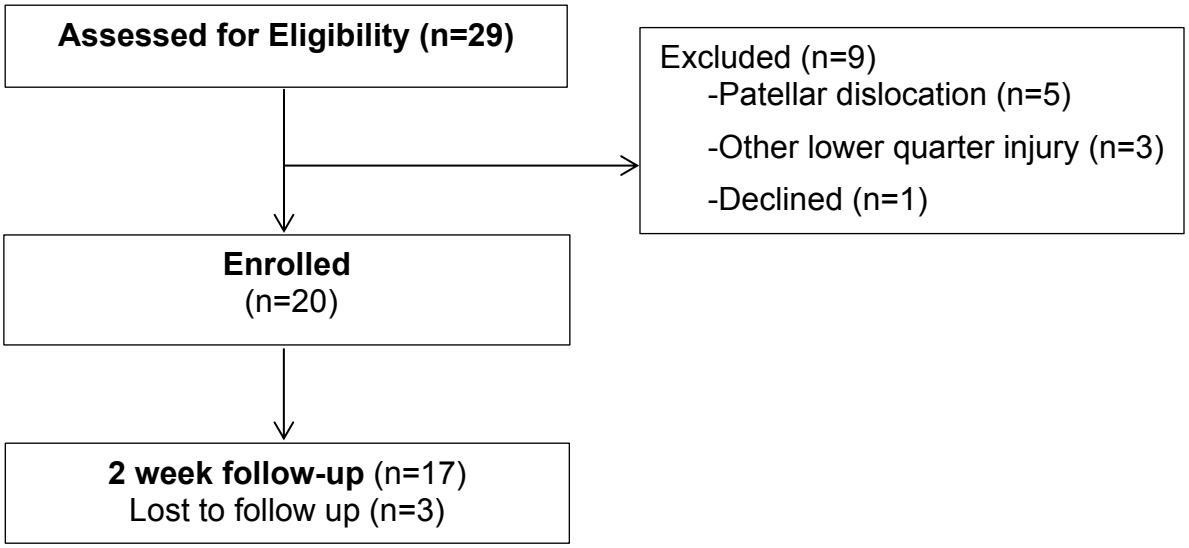


TABLE 4.1. Participant Demographics

	All Patients (n=20)
Age (years)	14.1 ± 2.4
Sex (% female)	10 (50%)
Body mass index (kg/m^2)	22.4 ± 4.4
Duration of symptoms (weeks)*	12 (6-25)
Bilateral knee pain (% yes)	6 (30%)
Participates in organized sport (% yes)	19 (95%)
Tegner Activity Level	7.5 ± 1.7
Highest pain in past 24 hours (0-10 NPRS)	4.0 ± 2.4
Anterior Knee Pain Scale	76.9 ± 13.3

Values are mean ± SD unless otherwise indicated
*median (interquartile range)

Repeated measures ANOVA determined that FABQ-PA differed statistically significantly between time points ($F=20.85$, $p<0.001$), with a large effect (partial $\eta^2= 0.57$). Post hoc tests using the Bonferroni correction revealed statistically significant reductions both immediately ($p = 0.001$ and at 2 weeks ($p<0.001$), however there was not a statistically

significant reduction from post-video to 2 weeks (p =0.23). A statistically significantly difference between time points was noted on the TSK-11 (F=26.10, p <0.001), with a large effect (partial η^2= 0.62). Post hoc tests revealed statistically significant reductions in the TSK-11 both immediately (p = 0.002 and at 2 weeks (p <0.001), and continued statistically significant reductions from post-video to 2 weeks were noted as well (p =0.02). Repeated measures ANOVA determined that PCS-c differed statistically significantly between time points (F=11.36, p <0.001), with a large effect (partial η^2= 0.42). Post hoc tests revealed statistically significant reductions in the TSK-11 both immediately (p = 0.002 and at 2 weeks (p <0.001), and continued statistically significant reductions from post-video to 2 weeks were noted as well (p =0.02). Clinically meaningful improvement was observed in the FABQ-PA (mean difference = 4.52, 95% CI 1.99, 7.07) and PCS-c (mean difference = 3.65, 95% CI 0.62, 6.68) immediately following the psychologically-informed video. The TSK-11 did not quite reach clinically significant improvement immediately with a 22% reduction (mean difference = 5.06, 95% CI 1.88, 8.24). By the two-week follow-up, clinically meaningful improvement was noted in the FABQ-PA (mean difference = 6.24, 95% CI 3.22, 9.26), PCS-c (mean difference = 6.59, 95% CI 1.93, 11.25), and TSK-11 (mean difference = 7.41, 95% CI 4.31, 10.51) **TABLE 4.2**.

TABLE 4.2. Change in Maladaptive Beliefs over Time

	Baseline (n=20)	Immediate Post Video (n=20)	2 weeks (n=17)	P value
PCS-c	14.3 ± 8.2	10.7 ± 8.5 (26% reduction)*	7.6 ± 6.5 (47% reduction)*	<0.001
FABQ-PA	12.0 ± 5.4	7.9 ± 5.3 (32% reduction)*	5.5 ± 4.8 (54% reduction)*	<0.001
TSK-11	22.1 ± 4.0	17.4 ± 4.5 (22% reduction)	14.7 ± 3.3 (33% reduction)*	<0.001

PCS-c, Pain Catastrophizing Scale-Chile; FABQ-PA, Fear Avoidance Beliefs Questionnaire-Physical Activity; TSK-11, Tampa Scale for Kinesiophobia-11
*Clinically meaningful change observed

Not all participants had an immediate significant reduction in maladaptive psychological beliefs. Twelve participants (60%) demonstrated a clinically meaningful reduction on the FABQ-PA immediately after the psychologically-informed video intervention. While four (20%) participants demonstrated improvement which did not achieve clinical significance, three (15%) participants demonstrated no change in their FABQ-PA score, and one participant scored a 0 at baseline and 0 immediately post intervention. On the PCS-c, 11 participants (55%) demonstrated a clinically meaningful reduction. Six participants (30%) demonstrated improvement which did not achieve clinical significance, and 3 (15%) participants demonstrated no change in their PCS-c score. Twelve participants (60%) demonstrated a clinically meaningful reduction on the TSK-11, while four participants (20%) demonstrated improvement which did not achieve clinical significance, and four (20%) participants demonstrated no change in their TSK-11 score.

Immediate changes in pain and functional ability were not assessed, but improvements were noted at 2 weeks. Participants improved a mean 7.5 points on the AKPS (84.4 ± 14.0) (p value = 0.01) and 2.1 points on the NPRS (1.8 ± 1.9) (p value <0.01). The improvement in functional ability was statistically significant, but was not clinically significant while the improvement in pain was both statistically and clinically significant. During this time, participants also received standard physical therapy interventions.

DISCUSSION

Emerging evidence suggests that when treating individuals with PFP, psychological factors and pain sensitization should be addressed.(154-157) Anxiety, depression, pain catastrophizing, and pain-related fear have been found to be elevated among individuals with PFP, and a positive correlation has been identified between patellofemoral symptoms and pain

catastrophizing and pain-related fear.(11) The current study found that after viewing the psychologically-informed video, most adolescents with PFP had immediate reductions in pain catastrophizing and fear-avoidance beliefs, and these reductions were sustained over a period of 2 weeks, when combined with continued physical therapy intervention.

There are many ways to provide information to attempt to address maladaptive psychological beliefs including one-on-one educational sessions, pamphlets, books and videos.(27) We chose to provide the psychologically-informed intervention by video for multiple reasons. We found that adolescents responded well to video on a tablet, as many adolescents are extremely comfortable with this technology. Use of a video format allows for standardized information across all participants. Additionally, videos allow for other clinicians to easily replicate the psychologically-informed intervention.

This study suggests that psychologically-informed information, including pain neuroscience education, can be understood by adolescents as young as 12 years and may reduce maladaptive beliefs. These findings are consistent with other studies in the adolescent population. Louw et al(129) found that a one-time education lecture to middle school children significantly increased their knowledge of pain. In a study of adolescents with chronic neck pain, pain neuroscience education and exercise was found to significantly increase knowledge of pain neurophysiology.(25) It is not currently known if a better understanding of pain neuroscience translates to improvements in function or pain in the adolescent population.

Change in these maladaptive psychological beliefs are strongly associated with change in pain and dysfunction among individuals with patellofemoral symptoms.(12, 14) Piva et al(14, 15) found that change in fear-avoidance beliefs (FABQ-PA) was predictive of change in pain and

function, even more so than change in any physical impairments. Additionally, Domenech et al (160) noted that change in pain catastrophizing significantly predicted change in an individual's reported pain. However, there is disagreement if educational interventions designed to address maladaptive psychological beliefs actually improve clinical outcomes. In a recent systematic review, pain neuroscience education was found to improve pain catastrophizing, fear-avoidance, pain ratings, pain knowledge, and disability.(27) In contrast, Traeger et al(158) found that intensive patient education was no more effective than placebo education for individuals with acute low back pain.

Recently, recommendations regarding the best care of individuals with PFP have been released.(28, 53) Both the Patellofemoral Pain Clinical Practice Guidelines(28) and the 2018 Consensus Statement from the Patellofemoral Pain Research Retreat(53) regards exercise therapy as the intervention of choice to treat PFP. Both sets of recommendations advocate for combined interventions when treating individuals with PFP, including foot orthoses, patellar taping, manual therapy, and lower extremity stretching.(28, 53) As it is currently unclear if reducing maladaptive beliefs is effective at improving clinical outcomes in adolescents with PFP, it is not known if this psychologically-informed video adds to the current best care.

Our understanding of the association between psychological beliefs and musculoskeletal conditions continues to grow. A brief psychologically-informed video such as the one used in this study, which does not represent a significant cost or time investment (~8 minutes), may represent a viable first-line method of addressing maladaptive psychological beliefs. Although the creation of these psychologically-informed videos should be reserved for those with specialized training, this intervention could be implemented by any clinician regardless of specialized training level. The concepts introduced in this informational video could be

reinforced by clinicians throughout the plan of care and in their interactions with the patient.(159) At this time however, the psychologically-informed video used in this study is not available for clinicians to view. Some individuals may likely benefit from continued traditional individualized interventions, such as cognitive behavioral therapy or more in-depth pain neuroscience education, particularly among adolescents with chronic pain or excessively elevated maladaptive psychological beliefs.

Limitations

This study was a case-series design with no control group and was designed to assess the effect of a psychologically-informed video on maladaptive beliefs, and not its effect on pain and functional ability. The immediate reductions in pain catastrophizing and pain-related fear may likely be attributed to the psychologically-informed video. However, it is unclear if the continued reductions in maladaptive beliefs or the improvements in pain and function observed at two weeks are a result of the video. The participants continued with a physical therapy plan of care as well as home exercises after they completed the research study session, and this likely had an impact on the 2-week follow-up data, particularly as it relates to pain and function. Adolescents with PFP have been shown to improve in the areas of pain-related fear, pain and function through physical therapy without psychological education.(14, 84) Additionally, we used both the FABQ-PA and the TSK-11 to measure maladaptive beliefs as both kinesiophobia and fear-avoidance beliefs have been shown to be associated with PFP.(13, 160, 161) However, these measures have not been specifically validated in the adolescent population. Finally, the results of this study can only be applied to the adolescent population as there are likely significant psychological differences between adult and adolescent patients.

Future research should assess the effectiveness of this psychologically-informed intervention on pain, self-reported function, and clinical measures of physical performance in this population through randomized controlled design.

Conclusion

This study provides preliminary evidence that incorporating a brief one-time psychologically-informed video into standard physical therapy care can significantly reduce maladaptive psychological beliefs in adolescents with PFP. Continued psychological intervention may likely be necessary, particularly among adolescents with chronic pain or excessively elevated maladaptive psychological beliefs.

This chapter presents the second of the four manuscripts that were prepared based on the results of this dissertation study. The status of the manuscript is under review.

CHAPTER FIVE

Adolescent Psychological Beliefs but Not Parent Beliefs Associated with Pain and Function in Adolescents with Anterior Knee Pain.

Contribution of Authors and Co-Authors

Author: Mitchell Selhorst

Contributions: Conceived and implemented the study design. Collected and analyzed data. Wrote first draft of the manuscript.

Co-Author: Jessica Hoehn

Contributions: Helped conceive study design. Provided feedback on statistical analyses and early drafts of the manuscript.

Co-Author: Laura Schmitt

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Co-Author: Alicia Fernandez-Fernandez

Contributions: Helped conceive study design. Provided feedback on statistical analyses and early drafts of the manuscript.

INTRODUCTION

Anterior knee pain (AKP) is one of the most common musculoskeletal complaints reported among adolescents, affecting 6-10% of all adolescents.(1-5) AKP results in decreased ability to participate in sports, recreation, and even daily activities.(6, 7) A common misconception is that AKP is benign and self-limiting, particularly in adolescence. Several studies have shown that this is not the case, as even after receiving treatment, many adolescents continue to have pain and disability, (1, 2, 8-10) and up to 91% of patients with AKP report persistent or recurring pain that lasts for years despite intervention.(6, 7)

Psychological beliefs have recently been shown to impact self-report measures of pain and function among adults with AKP.(11) Adults with AKP may have elevated anxiety, depression, pain catastrophizing, and pain-related fear, which correlate with increased pain and reduced function.(12-16) In a recent systematic review, Maclachlan et al.(11) reported that pain catastrophizing and pain-related fear were the psychological factors which demonstrated the strongest and most consistent correlation with pain and dysfunction among adults with AKP. Pain catastrophizing describes a maladaptive cognitive style with an irrational negative forecast of future events regarding pain, originally observed in patients with anxiety and depressive disorders.(17) Pain-related fear can be assessed by measuring fear-avoidance beliefs and kinesiophobia. Individuals are motivated to avoid activities in which they have experienced pain in order to reduce the likelihood of re-experiencing pain or causing further physical damage. (18) This fear is an adaptive behavioral strategy for dealing with situations involving acute pain, but pain-related fear can become maladaptive.(18)

Psychological beliefs have been found to be associated with self-reports of pain and function, however, the association between psychological beliefs and objective measures of

functional ability in individuals with AKP is unclear. Self-report measures of functional ability in AKP are based upon the individual's self-perception of what physical activity they can or cannot perform. Psychological beliefs, such as high levels of pain-related fear, are associated with an individual's self-perception of their physical capabilities and may not be associated with their actual physical capability. Two studies(19, 20) found a relationship between psychological beliefs and objective measures of function while a third study(21) found no relationship in adults with AKP.

Although AKP is most prevalent in the adolescent population,(4) 95% of the research is done in the adult population.(9) Of the studies assessing psychological beliefs and AKP, all were performed in the adult population.(11) Adolescents likely have different psychological factors which impact them compared to adults, with their daily life being composed of school, sport, friends and family. A pediatric psychological model has been proposed wherein parents play a significant influential role.(22) The influential force of parents may be an important factor which is not observed in adults with AKP, therefore the association between psychological beliefs and AKP observed in adults should not be generalized to adolescents with AKP. The primary *purpose of this study* was to assess the influence of kinesiophobia, fear avoidance beliefs, and pain catastrophizing on 1) self-reported functional ability, 2) pain and 3) objective measures of function. We hypothesize that psychological characteristics will be associated with the participant's pain and function and that psychological beliefs will provide further information on the participants function after accounting for demographic and physical factors associated with AKP. The secondary purpose was to assess the influence of the adolescent's parent beliefs on the participant's 1) psychological beliefs, 2) self-reported functional ability, and 3) pain. Based upon the theorized pediatric psychological model, we hypothesize that parental beliefs

will be associated with the participant's psychological beliefs, self-reported functional ability and pain.

METHODS

Design and Setting

This study was a prospective cross-sectional observational study performed in the outpatient physical therapy clinics of a pediatric hospital. Adolescents who reported pain in their anterior knee from March 2019 through October 2019 were considered for participation. The institutional review board approved this study prior to recruitment and data collection. All participants and guardians provided written informed consent prior to participation.

Participants

Participants were included if they were an adolescent (aged 12- 17 years) who reported pain around or behind the patella, which was aggravated by at least one activity that loads the patellofemoral joint during weight bearing on a flexed knee (e.g., squatting, stair ambulation, jogging/running, hopping/jumping).(149) Participants were excluded if there was a 1) prior patellar dislocation, 2) suspicion of other diagnosis of the knee, 3) other concomitant injury of the lower quarter, 4) previous surgery in the lower quarter, 5) neurologic or developmental disorder which altered lower extremity function.

Variables

All self-report measures on psychological beliefs, pain, and function were completed on a tablet using REDCap electronic data capture tools.(162, 163) Objective measurements were completed by one physical therapist with over ten years of experience treating adolescents with AKP.

Participant Demographics

Demographic data were collected on each participant including their age, sex, and body mass index (BMI). Injury data were collected including side injured (R, L, Bilateral) and duration of knee pain (weeks). Activity participation information was collected including participation in organized sports and the Marx Activity Rating Scale was used to provide a standardized method of grading the participant level of activity.(164)

Pain-Related Fear

Pain-related fear was assessed using the Modified Fear-Avoidance Beliefs Questionnaire-Physical Activity (FABQ-PA) subscale and the Tampa Scale for Kinesiophobia-11 (TSK-11).

The FABQ-PA subscale quantified the participant's fear of pain and beliefs about avoiding activity.(89) The FABQ-PA is a 5-item self-report measure which assesses an individual's fear-avoidance of painful activity and was modified for the knee.(14) The FABQ-PA was modified by changing the word "back" to "knee" on the questionnaire.(14) Each item was scored on a 0-6 scale, with 0 indicating completely disagree and 6 indicating completely agree. Questions 2-5 were summed to create a final score of 0-24, with higher scores indicating greater pain-related fear. This measure has a test-retest reliability of r = 0.59-0.64 for individuals with musculoskeletal conditions.(90, 91) The adolescent's parent filled out this same measure with the word "my" or "I" replaced by "my child's" for all questions.

The TSK-11 is an 11-item questionnaire that assesses fear of injury due to movement. Participants are asked to make ratings of their degree of agreement with each of the 11 statements, for instance, 'Pain lets me know when to stop exercising so that I don't injure myself'. Ratings range from 1 (strongly disagree) to 4 (strongly agree). The responses are summed to yield a total score where higher values reflect higher pain-related fear.(93) The test-

retest reliability of the TSK-11 is r = 0.81, and an internal consistency of alpha = 0.79(94, 95) The adolescent's parent filled out the TSK-11 with pronouns referring to the participant replaced with those referring to their child, for example with question 6 "Pain always means I have injured my body" became "Pain always means my child has injured their body".

Pain Catastrophizing

The Pain Catastrophizing Scale is a 13-item self-report measure designed to assess an individual's catastrophizing. Each item is rated on a 5-point scale, ranging from 0 (not at all) to 4 (all the time). The PCS-child (PCS-C) and PCS parent (PCS-P) are variations of the original and were assessed in the adolescent and parent respectively. The PCS-C demonstrated acceptable goodness of fit in a community sample of children 8-17 years, with an internal consistency ranging from an alpha of 0.84 to 0.89.(97) The PCS-C is predictive of chronic or recurring pain in adolescents, and has moderate-strong correlations with pain intensity (r = 0.49) and disability (0.50).(97) The PCS-P has high internal consistency ranging from alpha = 0.81-0.93.(98)

Other Psychological Beliefs

Adolescents also completed self-report measures of other psychological beliefs, including measures of anxiety, depressive symptoms, and stress. The Patient-Reported Outcomes Measurement Information System (PROMIS) anxiety item bank and the PROMIS pediatric depressive symptoms item bank short forms were used to assess anxiety and depressive symptoms in the adolescents with AKP.(109) The Perceived Stress Scale-10 (PSS-10) was used to assess stress in the adolescent participants. (116)

Self-Reported Function

The Anterior Knee Pain Scale, a 13-item self-report questionnaire, was used to assess participant's knee function and symptoms. The Anterior Knee Pain Scale is scored 0-100, with 100 representing no disability. The Anterior Knee Pain Scale has been found to have excellent validity and reliability among individuals 12-50 years old with AKP.(134, 135)

Pain

The Numeric Pain Rating Scale (NRPS), an 11-point pain-rating scale ranging from 0 (no pain) to 10 (worst imaginable pain), was used to assess the participant's highest knee pain in the past 24 hours.(132)

Objective Measures of Function

Adolescent's flexibility, strength, and functional performance were measured on the involved leg, or if a participant reported bilateral knee pain the leg with the most pain was tested as the involved leg. Two measurements were taken for each measure of objective function. If there was more than 10% difference between the two trials, a third trial was performed with the lowest value being dropped.

Flexibility

Quadriceps muscle length was assessed with the participant lying in prone while the therapist pressed down on the ipsilateral sacroiliac region. The participant's knee was passively flexed to end range of motion and a measurement was taken with a digital inclinometer.(82) Weight-bearing dorsiflexion was measured using the lunge test.(137) The participant lunged with the injured lower extremity in front, bringing the affected patella as close to a wall as possible without either heel coming up off the floor. A digital inclinometer was placed 1 cm

distal to the tibial tuberosity. A measurement was taken once maximum dorsiflexion was reached.

Strength

Muscle strength was quantified for hip abduction and knee extension with hand-held dynamometry. The participant exerted a maximal isometric contraction against the padded buttress of the dynamometer for 5 seconds. Participants had a 30 second rest between trials. The average maximal contraction was expressed as a percentage of the participant's body weight.

Hip abduction strength was tested with the participant side-lying with the tested side up. The contralateral hip and knee joints were positioned at approximately 30 degrees of flexion for stability and comfort. The knee of the tested limb was fully extended and the hip was positioned in approximately 10º of abduction. The dynamometer pad was located proximal (~5 cm) to the lateral malleolus.(15) Quadriceps strength was assessed with the participant seated and their knee positioned at 90º of flexion. The dynamometer pad was positioned perpendicular to the anterior aspect of the tibia, 5 cm proximal of the medial malleolus and was held in place with straps affixed to the treatment table.(138)

Functional Performance

The lateral step-down test was performed by having the participant stand on a 20 cm (8 inch) step and squat to approximately 60º of knee flexion. The participant was instructed to keep their hands on their waist and keep their knee over the second toe while squatting. Participants repeated the lateral step down five times. Quality of movement of the lateral step-down test was scored based on criteria previously reported in literature.(66, 136)

The single leg hop for distance was performed by having the participant stand on the tested leg only, then jump as far as possible landing on the same leg and stabilize for 1 second. Distance was measured to the nearest centimeter on a standard measuring tape affixed to the floor.(139) The average single leg hop distance was expressed as a percentage of the participant's height.

Sample Size Estimation

Sample size estimates were based on correlation statistical tests using alpha=0.05. A sample size of 85 participants was calculated to provide sufficient statistical power (80%) to detect a mild correlation between psychological factors and clinical tests of physical impairment ($r = 0.3$).

Data Analysis

Statistical analyses were made using IBM® SPSS® (Statistical Package for the Social Sciences) Statistics 24.0 software (IBM Corporation, Armonk, NY). Descriptive statistics were calculated for demographic and baseline variables. There were no missing data that needed to be accounted for among the participants. To test the hypothesis of the primary aim Spearman's correlation coefficients were used to describe the association between psychological variables and measures of pain and function. Statistical significance was established *a priori* ($\alpha \leq 0.05$) with a Holm's Sequential Bonferroni correction (24 comparisons) utilized to account for multiplicity of tests as necessary.(140) The adjusted statistical significance ranged from $\alpha \leq 0.0021$ to $\alpha \leq 0.0028$. To test the hypothesis that these psychological characteristics provide further information about the participant's function after demographic and physical factors associated with AKP are accounted for, a two-stage hierarchical regression analysis was performed. Self-reported function was the dependent variable. In the first block, factors

commonly associated with AKP were entered, including sex, pain, quadriceps strength, quadriceps flexibility, and hip abduction strength. In the second block the participant's FABQ-PA, TSK-11 and PCS-c scores were entered. The secondary aim was assessed using Spearman's correlation coefficients to describe the association between parent psychological beliefs, participant psychological beliefs, pain, and function.

RESULTS

Over a 7-month period, 86 adolescents with AKP enrolled in this study, and 72 adolescent's parent (78% mothers) agreed to complete the parental psychological self-report measures (**FIGURE 5.1**). None of the participants or parents had any unanswered items. Adolescent demographics, pain, and measures of function are presented in **TABLE 5.1**. Adolescent and parent scores on the psychological measures are presented in **TABLE 5.2**.

FIGURE 5.1. Participant Flow Diagram

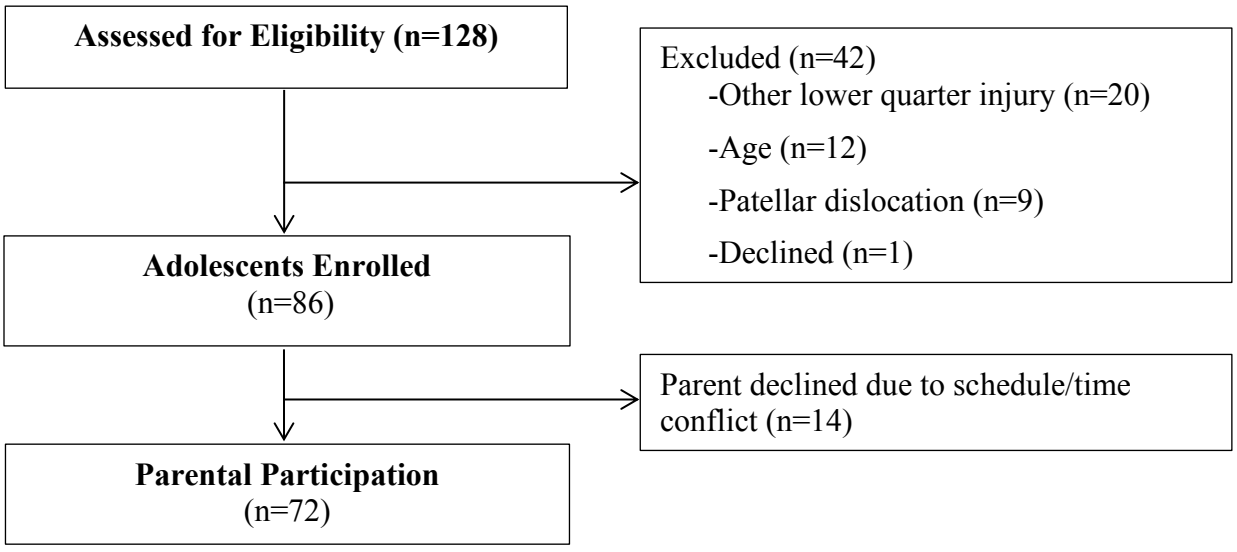

TABLE 5.1. Participant Demographics and scores obtained for pain, function

	Adolescents (n=86)
Age (years)	14.6 ± 1.7
Sex (% female)	53 (62%)
Body mass index (kg/m^2)	23.1 ± 5.4
Duration of symptoms (weeks)*	18 (7-41)
Bilateral knee pain (% yes)	32 (37%)
Participates in organized sport (% yes)	71 (83%)
Marx Activity Rating Scale	11.8 (range 0-16)
Highest pain in past 24 hours (0-10 NPRS)	4.6 ± 2.2
Anterior Knee Pain Scale	73.9 ± 13.7
Quadriceps strength (% body weight)	41.9% ± 13.8%
Hip abduction strength (% body weight)	14.3% ± 4.4%
Single Leg Hop for Distance (% of height)	70.5% ± 22.6%
Lateral Step-Down Score	2.7 ± 1.5
Quadriceps flexibility (º)	142.3 ± 15.3
Weight-Bearing Dorsiflexion motion (º)	42.2 ± 7.2

Values are mean ± SD unless otherwise indicated
*****median (interquartile range)

TABLE 5.2. Adolescent and Parental Psychological Measures

	Adolescent (n=86)	Parent (n=72)
FABQ-PA	12.14 ± 5.4	12.4 ± 5.0
TSK-11	22.3 ± 5.0	19.8 ± 4.9
PCS	16.4 ± 9.5	14.7 ± 10.5
PROMIS Anxiety	6.5 ± 6.6	-
PROMIS Depressive Symptoms	4.5 ± 6.3	-
PSS-10	14.3 ± 6.8	-

FABQ-PA, Fear Avoidance Beliefs Questionnaire-Physical Activity subscale; TSK-11, Tampa Scale for Kinesiophobia-11; PCS, Pain Catastrophizing Scale; PROMIS, Patient-Reported Outcomes Measurement Information System; PSS-10, Perceived Stress Scale-10

Adolescent Psychological Beliefs, Pain, and Measures of Function

The primary purpose of this study aimed to assess if pain-related fear and pain catastrophizing are associated with pain and measures of function in adolescents with AKP. Correlations between psychological variables, pain and measures of function are presented in **TABLE 5.3**. Adolescent pain catastrophizing and fear-avoidance beliefs were mildly and statistically significantly associated with pain. Fear-avoidance demonstrated a statistically significant and moderate negative association with self-reported function; whereas kinesiophobia demonstrated a mild, but still statistically significant, negative association. Adolescent fear-avoidance beliefs had a moderate and significant negative association with hip strength, explaining 17% of the variance. A mild and statistically significant association was noted between fear-avoidance beliefs and single leg hop for distance. Quadriceps strength and flexibility suggested a mild correlation with fear-avoidance beliefs ($p < 0.05$), but it was not considered statistically significant based on the sequential correction process. Kinesiophobia was statistically significantly and mildly negatively associated with hip abduction strength. Adolescent pain catastrophizing beliefs were not significantly associated with objective measures of function.

TABLE 5.3. Spearman's correlation between adolescent pain, function and the psychological variables

	FABQ-PA	**TSK-11**	**PCS-c**
Pain	0.33 * (p = 0.002)	0.22 (p = 0.04)	0.34* (p = 0.001)
Anterior Knee Pain Scale	-0.59* (p < 0.001)	-0.33* (p = 0.002)	-0.23 (p = 0.04)
Quadriceps strength (% bodyweight)	-0.26 (p = 0.02)	-0.20 (p = 0.06)	0.04 (p = 0.71)
Hip abduction strength (% bodyweight)	-0.41* (p < 0.001)	-0.32* (p = 0.002)	-0.20 (p = 0.06)
Single Leg Hop for Distance (% of height)	-0.38* (p < 0.001)	-0.26 (p = 0.02)	-0.18 (p = 0.09)
Quadriceps flexibility (º)	-0.23 (p = 0.03)	-0.22 (p = 0.04)	-0.14 (p = 0.21)
Weight-Bearing Dorsiflexion(º)	-0.17 (p = 0.12)	-0.13 (p = 0.25)	-0.04 (p = 0.73)
Lateral Step-Down	0.17 (p = 0.13)	0.12 (p = 0.28)	0.15 (p = 0.18)

FABQ-PA, Fear Avoidance Beliefs Questionnaire-Physical Activity subscale; TSK-11, Tampa Scale for Kinesiophobia-11; PCS-c, Pain Catastrophizing Scale-child
**Significant after Holm's Sequential Bonferroni Correction*

Regression Analysis

A hierarchical regression analysis was performed with self-reported function as the dependent variable. All the assumptions of the regression were met after one case was removed for being a significant outlier. There was linearity as assessed by partial regression plots and a plot of the studentized residuals against the predicted values. There was independence of the residuals as assessed by a Durbin-Watson statistic of 1.98. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. No significant multicollinearity was identified among the predictor variables, as assessed by tolerance values greater than 0.20. No significant outliers or highly influential points were identified. The assumption of normality was met, as assessed by a Q-Q Plot. The final

hierarchal regression model of sex, pain, quadriceps strength, quadriceps flexibility, hip abduction strength, FABQ-PA, TSK-11, PCS-c to predict adolescent Anterior Knee Pain Score, was statistically significant, $R^2 = 0.55$, $F\ (8, 74) = 11.1$, $p < 0.001$, adjusted $R^2 = 0.50$. The addition of the participant's psychological beliefs added a statistically significant increase to the prediction of adolescent Anterior Knee Pain Score $R^2 = 0.25$, $F\ (3, 74) = 13.3$, $p < 0.001$.

Parental Psychological Beliefs and Adolescent Pain, and Measures of Function

As can be observed in **TABLE 5.4,** parent psychological beliefs were not associated with adolescent psychological beliefs, pain, or self-reported function.

TABLE 5.4. Spearman's correlation between adolescent pain, function and parent psychological variables

	Parent FABQ-PA	**Parent TSK-11**	**PCS-p**
Pain	0.07	0.05	0.08
Anterior Knee Pain Scale	-0.01	-0.02	0.11
Participant FABQ-PA score	0.00	0.09	0.09
Participant TSK-11	0.03	0.02	0.02
Participant PCS-c	-0.10	0.12	0.17

FABQ-PA, Fear Avoidance Beliefs Questionnaire-Physical Activity subscale; TSK-11, Tampa Scale for Kinesiophobia-11; PCS-c, Pain Catastrophizing Scale-child; PCS-p, Pain Catastrophizing Scale-parent

DISCUSSION

Previous research demonstrates a consistent adverse relationship between psychological variables, pain, and self-reported function among adults with AKP.(11, 13, 14, 161) This study adds to the literature by describing the psychological characteristics of adolescents with AKP. Additionally, a consistent negative association was noted between adolescent psychological variables, pain, and self-reported function. Certain objective measures of function were significantly associated with adolescent pain-related fear (fear-avoidance beliefs and kinesiophobia), but not pain catastrophizing. Interestingly, no tested parent psychological belief was significantly associated with the adolescent's pain, or self-reported function.

This study found a significant and negative association between adolescent psychological variables and self-reported function, with fear-avoidance beliefs being the most associated with self-reported function. This finding is consistent with Piva et al,(14) who found that fear-avoidance beliefs were the strongest predictor of functional improvement in adults with AKP. In a recent systematic review, Maclachlan et al(11) identified a linear correlation between adult AKP symptoms and psychological factors such as catastrophizing and pain-related fear. Treatment for AKP traditionally focuses on improving strength, flexibility, neuromuscular control and physical performance. This study's regression analysis found that the adolescent's psychological beliefs significantly added to the prediction of self-reported function even after controlling for pain, and objective measures of function. This finding demonstrates that psychological variables are an important factor when considering adolescent self-reported functional ability.

The influence of psychological factors on objective measures of function has only recently been studied in adults with AKP, with conflicting results. Glaviono and Saliba,(20)

found that fear-avoidance beliefs have a moderate association with objective measures of function in adult females with AKP. In a study by de Oliveira et al,(165) kinesiophobia was found to be significantly associated with movement patterns during stair descent in adult women with AKP. In contrast, Priore et al(166) found that kinesiophobia and pain catastrophizing were not significantly associated with objective measures of function in adult women with AKP. Our current findings support and may inform these seemingly conflicting results regarding psychological factors and objective function. The results of this study found that pain-related fear and not pain catastrophizing were significantly associated with some aspects of objective function, similar to the previously reported studies. These results suggest that pain-related fear and not pain catastrophizing may be associated with certain aspects of objective function in individuals with AKP.

The fear avoidance model has evolved over the years and pain catastrophizing and pain-related fear may not be intrinsically linked as first proposed.(167) Pain catastrophizing has been characterized by the tendency to magnify the threat of pain stimulus and to feel helpless in the context of pain.(168) Pain-related fear is a negative emotional reaction to pain stimuli which elicits avoidance of the painful activity. Previous studies have found that pain-related fear is most associated with decreased self-reported function, while catastrophizing about pain is more associated with high pain levels.(169-171) Pain-related fear has been suggested as more disabling than pain itself.(172) More recent evidence has shown that this finding does not hold true in individuals with high pain intensities, however, this sample reported comparatively low levels of pain and pain-related fear was the most predictive factor of disability as suggested by Crombez et al.(172)

Clinicians who treat pediatric patients have hypothesized that different psychological factors affect children and have proposed a pediatric model, wherein parents play an influential role.(22) However, this study did not find a significant relationship between parent beliefs on fear-avoidance, kinesiophobia, pain catastrophizing and any aspect of adolescent psychological beliefs, pain, or self-reported function.

Limitations

This study had several limitations. First and foremost, this study was a cross-sectional study and although an association between adolescent psychological beliefs, pain and function was observed, a cause-and-effect relationship cannot be inferred. Second, parent pain-related fear beliefs were assessed by modifying existing measures and the resulting measures may have impacted their validity. Future randomized controlled trials are necessary to assess if a cause and effect relationship exists between psychological beliefs and pain and function in individuals with AKP.

Conclusion

The associations between adolescent psychological beliefs, pain, self-reported function and objective measures of function are similar to those seen in adults with AKP. Adolescent psychological beliefs significantly influence functional ability after accounting for important factors including sex, pain and physical ability. Parental psychological beliefs were not associated with adolescent pain or function.

This chapter presents the third of the four manuscripts that were prepared based on the results of this dissertation study. The status of the manuscript is currently unsubmitted.

CHAPTER SIX

THE INFLUENCE OF PAIN-RELATED FEAR ON KINEMATICS AND KINETICS DURING A SINGLE LEG HOP AMONG ADOLESCENTS WITH ANTERIOR KNEE PAIN.

Contribution of Authors and Co-Authors

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Contributions: Conceived and implemented the study design. Collected and analyzed data. Wrote first draft of the manuscript.

Co-Author: Alicia Fernandez-Fernandez

Contributions: Helped conceive study design. Provided feedback on statistical analyses and early drafts of the manuscript.

Co-Author: Jessica Hoehn

Contributions: Helped conceive study design. Provided feedback on statistical analyses and early drafts of the manuscript.

Co-Author: Laura Schmitt

Contributions: Helped conceive study design. Provided feedback on early drafts of the manuscript.

INTRODUCTION

Psychological beliefs are consistently adversely associated with anterior knee pain (AKP),(11-16) a condition common among young adults and adolescents.(4, 30-32) Individuals with AKP may have elevated anxiety, depression, pain catastrophizing, and pain-related fear, which correlate with increased pain and reduced self-reported function.(12-16) In a recent systematic review, Maclachlan et al.(11) reported that pain catastrophizing and pain-related fear were the psychological factors which demonstrated the strongest and most consistent correlation with pain and dysfunction among adults with AKP.

Psychological factors are associated with self-report measures of function among individuals with AKP, however, this self-perception may or may not actually reflect objective functional ability. The influence of psychological factors on objective measures of function has only recently been studied in adults with AKP, with conflicting results. Glaviono and Saliba,(20) found that fear-avoidance beliefs have a moderate association with objective measures of function in adult females with AKP. In a study by de Oliveira et al,(165) kinesiophobia was found to be significantly associated with movement patterns during stair descent in adult women with AKP. In contrast, Priore et al(166) found that kinesiophobia and pain catastrophizing were not significantly associated with objective measures of function in adult women with AKP. No studies have assessed the influence of psychological factors on objective function in adolescents with AKP.

The most commonly accepted theoretical cause of AKP is abnormal loading of the patellofemoral joint resulting in elevated stress through the patellofemoral joint.(150) Alterations in lower limb biomechanics can increase patellofemoral joint stress.(8) Individuals with AKP demonstrate greater differences in movement patterns than healthy controls. Altered movement

has been noted among individuals with AKP in the sagittal and frontal plane with reduced knee flexion, and increased hip adduction and knee abduction(141, 173-177) The *purpose of this study* was to explore if psychological beliefs are associated with altered biomechanics among adolescents with AKP. We hypothesized that adolescents with high pain-related fear will have greater peak external hip adduction and knee abduction moments while landing from a single leg hop than adolescents with either low pain-related fear or healthy controls.

METHODS

Participants

Three groups of adolescents (total n = 30), 12-17 years old were recruited. Twenty adolescents with AKP were recruited and grouped based upon psychological beliefs. As a threshold for elevated fear-avoidance beliefs has previously been established in this population, the fear avoidance beliefs questionnaire physical activity (FABQ-PA) subscale was used to identify eligible participants. Ten adolescents with AKP were recruited into the elevated maladapted beliefs group (scored ≥14 on the FABQ-PA), and 10 adolescents with AKP were recruited into the low maladapted beliefs group (scored ≤10 on FABQ-PA). Ten healthy adolescents, matched by age and sex to those in the elevated maladapted beliefs group, were also recruited to serve as controls.

Adolescents were considered to have AKP if they reported pain around or behind the patella, which was aggravated by at least one activity that loads the patellofemoral joint during weight bearing on a flexed knee (e.g., squatting, stair ambulation, jogging/running, hopping/jumping).(149) Adolescents were considered for inclusion in the control group if they had no history of lower quarter injury in the past 12 months. Patients were excluded if there was a 1) prior patellar dislocation, 2) suspicion of other diagnosis of the knee, 3) other concomitant

injury of the lower quarter, 4) previous surgery in the lower quarter, 5) neurologic or developmental disorder which altered lower extremity function.

Data Collection

The institutional review board approved this study prior to recruitment and data collection. All patients and guardians provided written informed consent prior to participation. For this study, participants attended a one-time visit to the laboratory which lasted approximately 1 hour for motion analysis testing. Participants' height and weight were measured, and BMI was calculated. Participants completed questionnaires about functional ability, pain, activity level, and maladaptive pain beliefs (if applicable).

Self-Reported Function

The Anterior Knee Pain Scale, a 13-item self-report questionnaire, was used to assess participant's knee function and symptoms. The Anterior Knee Pain Scale is scored 0-100, with 100 representing no disability. The Anterior Knee Pain Scale has been found to have excellent validity and reliability among individuals 12-50 years with AKP.(134, 135)

Pain

The Numeric Pain Rating Scale (NRPS), an 11-point pain-rating scale ranging from 0 (no pain) to 10 (worst imaginable pain), was used to assess the patient's highest knee pain in the past 24 hours.(132)

Psychological Beliefs

Adolescents were asked about their fear-avoidance, kinesiophobia and pain catastrophizing beliefs. These questionnaires are specifically related to participant injury, and therefore were not completed by the control group.

The FABQ-PA subscale quantified the patient's fear of pain and beliefs about avoiding activity.(89) The FABQ-PA is a 5-item self-report measure which assessed an individual's fear-avoidance of painful activity and was modified for the knee.(14) The FABQ-PA was modified by changing the word "back" to "knee" on the questionnaire.(14) Each item was scored on a 0-6 scale, with 0 indicating completely disagree and 6 indicating completely agree. Questions 2-5 were summed to create a final score of 0-24, with higher scores indicating greater fear-avoidance beliefs. The FABQ-PA was used to determine if the patient was included in the elevated maladaptive beliefs or low maladaptive beliefs group, as previous literature exist in this population describing thresholds.(84)

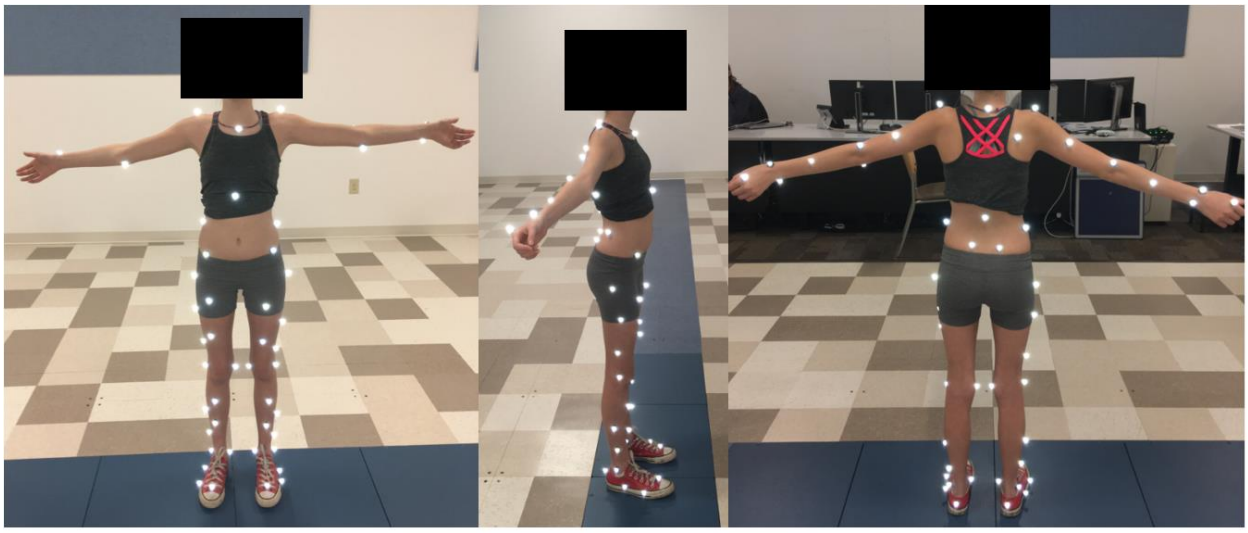
The Tampa Scale for Kinesiophobia-11 (TSK-11) is an 11-item questionnaire that assessed fear of injury due to movement. Patients were asked to make ratings of their degree of agreement with each of the 11 statements, for instance, 'Pain lets me know when to stop exercising so that I don't injure myself'. Ratings range from 1 (strongly disagree) to 4 (strongly agree). The responses are summed to yield a total score where higher values reflect high pain-related fear.(93) The test-retest reliability of the TSK-11 is $r = 0.81$, with an internal consistency of alpha = 0.79.(94, 95)

The Pain Catastrophizing Scale-Child (PCS-C) is a 13-item self-report measure designed to assess an individual's pain catastrophizing. Each item is rated on a 5-point scale, ranging from 0 (not at all) to 4 (all the time). The PCS-C demonstrates an internal consistency ranging from an alpha of 0.84 to 0.89.(97)

Motion Analysis Testing

Individual retro-reflective spherical markers (n = 61) were attached to the trunk and pelvis and bilaterally over the upper and lower extremities. (Figure 6.1) Anatomical and tracking markers were used to calculate lower extremity joint centers and track segment motion during the single leg hop task. The hip joint centers were determined functionally with the star-arc method.(143) The knee joint centers were calculated as the midpoint between the medial and lateral femoral condyles, and ankle joint centers were calculated as the midpoint between the medial and lateral malleolus. A static model was created based on anatomical marker placements, with the long axis of the thigh determined as the line from the knee joint center to hip joint center, medio-lateral axis as the line perpendicular to the long axis along the line between medial and lateral femoral condyles, and the antero-posterior axis normal to the long and medio-lateral axes. The shank was defined in a similar manner, with the long axis as the line from ankle joint center to knee joint center, medio-lateral axis defined as the line from the medial and lateral malleoli and perpendicular to the long axis, and the antero-posterior axis normal to the long and medio-lateral axes.

FIGURE 6.1. Marker Setup



Three-dimensional motion analysis was used to quantify each participant's movement patterns and biomechanics during a single leg hop for distance task. Three-dimensional motion analysis was used to calculate hip and knee kinematic and kinetic patterns and ground reaction force data. Kinematic data was collected using 22 OptiTrack cameras (NaturalPoint, Inc., Corvallis OR) and ground reaction forces were collected using 4 AMTI force plates (Advanced Mechanical Technology Inc., Watertown, MA). Motion capture and force plate data were synchronized. The motion analysis data was exported for subsequent analysis in Visual3D software (C-Motion, Germantown, MD). Knee joint moments were calculated using standard inverse dynamics equations and are reported as raw (Nm) and normalized to mass × height (Nm / (kg × m)) data. Peak knee abduction moment was the primary biomechanical variable of interest as it has been demonstrated to be a risk factor for AKP, and adolescents with higher knee abduction moments during landing are at increased risk.(141, 142) Marker trajectories and force plate data used for joint moment calculations were filtered with a fourth-order Butterworth digital filter with cutoff frequencies of 12 Hz and 100 Hz respectively.

Single Leg Hop for Distance Test: The single leg hop for distance was performed by having the participant stand on the tested leg only, then jump as far as possible landing on the same leg and stabilize for 1 second.(139) Kinematics and kinetics were quantified during the deceleration phase of landing. The deceleration phase was operationally defined from initial contact to the lowest vertical position of the body's center of mass. The frontal plane variables of interest included peak hip adduction angle, hip adduction excursion, peak hip adduction moment, peak knee abduction angle, knee abduction excursion, and peak knee abduction moment. The sagittal plane variables of interest included peak hip flexion angle, peak hip flexion moment, peak knee flexion angle, and peak knee flexion moment.

Sample Size Estimation

The goal of this study was to detect trends and areas for future research. We recruited injured and healthy participants into 3 groups (elevated maladaptive beliefs, low maladaptive beliefs, healthy controls) with 10 participants in each group for a total of 30 participants.(144)

Data Analysis

All statistical analyses were performed with IBM SPSS (v 24, SPSS Inc., Chicago, IL). Descriptive statistics were used to describe the participants baseline demographics and characteristics. To test the hypothesis that adolescents with elevated maladaptive beliefs demonstrate greater peak knee abduction moments during a single leg hop task compared with the low maladaptive beliefs and healthy control groups, a Kruskal-Wallis test was performed. Additional Kruskal-Wallis tests were performed to assess between group differences in the baseline variables and secondary variables of interest. Post-hoc Mann-Whitney U tests were performed to determine specific between-group differences.

RESULTS

Thirty adolescents were recruited into three separate groups from June 2019 through January of 2020 (FIGURE 6.2). Adolescents in all three groups were similar in all baseline characteristics except for the anticipated differences in pain-related fear (FABQ-PA, TSK-11) which were significantly different between groups (TABLE 6.1).

During the single leg hop test, there were no significant differences between groups for vertical ground reaction forces and normalized (N/Kg) ground reaction forces. There were no significant differences between groups for single leg hop distance (TABLE 6.2).

FIGURE 6.2. Participant Flow Diagram

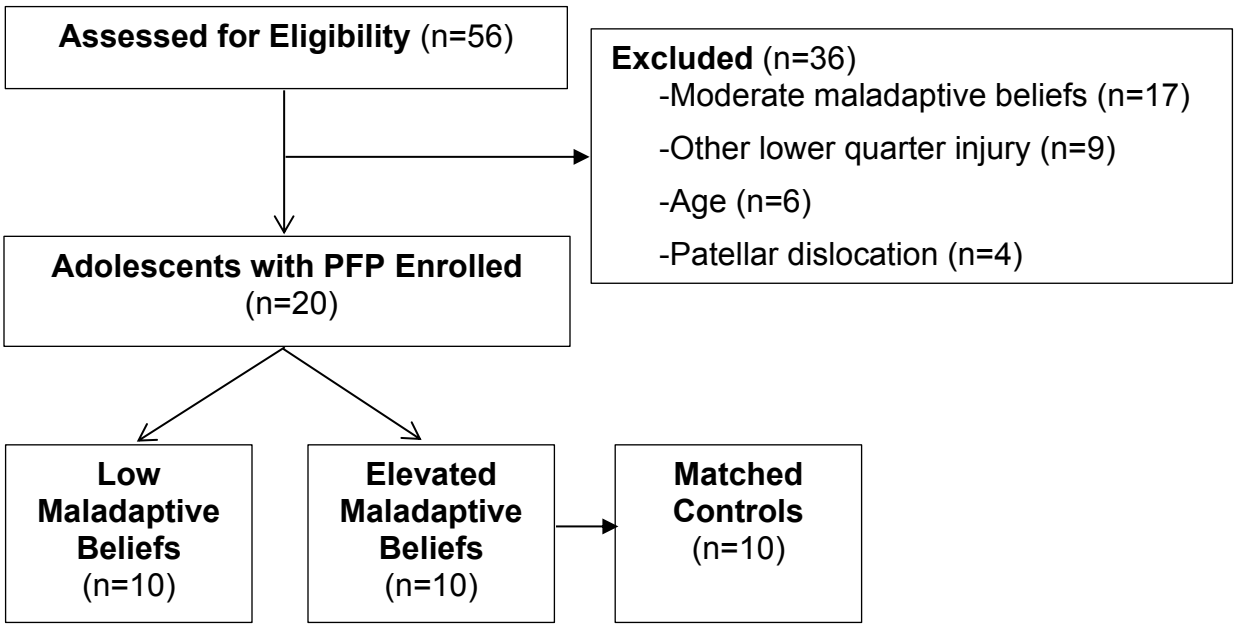


TABLE 6.1. Participant demographics, pain, function and psychological beliefs

	Elevated Maladaptive Beliefs (n=10)	Low Maladaptive Beliefs (n=10)	Control Participants (n=10)	P value
Age (years)	15.4 ± 1.6	13.8 ± 1.6	15.5 ± 1.8	0.57
Sex (% Female)	6 (60%)	8 (80%)	6 (60%)	0.55
Height (cm)	169.3 ± 14.4	162.3 ± 9.7	167.1 ± 10.2	0.40
Weight (kg)	58.5 ± 12.2	53.5 ± 14.3	55.3 ± 12.9	0.69
BMI	20.2 ± 1.5	20.0 ± 3.3	19.5 ± 2.6	0.83
Marx Score	12.5 ± 5.1	11.9 ± 4.1	11.0 ± 6.3	0.82
Duration of symptoms (weeks)	16 (4, 16)	25 (9, 54)	-	0.58
AKPS	71.4 ± 14.1	81.5 ± 11.8	100 (-)	0.10
Highest Pain	4.4 ± 2.3	4.7 ± 1.6	0 (-)	0.73
FABQ-PA	16.6 ± 3.5	7.7 ± 3.4	-	<0.001*
TSK-11	25.1 ± 4.8	18.5 ± 3.4	-	0.002*
PCS-c	21.3 ± 10.4	13.1 ± 7.4	-	0.06

Data are means (SD) or percentages (%)

TABLE 6.2. Vertical Ground Reaction Forces
All data are medians (interquartile range)

	Elevated Maladaptive Beliefs (n=10)	**Low Maladaptive Beliefs (n=10)**	**Control Participants (n=10)**	**P value**
Single Leg Hop for Distance (% of height)	62% (48-75)	55% (45-71)	68% (62-83)	0.111
Ground Reaction Force (N)	1247 (1050, 2043)	1335 (1005, 1434)	1517 (1084, 1838)	0.698
Ground Reaction Force, normalized (N/kg)	23.4 (22, 31)	24.6 (22, 26)	26.5 (24, 29)	0.466

Frontal Plane

To test the primary hypothesis, frontal plane kinematics and kinetics were assessed between groups. Significant between-group differences were noted for external peak knee abduction moments, both raw and normalized (TABLE 6.3). Post-hoc testing revealed that healthy controls had significantly higher knee abduction moments than adolescents with AKP in both the elevated and low maladaptive belief groups. There was not a significant difference in peak knee abduction moments between adolescents who had elevated maladaptive beliefs and those with low maladaptive beliefs ($p = 0.17$ raw, $p = 0.68$ normalized). No other significant between-group differences were noted in the frontal plane.

Sagittal Plane

Healthy adolescents demonstrated significantly greater amounts of hip flexion while landing from a single leg hop than adolescents with AKP, however there were no significant differences between the elevated and low maladaptive belief groups for peak hip flexion angle (TABLE 6.4). Additionally, healthy adolescents trended towards greater peak external hip

differences or trends were noted between the elevated and low maladaptive belief groups for sagittal plane kinematics or kinetics.

TABLE 6.3. Injured Leg Frontal Plane Kinematics and Kinetics

	Elevated Maladaptive Beliefs (n=10)	Low Maladaptive Beliefs (n=10)	Control Participants (n=10)	P value
Peak hip adduction angle°	4.8 (2, 13)	4.4 (1, 8)	2.5 (1, 7)	0.447
Hip adduction excursion°	17.8 (12, 22)	13.8 (10, 17)	14.3 (11, 18)	0.368
Peak hip adduction moment (N*m)	83.3 (62, 148)	60.2 (54, 89)	97.4 (56, 140)	0.170
Peak hip adduction moment normalized (N*m/kg)	1.0 (0.7, 1.2)	0.83 (0.7, 1.0)	0.92 (0.8, 1.5)	0.371
Peak knee abduction angle°	3.8 (1, 6)	3.0 (1, 7)	4.1 (1, 11)	0.910
Knee abduction excursion°	9.2 (7, 13)	9.1 (8, 12)	11.4 (6, 13)	0.965
Peak knee abduction moment (N*m)	7.5 (1, 10)	11.2 (4, 20)	20.5 (11, 63)	0.006*
Peak knee abduction moment normalized (N*m/kg)	0.07 (0.02, 0.11)	0.13 (0.05 0.19)	0.24 (0.13, 0.47)	0.002*

All data are medians (interquartile range)

TABLE 6.4. Injured Leg Sagittal Plane Kinematics and Kinetics

	Elevated Maladaptive Beliefs (n=10)	Low Maladaptive Beliefs (n=10)	Control Participants (n=10)	P value
Peak hip flexion angle°	37.6 (30, 50)	42.5 (36, 48)	53.3 (46, 61)	0.046
Peak hip flexion moment (N*m)	52.1 (40, 70)	50.7 (40, 74)	85.1 (52, 336)	0.139
Peak hip flexion moment normalized (N*m/kg)	0.5 (0.4, 0.8)	0.6 (0.4, 0.8)	1.0 (0.6, 4.1)	0.042
Peak knee flexion angle°	48.8 (45, 62)	47.9 (43, 51)	57.2 (47, 65)	0.118
Peak knee flexion moment (N*m)	158.3 (111, 251)	156.1 (126, 179)	135.3 (99,195)	0.598
Peak knee flexion moment normalized (N*m/kg)	1.7 (1.3 2.3)	1.9 (1.6, 2.1)	1.6 (1.1, 2.2)	0.801

All data are medians (interquartile range)

DISCUSSION

The hypothesis of this study was not supported by the results. Significant differences were noted between healthy controls and adolescents with AKP, however, no significant differences in kinematics or kinetics were observed between adolescents who had elevated and low maladaptive beliefs.

Previous findings are mixed regarding the association of psychological beliefs and objective function in individuals with AKP.(20, 21, 165) The findings of this study are not consistent with the findings of De Oliveira Silva et al(165) and Glaviano et al(20) who found that pain-related fear was significantly associated with kinematics among women with AKP. De Oliveira Silva et al(165) found that kinesiophobia was significantly negatively associated with peak knee flexion and cadence during stairs. Glaviano et al(20) found that fear-avoidance beliefs were significantly associated with frontal plane kinematics during single leg squat, step down and jogging. Our findings were consistent with Priore et al(21) who found that although adult women with AKP had reduced objective function on the single leg hop for distance task compared with healthy controls, kinesiophobia was not associated with objective function. Our previous work in adolescents with AKP found that single leg hop distance was significantly associated with fear-avoidance beliefs, but this finding did not carry forward into the kinematics or kinetics of the single leg hop.

Frontal plane motion, hip adduction and knee abduction, has been found to be elevated in individuals with AKP compared to healthy controls.(10, 176, 178) Our study did not support these findings, where there were no significant differences in peak hip adduction or knee abduction angles between groups, and healthy controls actually demonstrated significantly greater peak knee abduction moments. A potential reason that we found significantly lower knee

abduction moments among individuals with AKP was their marginally shorter hop distance and their altered sagittal plane mechanics. Previous research has demonstrated that individuals with AKP demonstrate reduced knee flexion during stairs, walking and running compared to healthy controls.(177, 179, 180) This compensatory pattern was also noted in this study where individuals with AKP demonstrated reduced hip and knee flexion. A task that requires similar knee flexion, such as a lateral-step-down, may be a useful additional task to assess frontal plane movement patterns to further explore the impact of psychological beliefs among adolescents with AKP.

Limitations

It should be noted that there were several limitations in this study. First, the adolescent participants with AKP were separated into groups based on psychological beliefs. The FABQ-PA and TSK-11 which were used to assessed pain-related fear have not been specifically validated in the adolescent population. Second, we analyzed the movement patterns of one specific task, the single-leg hop for distance, which may not provide a complete picture of movement patterns for this population. Third, we did not analyze movement patterns of the trunk or ankle which may influence knee mechanics.(181) Finally, our results were limited to small homogenous groups based on a narrow age range and specific ranges of fear-avoidance beliefs which may limit the generalizability of the results.

Conclusion

Psychological beliefs have been found to be associated with pain, self-reported function and some aspects of objective function in adolescents with AKP, we did not, however, find the same to be true regarding mechanics in this population. Adolescents with AKP who demonstrated elevated pain-related fear had similar frontal and sagittal plane mechanics

compared to adolescents with low pain-related fear during a single leg hop task. This was a small exploratory study, and larger trials are necessary to conclude that psychological beliefs are not associated with mechanics among adolescents with AKP.

This chapter presents the third of the four manuscripts that were prepared based on the results of this dissertation study. The status of the manuscript is under review.

CHAPTER SEVEN

THE EFFECT OF A PSYCHOLOGICALLY INFORMED INTERVENTION TO TREAT ADOLESCENTS WITH ANTERIOR KNEE PAIN: A RANDOMIZED CONTROLLED TRIAL

Contribution of Authors and Co-Authors

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Contributions: Conceived and implemented the study design. Collected and analyzed data. Wrote first draft of the manuscript.

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Contributions: Helped conceive study design. Provided feedback on statistical analyses and early drafts of the manuscript.

Co-Author: Jessica Hoehn

Contributions: Helped conceive study design. Provided feedback on early drafts of the manuscript.

Co-Author: Laura Schmitt

Contributions: Helped conceive study design. Provided feedback and assisted in interpretation of three-dimensional analysis and assisted with early drafts of the manuscript.

INTRODUCTION

Anterior knee pain (AKP) represents the most common complaint of the knee, and is one of the most frequently reported musculoskeletal complaints in adolescent patients.(30, 31) AKP is characterized by pain in or around the patellofemoral joint during weight-bearing on a flexed knee without observable cartilage damage.(29, 149) Although prevalent among young adults 18-35 years old,(32) AKP is most common among adolescents, affecting 29% of this population.(4) AKP can have a pronounced impact on an adolescent's function and quality of life, reducing their ability to participate in sports, recreation, and even daily activities.

Therapeutic exercise is beneficial for treating AKP and is considered the mainstay treatment;(56) however, many adolescents have continued pain and dysfunction even after treatment. Rathleff et al(7) found that 65% of adolescents diagnosed with AKP reported pain and dysfunction two years later, while Stathopulu and Baildam(6) found that 91% reported patellofemoral symptoms 4 to 18 years after initial diagnosis. Additionally, 71% of adolescents reported that they needed to stop or reduce their sport participation due to the continued pain.(7) The unresolved pain and dysfunction observed in this population suggests that additional interventions are needed to improve the clinical outcomes of adolescents with AKP.

AKP is a multifactorial condition, and recent evidence demonstrates that there is a distinct psychological component to AKP.(11) Individuals with AKP may have elevated anxiety, depression, pain catastrophizing, and pain-related fear, which correlate with greater pain and reduced functional ability.(11-14, 20, 21) A recent systematic review found that pain-related fear and pain catastrophizing show the strongest and most consistent correlation with pain and physical function.(11) Pain catastrophizing describes a maladaptive cognitive style with an irrational negative forecast of future events regarding pain.(17) Pain-related fear motivates

individuals to avoid activities in which they have experienced pain in order to reduce the likelihood of re-experiencing pain or causing further physical damage.(18) Pain-related fear can be assessed by measuring fear-avoidance beliefs and kinesiophobia.

Based on the current evidence regarding psychological factors and AKP, it is unknown whether pain and the associated decreased function lead to the development of maladaptive psychological beliefs, or if elevated maladaptive beliefs lead to greater levels of pain and dysfunction. Change in fear-avoidance beliefs has been reported as the strongest predictor of function and pain outcomes in AKP.(14) Similarly, changes in pain and function were found to coincide with changes in individuals' pain catastrophizing and kinesiophobia beliefs.(12) These studies were observational and could not determine a causal relationship between psychological factors, pain, and functional ability. Selhorst et al.(182) found that when adolescents were treated using a sequential cognitive and physical treatment approach, greater improvements in pain and functional ability were noted. However, due to the study's design and limited sample size, the study was unable to determine if the improved clinical outcomes were a result of the psychological intervention, the sequential treatment of the physical impairments, or a combination of the two.(182)

Psychologically-informed interventions are typically intensive,(27) which potentially poses an issue when treating AKP because current evidence demonstrates that exercise should be the primary focus of a treatment approach.(28) Therefore, there is a need for a concomitant intervention that can efficiently and effectively address maladaptive psychological beliefs. The authors recently demonstrated that incorporating a brief one-time psychologically-informed video into standard physical therapy care can significantly reduce maladaptive psychological beliefs in adolescents with AKP.(183) The purpose of this study was to determine if the addition

of a brief psychologically-informed video to traditional physical therapy had an effect on the function (primary aim) and pain (secondary aim) outcomes among adolescents with AKP. We hypothesize that the adolescents who view the brief psychologically-informed video will demonstrate significantly greater improvements in functional ability when compared to those who view the control video.

METHODS

Design

This study was a randomized controlled trial performed in the outpatient physical therapy clinics of a pediatric hospital. Adolescents who reported pain in their anterior knee from April 2019 through October 2019 were considered for participation. The institutional review board approved this study prior to recruitment and data collection. All patients and guardians provided written informed consent prior to participation. This study was registered at ClinicalTrials.gov (Identifier number NCT03897907).

Participants

Patients were included if they were an adolescent (aged 12-17 years) who reported pain around or behind the patella, which was aggravated by at least one activity that loads the patellofemoral joint during weight-bearing on a flexed knee (e.g., squatting, stair ambulation, jogging/running, hopping/jumping).(149) Patients were excluded if there was a 1) prior patellar dislocation, 2) suspicion of other diagnosis of the knee, 3) other concomitant injury of the lower quarter, 4) previous surgery in the lower quarter, or 5) neurologic or developmental disorder which alters lower extremity function.

Intervention

Participants completed one research study session where they underwent a baseline assessment and watched one of two videos on an iPad: the psychologically-informed video or a control video. After the research session, participants completed traditional physical therapy (two sessions per week) focusing on exercises to improve flexibility, strength, and neuromuscular control. The treating therapists were blinded to the allocated video group and did not provide any psychologically-informed education or treatment.

Psychologically-Informed Video Group

The experimental group watched a short psychologically-informed video (8 minutes and 30 seconds) which has previously been shown to significantly reduce maladaptive psychological beliefs in adolescents with AKP.(183) The psychologically-informed video addressed pain-related fear and pain catastrophizing using the "Common Sense Model of Self-Regulation" framework. This framework advocates for information to address five cognitive dimensions: (1) identity (the effort to evaluate symptoms and label the illness); (2) cause (the subjectively formulated belief of what is causing the symptoms); (3) time-line (the patient's perception of how long the problem will last); (4) consequences (the patient's predictions of how the illness will affect them in different areas of their life); and (5) controllability (the patient's belief regarding their outcome and personal ability to change it).(145) Additionally, the video provided participants components of pain neuroscience education, with information on how their body processes nociception, experiences pain, and the concept that pain does not always mean tissues are being damaged. Recommended adult pain neuroscience education was modified using published recommendations for the adolescent population and tailored to AKP.(119)

Key information provided in the psychologically-informed video addressed each part of the five cognitive dimensions listed above as follows. 1) First, the video explained that although their diagnosis may sound complicated, it should not be scary, and provided an overview of AKP in easy to understand terms. 2) The video explained that AKP can be from too much stress, both from patellofemoral joint stressors and psychological stressors. 3) It then provided a timeline, telling participants that through exercise and by modifying activity many adolescents can greatly reduce their pain and improve function within a month.(82-84) 4) However, if left unaddressed, the pain for some can last for months or even years. 5) Finally, the video relates that many of the stressors which contribute to AKP can be controlled by the adolescent and ends by providing a few simple tips to help reduce these stressors.

Control Video Group

Participants in the control group watched a video equal in length to the psychologically-informed video (8 minutes and 30 seconds). The control video discussed basic anatomy of the lower extremity and the theorized biomedical factors involved in AKP. The control video provided no psychologically-informed education or positive reinforcement about their condition.

Outcomes

All self-report measures on psychological beliefs, pain and function were completed on a tablet using REDCap electronic data capture tools.(162, 163) The self-report measures were completed at baseline (pre-video intervention), immediately following the video (psychological measures only), 2 weeks, and at 6-week follow-up. The follow-up measures were completed through an email REDcap survey.

Participant Demographics

Demographic data was collected on each participant including their age, sex, and body mass index (BMI). Participants were asked the duration of their knee pain, and the knee injured (R, L, Bilateral). Activity participation information was collected including participation in organized sports and the Marx Activity Rating Scale was used to provide a standardized method of grading the participant level of activity.(164)

Function

The Anterior Knee Pain Scale (AKPS), a 13-item self-report questionnaire, was used to assess participant's knee function and symptoms. The AKPS is scored 0-100, with 100 representing no disability. The AKPS has a minimal clinically important difference of 10 points and has been found to have excellent validity and reliability among individuals 12-50 years with AKP.(134, 135)

Pain

The Numeric Pain Rating Scale (NRPS), an 11-point pain-rating scale ranging from 0 (no pain) to 10 (worst imaginable pain), was used to assess the patient's highest knee pain in the past 24 hours.(132) The NRPS has a minimal clinically important difference of 1.2 points in individuals with AKP.(133)

Psychological Beliefs

Pain-related fear and pain catastrophizing demonstrate the strongest and most consistent correlation with both pain and physical function among individuals with AKP.(11) Pain-related fear was assessed using the Modified Fear-Avoidance Beliefs Questionnaire-Physical Activity

(FABQ-PA) subscale(14, 89) and the Tampa Scale for Kinesiophobia-11 (TSK-11),(95) and pain catastrophizing was assessed using the Pain Catastrophizing Scale-Child (PCS-c).(97) The FABQ-PA was modified by changing the word "back" to "knee" on the questionnaire.(14) Each item was scored on a 0-6 scale, with 0 indicating completely disagree and 6 indicating completely agree. Questions 2-5 were summed to create a final score of 0-24, with higher scores indicating greater fear-avoidance beliefs. The TSK-11 is an 11-item questionnaire that assessed fear of movement and re-injury. Participants were asked to make ratings of their degree of agreement with each of the 11 statements. Ratings range from 1 (strongly disagree) to 4 (strongly agree). The responses are summed to yield a total score ranging from 11- 44, where higher values reflect greater fear of injury due to movement.(93) The PCS-c is a 13-item self-report measure used to assess pain catastrophizing. Each item was rated on a 5-point scale, ranging from 0 (not at all) to 4 (all the time) and was summed to create a final score of 0-52, with higher scores indicating greater pain catastrophizing.(97)

Randomization and Blinding

This was a double-blinded randomized controlled trial. The participants knew they were watching an educational video but were not made aware if it was the control or experimental video. The study staff and treating physical therapists were blinded to group allocation until after all measurements were completed. Randomization was performed using a computer-generated list, which was created by an individual not involved in the study using the website www.randomizer.org. The computer-generated list was uploaded to the REDcap system, which allowed participants to watch the allocated video while keeping the study staff blinded.

Sample Size Estimation

Sample size estimates were based on anticipated differences necessary to detect clinically important change using the Anterior Knee Pain Scale. Sample size calculations were made using alpha=0.05, a minimal clinically important difference of 10, and a within-group standard deviation (SD) of 12.4.(135, 146) Assuming a dropout rate of 10%, a sample size of 28 participants in each group was calculated to provide sufficient statistical power (80%) to detect a meaningful between-group difference.

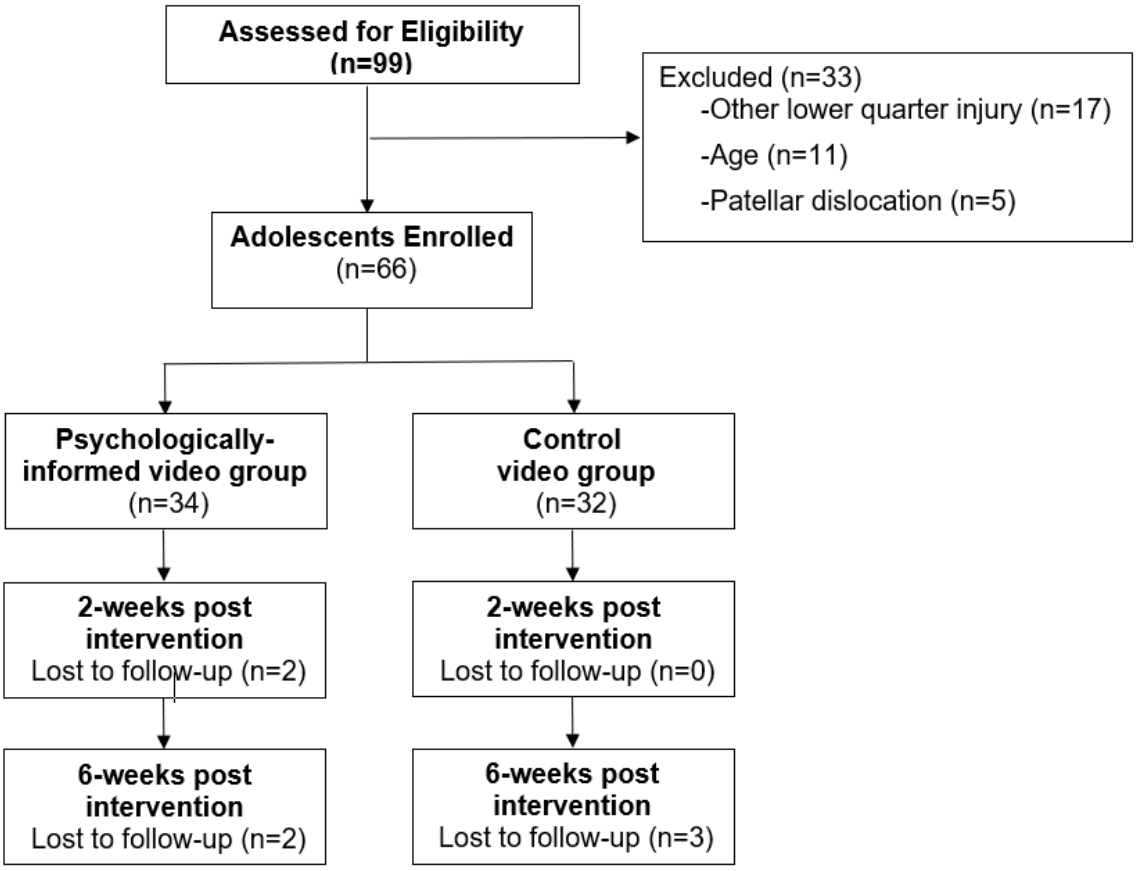
Data Analysis

Statistical analyses were made using IBM® SPSS® (Statistical Package for the Social Sciences) Statistics 24.0 software (IBM Corporation, Armonk, NY). An intent-to-treat design with the multiple-imputation model was used for any missing values due to patient drop-out.(147) Descriptive statistics were calculated for demographic and baseline variables. To ensure the intervention worked as anticipated, change in psychological beliefs (FABQ-PA, TSK-11, and PCS-c) were assessed with a two-way multivariate analysis of variance (MANOVA). To test the hypothesis of the study's primary aim, a two-way mixed analysis of variance (ANOVA) was performed, with the treatment group as the between-subject variable and time as the within-subject variable. The dependent variable for the primary objective was the Anterior Knee Pain Scale score. Effect size for the Anterior Knee Pain Scale was assessed using partial η^2. A partial $\eta^2 = 0.01$ is considered small, 0.1 is medium, and 0.25 is a large treatment effect.(148) Post-hoc univariate testing was performed to assess the interaction and between group differences at 2 weeks and 6 weeks, as well as the change in function over the 6 weeks. To test the hypothesis of the study's secondary aim, a two-way mixed ANOVA was performed to asses between-group differences in pain over time.

RESULTS

Over the course of 7 months, 66 adolescents with AKP were recruited for participation in this study (FIGURE 7.1). Patients were randomized into the psychologically-informed video group (n = 34) or the control video group (n =32). All participants received treatment as allocated. Two participants (3%) failed to complete the two-week follow-up questionnaire and 5 participants (8%) failed to complete the six-week follow-up questionnaire. Patient drop outs were not significantly different between groups (*p* value = 0.59).

Figure 7.1. Participant Flow Diagram



Baseline characteristics were collected on all participants at the start of the study and there were no significant between group differences (TABLE 7.1). Both groups completed a

similar number of physical therapy visits over the six-week time period (psychologically-informed group = 4.8 ± 3.6 visits, control group = 5.9 ± 2.6 visits, *p* value = 0.17).

TABLE 7.1. Baseline Characteristics

	All Patients (n=66)	Psychologically-informed video group (n=34)	Control video group (n=32)
Age (years)	14.8 ± 1.7	15.3 ± 1.7	14.3 ± 1.7
Sex (% female)	43 (65%)	24 (71%)	19 (59%)
Body mass index (kg/m^2)	23.1 ± 5.4	24.0 ± 5.8	22.4 ± 5.5
Duration of symptoms (weeks)*	18 (7, 53)	13 (7, 41)	25 (7, 54)
Bilateral knee pain (% yes)	26 (39%)	12 (35%)	14 (44%)
Participates in organized sport (% yes)	52 (79%)	27 (79%)	25 (78%)
Marx activity rating scale	11.5 ± 4.5	11.2 ± 4.7	11.7 ± 4.3
Numeric Pain Rating Scale	4.8 ± 2.1	5.0 ± 1.9	4.5 ± 2.3
Anterior Knee Pain Scale	73.1 ± 13.8	69.9 ± 13.7	76.4 ± 13.4
Fear Avoidance Beliefs Questionnaire-Physical Activity Subscale	12.2 ± 5.5	13.0 ± 5.6	11.4 ± 5.3
Tampa Kinesiophobia Scale-11	22.4 ± 5.3	22.9 ± 5.9	21.9 ± 4.8
Pain Catastrophizing Scale-child	17.1 ± 9.8	16.6 ± 9.3	17.6 ± 10.4

Values are mean ± SD unless otherwise indicated
*median (interquartile range)

Change in Psychological Beliefs

To determine if the intervention was able to reduce psychological beliefs, changes in adolescent psychological beliefs (FABQ-PA, TSK-11, and PCS-c) were reassessed immediately after the intervention and at 2 weeks. There was a statistically significant interaction and large treatment effect between the intervention and time on psychological beliefs, F (6, 48) = 3.69, p = 0.01, Wilks' Λ = 0.69, partial η^2 = 0.32 (TABLE 7.2). Univariate analysis revealed that the psychologically-informed video significantly reduced FABQ-PA (F(1, 64) = 14.6, p<0.001, partial η^2 = 0.19), TSK-11 (F(1, 64) = 7.5, p = 0.01, partial η^2 = 0.11), and PCS-c (F(1, 64) = 5.8, p = 0.02, partial η^2 = 0.08) scores from baseline to immediately post-intervention. No significant interaction was noted between the intervention and time on psychological beliefs

between immediately post-intervention and the two-week follow-up (FABQ-PA $p = 0.36$; TSK-11 $p = 0.10$; and PCS-c $p = 0.51$).

TABLE 7.2. Change in Maladaptive Beliefs over Time

	Group	Baseline	Immediate Post Video	2 weeks
FABQ-PA	Psychologically-informed	13.0 ± 5.6	9.7 ± 5.1	8.0 ± 5.5
	Control	11.4 ± 5.3	11.5 ± 5.7	9.4 ± 6.0
TSK-11	Psychologically-informed	22.9 ± 5.9	19.7 ± 6.2	18.1 ± 6.9
	Control	21.9 ± 4.8	21.4 ± 5.6	21.3 ± 6.6
PCS-c	Psychologically-informed	16.6 ± 9.3	13.4 ± 9.8	12.1 ± 9.2
	Control	17.6 ± 10.4	15.1 ± 9.3	13.9 ± 8.9

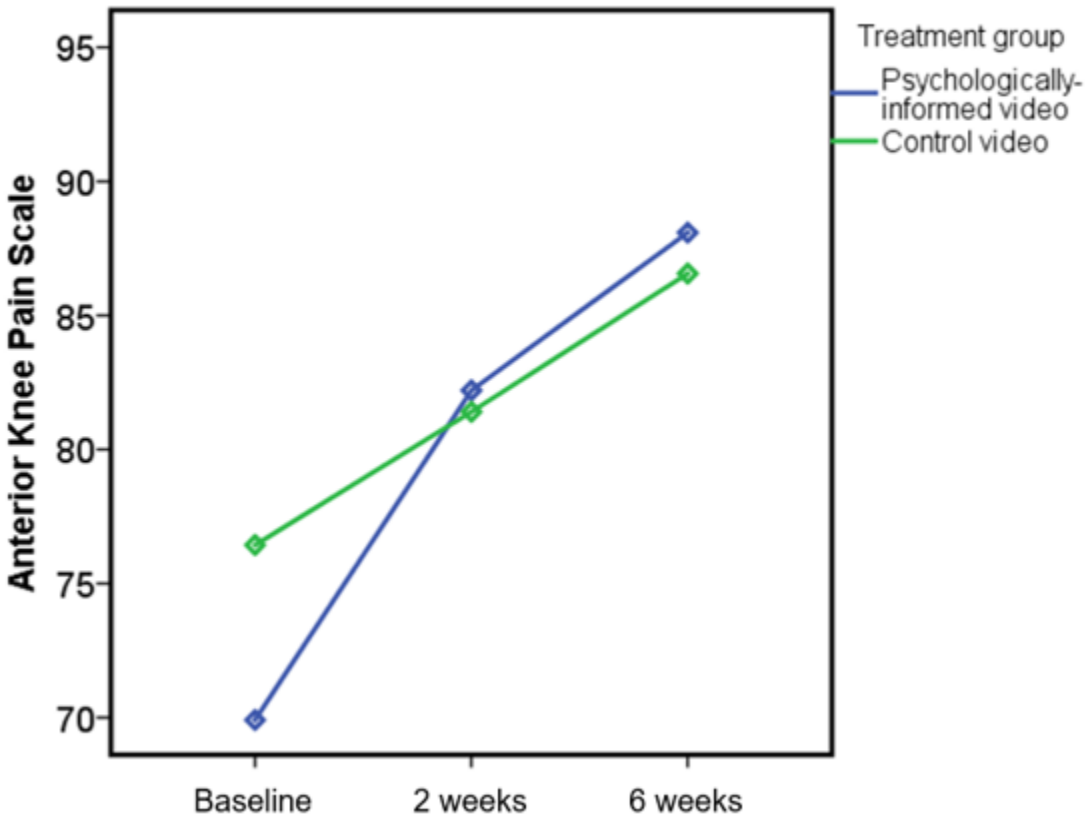
FABQ-PA, Fear Avoidance Beliefs Questionnaire-Physical Activity; TSK-11, Tampa Scale for Kinesiophobia-11; PCS-c, Pain Catastrophizing Scale-Child.

Primary Outcome-*Function*

The assumptions of the two-way ANOVA were assessed and met. There were outliers in each group at the two-week and six-week time points as assessed by inspection of boxplots (psychologically-informed, n=2; control, n=3). With the outliers kept, the data were not normally distributed with both groups having significant p values on the Shapiro-Wilk's test of normality at 6-week follow-up (psychologically-informed group $p = 0.01$ and control group $p = 0.01$). With the outliers removed, the data were normally distributed, as assessed by Shapiro-Wilk's test of normality ($p > 0.05$). Analyzing the mixed ANOVA with and without the outliers revealed there was no significant differences in the results, therefore the outliers were kept in the analysis. Mauchly's test of sphericity indicated that the assumption of sphericity was violated for the two-way interaction, $\chi^2(2) = 12.26$, $p = 0.002$, therefore the results were interpreted using a Greenhouse-Geisser correction. There was a statistically significant interaction and a moderate treatment effect noted between the intervention and time on self-reported function, F (1.69, 102.62) = 6.63, $p = 0.003$, partial $\eta^2 = 0.1$ (FIGURE 7.2). Further post-hoc testing revealed that there were no significant between-group differences at any time point. Adolescents in the

psychologically-informed video group experienced statistically significantly greater change in function over the six-weeks than those in the control video group, with a mean difference of 8.0 points of the AKPS (95% CI 2.4, 13.5; $p = 0.01$). However, the difference noted between groups did not achieve clinical significance (TABLE 7.3).

FIGURE 7.2. Change in Function



Pain

Both groups demonstrated a clinically significant improvement in pain at 2 weeks, although this improvement was not maintained for the control group at the 6-week follow-up. The assumptions of the two-way ANOVA were assessed and met. Mauchly's test of sphericity indicated that the assumption of sphericity was met, $\chi^2(2) = 3.86$, $p = 0.15$. There was no significant interaction between the intervention and time on self-reported pain, F (2, 128) = 1.68, $p = 0.20$, partial $\eta^2 = 0.03$. Post-hoc testing revealed that there were no significant between-group differences or interactions at any time point (TABLE 7.3).

TABLE 7.3. Change in Clinical Outcomes Over Time

	Treatment Group	**Baseline**	**2-week**	**6-week**
Anterior Knee Pain Scale	Psychologically-informed	69.9 ± 13.7	82.2 ± 13.3	88.1 ± 11.8
	Control	76.4 ± 13.4	81.4 ± 13.6	86.6 ± 14.1
Numeric Pain Rating Scale	Psychologically-informed	5.0 ± 1.9	3.1 ± 1.9	2.2 ± 2.5
	Control	4.5 ± 2.3	3.3 ± 2.2	2.8 ± 2.5

DISCUSSION

Emerging evidence shows that when treating individuals with AKP, psychological factors and pain sensitization should be considered.(154-157) Anxiety, depression, pain catastrophizing, and pain-related fear have been found to be elevated among individuals with AKP, and the greatest correlation has been identified between patellofemoral symptoms and pain catastrophizing and pain-related fear.(11) The current study found that after viewing the psychologically-informed video, adolescents experienced statistically significantly greater improvements in pain-related fear, pain catastrophizing and functional ability than adolescents in the control group. These findings suggest that a brief psychologically-informed education

intervention may be a beneficial addition to a traditional exercise program for adolescents with AKP.

This study is the first to assess the effect of adding a psychologically-informed intervention for individuals with AKP. We found that the addition of the psychologically-informed video had a moderate effect on pain-related fear and a moderate interaction between the intervention over time on function. These findings are supported by previous observational studies which found that change in function was strongly correlated with change in pain-related fear.(12, 160) Interventions to reduce maladaptive beliefs in other musculoskeletal conditions have shown conflicting results. In a recent systematic review,(27) pain neuroscience education was found to improve pain catastrophizing, fear-avoidance, pain ratings, pain knowledge, and disability. In contrast, Traeger et al(158) found that intensive patient education was no more effective than placebo education for individuals with acute low back pain.

This study found that the addition of the psychologically-informed video did not statistically significantly improve changes in reported pain when compared to the control group. The addition of the psychologically-informed video had a moderate effect on pain-related fear, but only a small effect was observed for pain catastrophizing. Previous studies have found that pain-related fear is most associated with decreased self-reported function, while catastrophizing about pain is more associated with high pain levels.(169-171) In regards to AKP specifically, research on psychological beliefs demonstrates that pain catastrophizing is most associated with reported pain.(12, 13) Education which better addresses pain catastrophizing beliefs may better affect an individual's pain.

Traditional psychologically-informed education is intensive and requires a significant amount of time and training to correctly incorporate into treatment.(27) This study's psychologically-informed intervention was brief and only occurred once. We found that adolescents responded well to video on a tablet, and use of a video format allows for standardized information across all participants. Additionally, videos allow for other clinicians to easily replicate the psychologically-informed intervention without advanced training. However, the effects noted from the one-time intervention did not continue throughout the course of care. The intervention significantly reduced maladaptive beliefs immediately, but after two weeks, similar reductions in psychological beliefs were noted in both groups. Additionally, the interaction between the intervention and time observed for functional change only occurred between baseline and the two-week follow-up when the psychologically-informed video was watched. These findings suggest that while the brief-one-time psychologically-informed video was initially effective, these effects do not carry on and continue to improve maladaptive beliefs or clinical outcomes among adolescents with AKP. It is possible that repeated exposure to this intervention would result in more sustained treatment effects. Providing a series of brief psychologically-informed videos may increase the effect observed from the intervention in this study over the course of care.

Limitations

Although this study sample was randomized, the psychologically-informed group demonstrated a marginally lower functional ability on the Anterior Knee Pain Scale at baseline than the control group. This initial between-group difference suggests a potential study bias, where the interaction effect observed may represent regression towards the mean. The chance that we observed regression towards the mean instead of a true treatment effect is lessened by the

facts that 1) the initial between-group difference, although trending, was not statistically significant using an independent t-test ($p = 0.056$), 2) both groups had a chronic median duration of AKP (>3 months) and 3) after the two-week follow-up both groups improved at a similar rate.

Conclusion

This study provides the first evidence that addressing maladaptive psychological beliefs effects functional ability in adolescents with AKP. Incorporating a brief one-time psychologically-informed video into standard physical therapy care significantly reduced maladaptive psychological beliefs and improved function. The effect noted from the single intervention did not achieve clinically significantly greater improvements in function over time, and adolescents may benefit from continued psychologically-informed interventions.

CHAPTER EIGHT: SUMMARY

INTRODUCTION

This chapter will discuss the findings related to each of the three research questions, and how our findings addressed the problem statement introduced in Chapter 1. Additionally, we will describe the implications of the results on clinical practice. This chapter will conclude with a discussion of the study limitations and recommendations for future research.

Our problem statement introduced in Chapter 1 stated that: *Psychological factors impact self-report measures of pain and function among adults with Anterior Knee Pain (AKP), but we do not know if (1) psychological factors also impact pain, self-reported function and objective measures of function among adolescents with AKP and (2) a psychological intervention would affect their function.* The results of this research demonstrated that psychological beliefs are adversely associated with function, pain and certain measures of function in adolescents with AKP. Moreover, addressing these maladaptive beliefs through psychologically-informed education can improve self-reported function in this population.

Research question 1 found that psychological beliefs including pain-related fear and pain catastrophizing were moderately associated with an adolescent's function and reported pain. These findings are similar to what has been previously observed in adults with AKP.(11) However, our hypothesis that parental psychological beliefs would also influence the adolescent's pain and functional ability was not supported by our findings. This study did not find a significant relationship between parent beliefs on fear-avoidance, kinesiophobia, pain catastrophizing and any aspect of adolescent psychological beliefs, pain, or self-reported function. However, there remains the likely possibility that other aspects of parental beliefs

influence adolescent patients as has been theorized in pediatric psychological models.(22, 119) The parental report questionnaires were brief and only assessed a small aspect of parent influence, pain beliefs. Other factors such as modeling, and involvement in sport participation should be assessed in future work.

The majority of research assessing the influence of psychological factors in individuals with AKP assessed self-report measures of function and pain, but not objective measures of functional ability. Research questions 1 and 2 helped to provide insight on how psychological factors influence objective measures of functional ability. Research question 1 assessed standard clinical tests. While research question 2 explored if pain-related fear affected frontal plane biomechanics assessed with three-dimensional motion analysis. We found that psychological factors were significantly associated with some, but not all aspects of objective functional ability. Fear-avoidance beliefs were most associated with clinical measures of functional ability. We found that fear-avoidance beliefs were mildly adversely associated with hip abduction strength and single-leg hop for distance. Fear-avoidance beliefs also trended to a mild association with quadriceps strength and quadriceps flexibility with a p value of <0.05, however, we could not conclude a significant relationship with this work due to the need to account for the multiple comparisons. Kinesiophobia was mildly associated with hip abduction strength. We did not observe differences among adolescents with AKP who had elevated pain-related fear when compared to adolescents with low pain-related fear regarding frontal-plane kinematics and kinetics during a single leg hop test. Pain catastrophizing beliefs were not associated with any objective measure of functional ability. Pain-related fear (fear-avoidance beliefs and kinesiophobia) had significant associations with self-reported function (FABQ-PA r = -0.59, TSK-11, r = -0.33), hip abduction strength (FABQ-PA r = -0.41, TSK-11, r = -0.32), (FABQ-PA

r = -0.59, TSK-11, r = -0.33), and single leg hop for distance (FABQ-PA r = -0.38), These findings suggest that pain-related fear not only influences the patient's perception of their function, but also several aspects of their objective functional ability.

Finally, research question 3 determined that providing a psychologically-informed intervention, which reduced maladaptive psychological beliefs, resulted in significant improvements in function. This study was a randomized controlled trial and was the first study to assess the cause-and-effect relationship of psychological beliefs and function among individuals with AKP. The brief one-time psychologically-informed educational intervention significantly reduced the adolescent's pain-related fear and pain catastrophizing beliefs and provided short-term improvements in function. However, the effects noted from the one-time intervention did not continue throughout the course of care. These findings suggest that while the brief-one-time psychologically-informed video was initially effective, additional psychologically-informed interventions may be necessary for greater improvements. We do not recommend repeated watching of the same video to achieve improved results, but rather the introduction of different concepts such as cognitive restructuring, methods of taking control of your pain, and self-reflection. The video series would ideally educate adolescents in multiple aspects of psychological beliefs while providing brief reviews of previous videos.

The results of this research have important implications on clinical practice. When treating adolescents with AKP, clinicians should consider pain-related fear and pain catastrophizing beliefs as relevant factors which impact patient presentation and prognosis. We found that the adolescent's psychological beliefs significantly added to the prediction of self-reported function even after controlling for pain and objective measures of function. Moreover, addressing these

psychological beliefs through a psychologically-informed intervention significantly improved functional ability when compared to the control group.

Limitations

There are several limitations in this study which must be acknowledged. First, the research was performed in a limited geographical area in an adolescent population; the results of this study can only be applied to the adolescent population as there are likely significant psychological differences between adult and adolescent patients. Additionally, the same psychological beliefs may not hold true in other countries or cultures. Second, we used both the FABQ-PA and the TSK-11 to measure maladaptive beliefs as both kinesiophobia and fear-avoidance beliefs have been shown to be associated with AKP.(13, 160, 161) However, these measures have not been specifically validated in the adolescent population. Third, although we did not find any differences in movement patterns between adolescents with high and low fear beliefs, we only assessed a small number of participants on one task and only evaluated the movement patterns of the knee and hip. Movement patterns of the trunk and ankle have previously been found to influence knee mechanics.(181) Future work should assess more participants, focus on proximal and distal movement patterns, and assess more functional tasks to better assess the impact of psychological beliefs on movement patterns. Finally, although the study sample for research question 3 was randomized, the psychologically-informed group demonstrated a marginally lower functional ability on the Anterior Knee Pain Scale at baseline than the control group. This initial between-group difference suggested a potential study bias, where the interaction effect observed may represent regression towards the mean. The chance that we observed regression towards the mean instead of a true treatment effect was lessened by the facts that 1) the initial between-group difference, although trending, was not statistically

significant using an independent t-test ($p = 0.056$), 2) both groups had a chronic median duration of AKP (>3 months), and 3) after the two-week follow-up, both groups improved at a similar rate.

Recommendations for Future Research

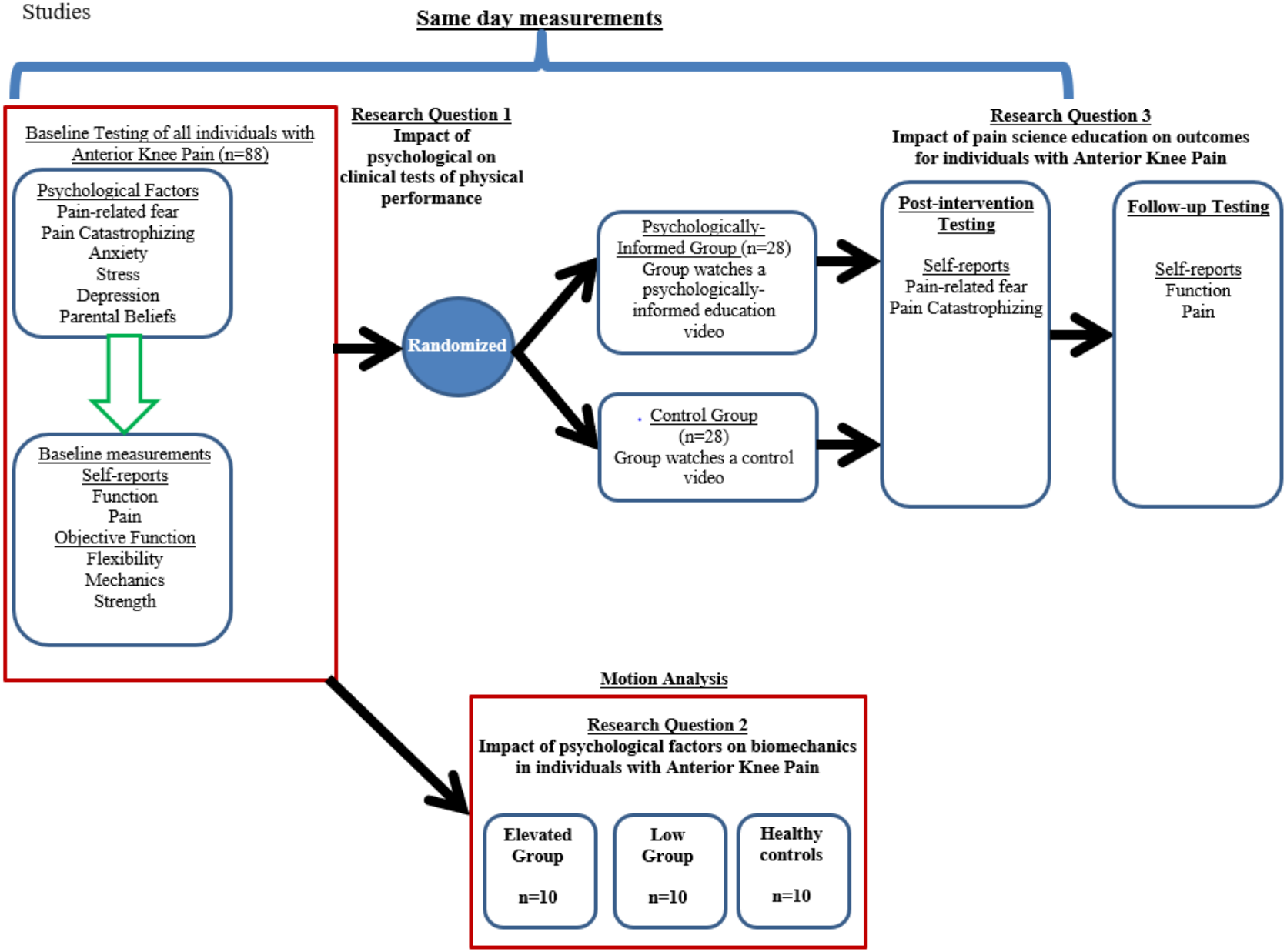
This research lays the initial groundwork for a psychologically-informed educational intervention to assist in treating young individuals with AKP. There are several opportunities to expand upon this work to improve our understanding. First, we noted a significant improvement in function following the psychologically-informed education, but the effect did not continue over the course of care. Future work may assess the effects of a series of brief psychologically-informed educational interventions delivered throughout the course of care. Providing a series of educational interventions may result in a greater treatment effect than the one-time educational intervention performed in this study. Second, it will be important to determine how the severity of maladaptive beliefs interact with the psychologically-informed intervention. There may be different effects noted in individuals with low, moderate, or high maladaptive beliefs. A final suggestion for future research involves making these results generalizable to other populations. This study only assessed adolescents with AKP, but AKP is also quite prevalent in young adults. Future work can assess how adults with AKP respond to a psychologically-informed educational intervention. Furthermore, the psychologically-informed intervention focused on AKP, however by using the same underlying principles, the educational video could be modified for patients with other musculoskeletal conditions and its impact on function could be assessed.

Chapter Summary

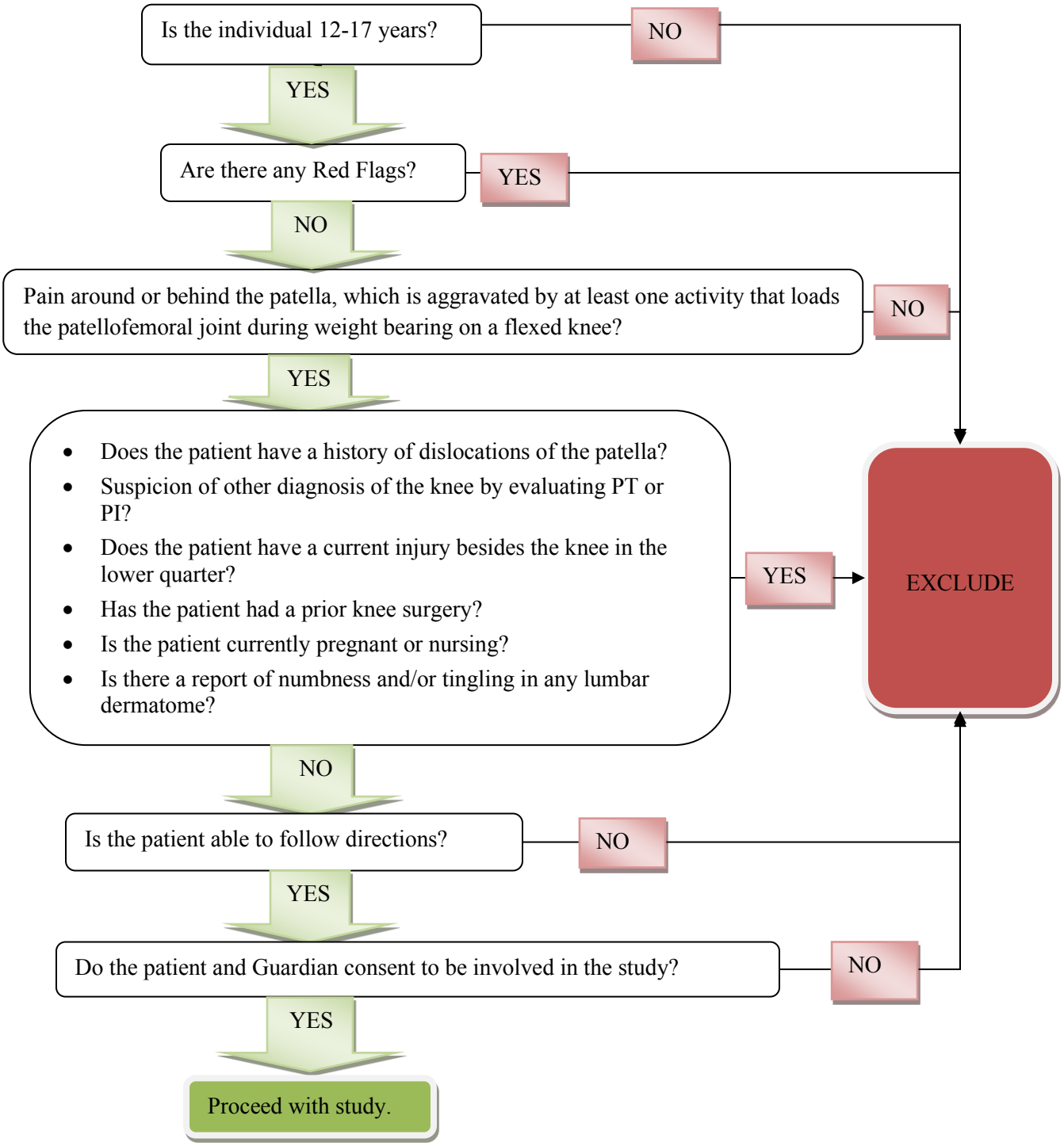
Maladaptive beliefs including fear-avoidance, kinesiophobia, and pain catastrophizing were common among adolescents with AKP. These maladaptive beliefs were adversely

associated with pain, self-reported function, and objective measures of function. Additionally, adolescent psychological beliefs significantly influenced functional ability after accounting for important factors including sex, pain and physical ability. Significant differences in kinematics and kinetics were observed between adolescents with AKP and healthy controls, but no differences were noted in adolescents with elevated pain-related fear (fear-avoidance beliefs and kinesiophobia) compared to adolescents with low pain-related fear. A brief psychologically-informed educational video designed by the investigators was effective at reducing pain-related fear and pain catastrophizing. When the psychologically-informed educational intervention was compared against a control group, significantly greater improvements in function were noted in the short term.

APPENDIX 1. Diagram of Dissertation Studies



Appendix 2. AKP Cohort Eligibility Flowsheet



Participant #_____ Participant Initials _____ Meets Inclusion Criteria? Yes / No

Screening Study Staff Signature_____

Date _____ Time _____ am / pm

APPENDIX 3. Fear Avoidance Beliefs Questionnaire-Physical Activity subscale

Fear Avoidance Beliefs Questionnaire-Physical Activity (FABQ-PA)

Here are some of the things which <u>other</u> patients have told us about their pain. For each statement please circle any number from 0 to 6 to say how much physical activity such as walking, running, kneeling, or driving would affect <u>your</u> knee pain.

	COMPLETELY DISAGREE			UNSURE			COMPLETELY AGREE
1. My pain was caused by physical activity	0	1	2	3	4	5	6
2. Physical activity makes my pain worse	0	1	2	3	4	5	6
3. Physical activity might harm my knee	0	1	2	3	4	5	6
4. I should not do physical activities which (might) make my pain worse	0	1	2	3	4	5	6
5. I cannot do physical activities which (might) make my pain worse	0	1	2	3	4	5	6

APPENDIX 4. Tampa Scale for Kinesiophobia-11

Tampa Scale-11 (TSK-11) **Name:** **Date:**

This is a list of phrases which other patients have used to express how the view their condition. Please circle the number that best describes how you feel about each statement.

	Strongly Disagree	Somewhat Disagree	Somewhat Agree	Strongly Agree
1. I'm afraid I might injure myself if I exercise.	1	2	3	4
2. If I were to try to overcome it, my pain would increase.	1	2	3	4
3. My body is telling me I have something dangerously wrong.	1	2	3	4
4. People aren't taking my medical condition serious enough.	1	2	3	4
5. My accident/problem has put my body at risk for the rest of my life.	1	2	3	4
6. Pain always means I have injured my body.	1	2	3	4
7. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening.	1	2	3	4
8. I wouldn't have this much pain if there wasn't something potentially dangerous going on in my body.	1	2	3	4
9. Pain lets me know when to stop exercising so that I don't injure myself.	1	2	3	4
10. I can't do all the things normal people do because it's too easy for me to get injured.	1	2	3	4
11. No one should have to exercise when he/she is in pain.	1	2	3	4

APPENDIX 5. Pain Catastrophizing Scale-child

PCS-C

Thoughts and feelings during pain

We are interested in what you think and how strong the feelings are when you are in pain. Below are 13 sentences of different thoughts and feelings you can have when you are in pain. Try to show us as clearly as possible what you think and feel by putting a circle around the word under each sentence that best reflects how strongly you have each thought..

1. When I am in pain, I worry all the time about whether the pain will end.
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

2. When I am in pain, I feel I can't go on like this much longer.
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

3. When I am in pain, it's terrible and I think it's never going to get better.
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

4. When I am in pain, it's awful and I feel that it takes over me
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

5. When I am in pain, I can't stand it anymore
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

6. When I am in pain, I become afraid that the pain will get worse
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

7. When I am in pain, I keep thinking of other painful events
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

8. When I am in pain, I want the pain to go away
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

9. When I am in pain, I can't keep it out of my mind
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

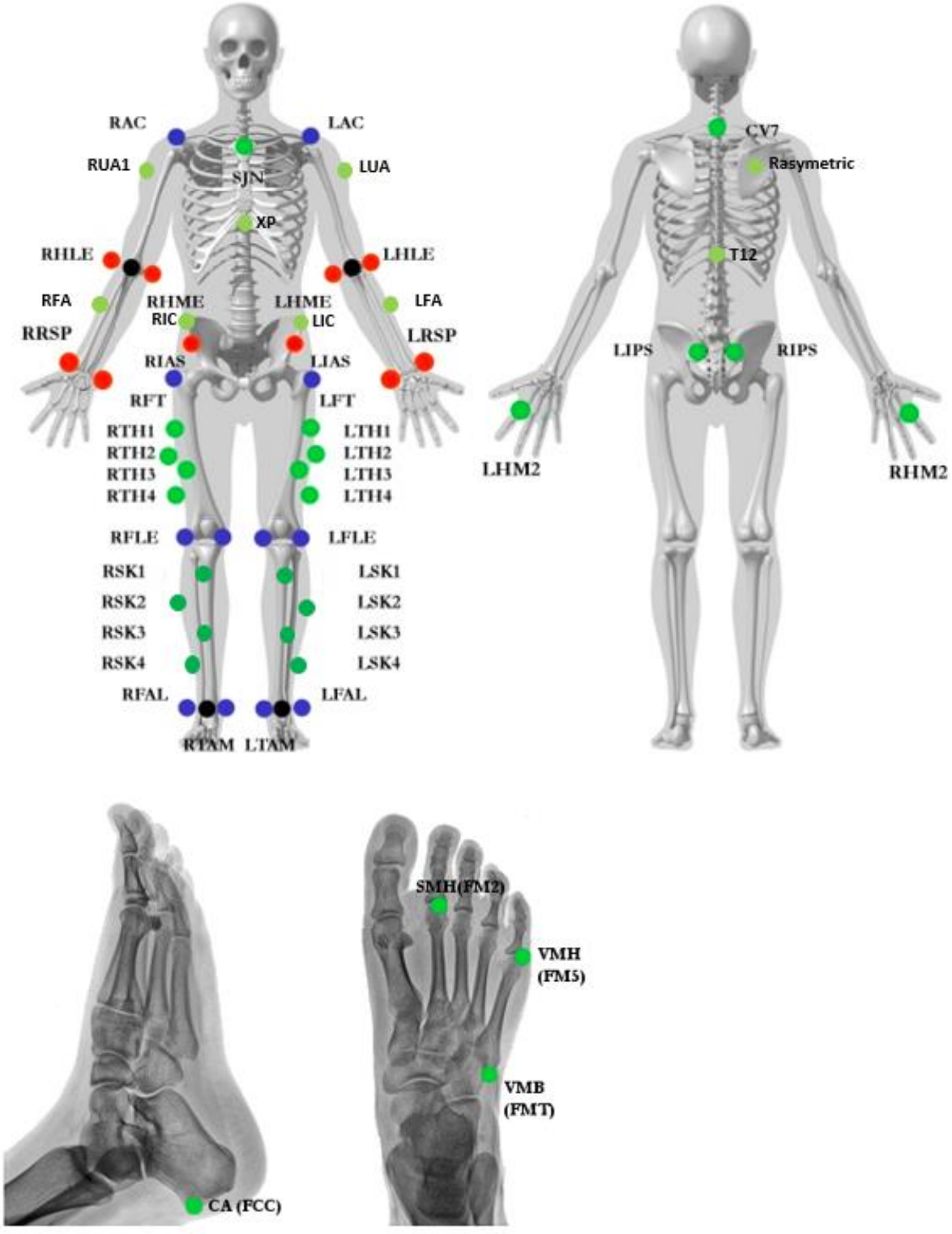
10. When I am in pain, I keep thinking about how much it hurts
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

11. When I am in pain, I keep thinking about how much I want the pain to stop
. NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

12. When I am in pain, there is nothing I can do to stop the pain.
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

13. When I am in pain, I wonder whether something serious may happen
NOT AT ALL MILDLY MODERATELY SEVERELY EXTREMELY

APPENDIX 6. Motion Capture Marker Locations



APPENDIX 7. IRB Approval

September 21, 2018

Mitchell Selhorst
OT/PT/TR

Study ID: IRB18-00724
Study Name: The psychosocial impact on pain and function in adolescents with anterior knee pain.

The Institutional Review Board Expedited Committee has reviewed and approved the response to modifications for the above study application on 9/21/2018. **STUDY APPROVED**

Date of Approval:	9/19/2018
Date of Expiration:	9/18/2019
(the expiration date is the last day that the study has IRB approval)	
Expedited Review Category:	4 and 5
Risk Level:	The IRB assigned a Risk Level 1 - no greater than minimal risk (45 CFR 46.404; 21 CFR 50.51).
Waivers Granted:	None

Please note the following responsibilities:

AMENDMENTS: The Principal Investigator (PI) is responsible for notifying the IRB of any changes in the protocol, procedures, recruitment, consent forms, etc. This approval is based on the information as submitted. New procedures cannot be initiated until IRB approval has been given. If you wish to change any aspect of this study, please submit an amendment providing as justification for each change.

CONTINUING REVIEW: The PI is responsible for submitting a Continuing Review to the IRB at least 30 days prior to the expiration date listed above. Please note that study procedures may only continue into the next year if the IRB has reviewed and granted re-approval prior to the expiration date.

UNANTICIPATED PROBLEMS: The PI is responsible for reporting unanticipated problems involving risks to participants or others promptly to the IRB according to the current reporting policy found on our website. (SEE SOP IRB-12)

STUDY COMPLETION: Please complete a Final Report when the research, including data analysis, has been completed.

LEAVING THE INSTITUTION: You must notify the IRB of the disposition of all research studies when you leave NCH.

OTHER INFORMATION:

- IRB Policy requires that provisions are made for assent of subjects age nine and older.
- The Federalwide Assurance number assigned to the IRB at Nationwide Children's Hospital is **FWA00002860.**

If we can provide additional assistance, please do not hesitate to call the IRB office at 614-722-2708.

Sincerely,

Karen A. White, Ph.D., Chair
Institutional Review Board
This is an official email communication from Research Information Solutions and Innovation (RISI).
Always use caution when clicking on links or opening attachments in emails. RISI will never ask you for your password.
To validate the legitimacy of any questionable email, contact the RISI Support Center at (614) 355-5600.

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