<u>Original Research</u>

Health-Related Quality of Life and Psychological Outcomes in Participants with Symptomatic and Non-Symptomatic Knees after ACL Reconstruction

Johanna M. Hoch[1][a], Ansley Swann[2], Rachel Kleis[3], Matthew C. Hoch[4,5], Carrie Baker[4], Dee Dlugonski[4,5]

[1] Athletic Training and Clinical Nutrition, University of Kentucky, [2] Bluegrass Orthopaedics, [3] Department of Kinesiology, University of Wisconsin-Eau Claire, [4] Department of Athletic Training and Clinical Nutrition, University of Kentucky, [5] Sports Medicine Research Institute, University of Kentucky

International Journal of Sports Physical Therapy

Background

Individuals who sustain an ACL injury and undergo reconstruction (ACLR) are at risk for the development of osteoarthritis. Recent investigations have applied the Englund criteria to categorize people with a history of ACLR as someone with a symptomatic or asymptomatic knee.

Purpose/Hypothesis

The purpose of this study was to examine differences in health-related quality of life (HRQL) and psychological outcomes in people with a history of ACLR who were categorized as symptomatic or non-symptomatic by application of the Englund criteria. The authors' hypothesized participants classified as symptomatic would have lower HRQL, increased fear-avoidance beliefs, and decreased resilience compared to participants classified as non-symptomatic.

Study design

Cross-sectional, survey

Methods

Participants at least one-year after ACLR were recruited for the study and completed the Tegner Activity Scale, the Brief Resilience Scale (BRS), the modified Disablement in the Physically Active Scale (mDPA), and the Fear-Avoidance Belief Questionnaire (FABQ) at one time-point. Descriptive statistics were summarized using median [interquartile range] and differences between groups were examined using separate Mann-Whitney U tests.

Results

Participants with symptomatic knees had a significantly higher BMI (24.8 [6.4]) than the non-symptomatic group (21.2 [4.3], p=0.013). Participants in the symptomatic group had worse HRQL on the physical subscale (12.5 [16.3] vs. 0.0 [2.5], p<0.001) and mental subscale (2.0 [1] vs. 0.0 [1], p=0.031), higher scores on the FABQ-Sport (14.5 [11] vs. 0.0 [6], p<0.001) and FABQ-Physical Activity (20 [24] vs. 1 [4], p<0.001) and less resilience (3.7[0.42] vs. 4.0 [0.83], p=0.028) compared to those participants in the non-symptomatic

a Corresponding Author:
Johanna M. Hock
Department of Athletic Training and Clinical Nutrition
University of Kentucky
206A Charles T. Wethington Building
Lexington, KY 40509
859-323-7070
Johanna.hoch@uky.edu

group. There were no differences in current physical activity (p=0.285) or change in physical activity (p=0.124) levels between the two groups.

Conclusions

This series of differences may represent a cascade of events that can continue to negatively impact health outcomes across the lifespan for individuals with a history of ACLR. Future research should consider longitudinal investigations of these outcomes after injury and throughout the post-surgical and post-rehabilitation timeframe.

Level of Evidence

Level 3b

INTRODUCTION

Injury to the anterior cruciate ligament (ACL) and subsequent reconstruction (ACLR) can be associated with a multitude of negative outcomes including decreased physical activity,[1-3] decreased health-related quality of life (HRQL)[4] and earlier development of osteoarthritis[5,6] for some patients. Systematic reviews with meta-analyses have revealed that ACLR is associated with the development of osteoarthritis[5,6] and prevalence estimates are as high as 36% as soon as 10-years after reconstruction.[7] Typically, once a patient undergoes ACLR and completes formal rehabilitation, they are no longer under the direct care of a physician until early osteoarthritis symptoms have developed. By the time a patient presents to their provider with clinical signs and radiographic evidence of arthritic changes, the damage to the joint is irreversible.[8] Given the nature of the development and presentation of osteoarthritis, clinicians and researchers alike have aimed to identify assessments that can classify individuals as symptomatic or non-symptomatic early on in their disease progression.[9] The ability to identify patients that are symptomatic before the visualization of radiographic changes is pertinent for the advancement of intervention strategies to delay osteoarthritis development.[9]

The Englund classification system was originally developed to identify patients with a history of meniscectomy who had symptomatic knees associated with osteoarthritis development.[10] Specifically, the Englund classification classifies patients with symptomatic knees if they have a score of ≤87.5 on the Knee Osteoarthritis Outcome Score (KOOS) Quality of Life subscale, and two or more of the following scores on the remaining subscales: ≤86.1 on the KOOS-Pain, ≤85.7 on the KOOS-Symptoms, ≤ 86.8 on the KOOS-Activities of Daily Living (ADL) and ≤85.0 on the KOOS-Sports and Recreation (Sports) subscale.[10] The Englund classification has also been applied to patients early after ACLR.[11,12] Recent investigations have explored the relationship between symptomatic knees and clinical outcomes,[12] and explored the utilization of these criteria in patients approximately 6-months post-ACLR.[11] However, to the authors' knowledge, there is limited evidence that has explored the relationship between osteoarthritis symptomology, health-related quality of life and psychological outcomes in people with a history of ACLR.

Deficits in HRQL and fear-avoidance beliefs in people with a history of ACLR have been identified compared to healthy controls.[13] However, there is a lack of evidence to suggest these outcomes are different between people that are classified by the Englund criteria as symptomatic or non-symptomatic.[10] Understanding this relationship is important as clinicians and researchers begin to focus on the development of holistic patient-centered treatment strategies to address pain, symptoms and osteoarthritis in people with a history of ACLR. In addition, physical activity is a part of the non-surgical treatment strategy for osteoarthritis.[14] Therefore, it is important to examine psychological outcomes that may influence physical activity participation in this population such as fear-avoidance beliefs and resilience. Fear- avoidance beliefs have been associated with physical activity after ACLR.[4,15] Resilience is a term often used to describe a person's ability to adapt and overcome to their circumstances.[16] Factors associated with resilience such as communication and social support, self-efficacy and goal setting have been previously examined in patients who successfully undergo ACLR.[17] Previous literature has determined that patients with knee osteoarthritis with high resilience had a higher odds of having better self-reported overall health.[18] Therefore, the purpose of this study was to examine differences in HRQL and psychological outcomes in symptomatic and non-symptomatic individuals with a history of ACLR, as classified by the Englund criteria.[10] It was hypothesized that there would be significant differences in HRQL and psychological outcomes between these two groups. Specifically, we hypothesize that participants classified as symptomatic will have lower HRQL, increased fear-avoidance beliefs and decreased resilience compared to participants classified as non-symptomatic. These results will further support the need to develop treatment algorithms that can effectively address HRQL and psychological outcomes in people with a history of ACLR that have symptomatic knees.

METHODS

STUDY DESIGN

A cross-sectional survey-study was used to examine differences in patient-reported outcomes between participants with a history of ACLR with symptomatic knees and those without symptomatic knees. The dependent variables were scores on the Tegner Activity Scale, the Brief Resilience Scale (BRS), the modified Disablement in the Physically Active Scale (mDPA), and the Fear-Avoidance Belief Questionnaire (FABQ).

PARTICIPANTS

Participants with a history of ACLR were recruited via ResearchMatch. ResearchMatch is a national health volunteer registry that was created by several academic institutions and supported by the U.S. National Institutes of Health as part of the Clinical Translational Science Award (CTSA) Program.[19] To be included, participants must have been between the ages of 18-40 years, had a history of a unilateral or bilateral ACLR within the prior 10 years and had been cleared to participate in physical activity by a physician. Participants were excluded if they had surgery to the lower extremity within the last year, reported any additional ligament repair at the time of ACLR surgery, had a lower extremity injury within the prior six weeks, were diagnosed with any condition that may affect their ability to participate in physical activity, or were unable to speak or read English. This study was approved by the University of Kentucky Institutional Review Board.

PROCEDURES

Participant recruitment occurred from July 2020 to December 2020. Interested participants received a link via email to participate that first included an electronic consent form. If the participant agreed to participate, they clicked "yes" on the electronic consent form, and proceeded to the anonymous survey. Next, the participants completed an inclusionary form to ensure all participants met the inclusion criteria followed by a demographic questionnaire that recorded age, race, sex, ethnicity, physical activity participation, and lower extremity injury history information. Included in this questionnaire, participants recorded details of their ACLR(s) such as graft type, post-operative bracing, and post-operative rehabilitation participation and years since their most recent ACLR. Each participant then completed the patient-reported outcomes. The patient-reported outcomes were not administered in a randomized order. All data were collected utilizing Real Electronic Data Capture (REDCap).[20,21]

INSTRUMENTATION

The Tegner Activity Scale: The Tegner Activity Scale was utilized to determine participants' activity level prior to their knee injury and after their knee injury. From these data, an activity change score was calculated by subtracting their previous activity level from their current activity level. A negative value indicates a decrease in activity level after their injury, a positive value indicates an increase in activity level after their injury. The Tegner is a reliable measure of self-reported physical activity in patients with a history of ACLR.[22] Recent analyses revealed acceptable test-retest reliability and a minimal detectable change of one point in patients that had recently undergone ACLR.[22]

The Brief Resilience Scale: The 6-item Brief Resilience Scale (BRS) was used to measure self-reported resilience. Questions 1,3 and 5 were assessed on a 5-point Likert Scale with 1 meaning "strongly disagree" and 5 meaning "strongly agree".[23,24] Questions 2,4, and 6 were reversed scored and assessed on a 5-point Likert Scale with 1 meaning "strongly agree" and 5 meaning "strongly disagree".[23, 24] The final scores are interpreted as 1.00-2.99 low resilience, 3.00-4.30 normal resilience, and 4.30-5.00 high resilience.[24] The BRS has acceptable test-retest reliability and internal consistency in healthy populations and populations with various health conditions.[24]

The Modified Disablement in the Physically Active Scale: The mDPA was used to measure general HRQL. The mDPA consists of two summary components that comprise the original DPA, the Physical summary component (PSC) and the Mental summary component (MSC).[25] The 12-item mDPA-PSC and 4-item mDPA-MSC are scored on a 5-point Likert scale with 0 representing "no problem" and 4 representing a "severe problem." The scores for each subscale are summed, and a higher overall score indicates a higher level of disablement.[25] The original DPA has acceptable test-retest reliability, internal consistency and validity for people with a history of injury, acute injury and individuals classified as healthy.[26] The mDPA has excellent internal consistency.[25]

Fear Avoidance Beliefs Questionnaire: The FABQ modified for the knee and sports is a 15-item instrument that was used to measure fear-avoidance beliefs. The original FABQ consisted of two subscales, physical activity (PA) and work,[27] but has since been modified for patients with knee injury by changing the word "back" to the word "knee"[28] and for sports where the word "work" was changed to "sport".[29] The 5-item FABQ-PA subscale and 10-item FABQ-Sports subscale are scored on a 7-point Likert scale where 0 indicates "completely disagree" and 6 indicates "completely agree." Higher scores for each subscale indicates higher fear avoidance beliefs.[27] The original FABQ has acceptable test retest reliability and internal consistency for both subscales in patients with chronic low back pain.[27]

Knee Injury and Osteoarthritis Outcomes Score : The KOOS was used to measure self-reported knee function and classify the participants as symptomatic or non-symptomatic according to the Englund symptomatic knee classification.[10] The 42-item KOOS evaluates five dimensions regarding knee function: pain (KOOS-Pain), current symptoms (KOOS-Symptoms), activities of daily living (KOOS-ADL), function in sports activities (KOOS-Sports), and quality of life (KOOS-QOL) relating to the knee.[30] A 5-point Likert Scale is use to score the separate subscales.[30] The highest possible score on each subscale is 100 with higher scores indicating higher function.[30] In order to be classified as symptomatic, participants had to score ≤ 87.5 on the KOOS-QOL, and score below the following cut-offs on two or more of the remaining subscales: ≤ 86.1 on KOOS-Pain, ≤ 85.7 on KOOS-Symptoms, ≤ 86.8 on KOOS-ADL, and ≤ 85 on KOOS-Sports.[10] All five subscales have demonstrated acceptable internal consistency and test retest reliability in athletes with a history of ACLR[31] and many other patient populations with knee injuries and osteoarthritis.[32]

STATISTICAL ANALYSIS

Descriptive statistics (means and standard deviations) were calculated for participant demographics. If an instrument

Table 1. Summary of demographic variables for included participants (median (interquartile range).

Variable	Symptomatic Participants (n=17)	Non-Symptomatic Participants (n=12)	p-value
Age in years	25 (7)	23.5 (11)	0.347
BMI	24.5 (4.0)	21.2 (4.3)	0.021*
Years Since Most Recent Surgery	5.5 (5)	4.0 (7)	0.879
Current Tegner Activity Level	6 (2)	7 (2)	0.347
Previous Tegner Activity Level	8 (2)	9 (2)	0.948
Change in Tegner Activity Level	-2 (3)	0 (3)	0.152
KOOS Subscale Scores			
Symptoms	78.6 (14.3)	94.6 (8.9)	
Pain	87.5 (16.7)	100 (2.1)	
Activities of Daily Living	97.1 (9.6)	100 (0.0)	
Sports and Recreation	75.0 (17.5)	100 (3.8)	
Quality of Life	68.8 (31.3)	100 (8.3)	

* significantly different between groups, p<0.05

was missing a response to an item, the person mean was calculated for that specific scale and inserted for the missing data point. The outcome data were not normally distributed and thus summarized using median and interquartile ranges (IQR). Due to the non-normal distribution of the data, independent-samples Mann-Whitney U tests were used to examine differences in the demographic variables and patient-reported outcomes between those participants categorized with symptomatic knees and those classified with asymptomatic knees. Alpha was set a-prior to p<0.05. All statistical analyses were performed in IBM SPSS Statistics Processer version 28.0.0.0.

RESULTS

There were a total of 29 participants, 17 (3 females) were classified as participants with symptomatic knees and 12 (7 females) classified as non-symptomatic knees. A total of five participants classified in the symptomatic knee group had a history of two ACLRs, while none of the participants classified in the non-symptomatic knee group had a history of more than one ACLR. Summaries of the demographic variables can be found in Table 1. Participants with symptomatic knees had a significantly higher BMI than participants with non-symptomatic knees (p=0.021).

Summaries of the dependent variables for each group can be found in Table 2. Participants in the symptomatic group had worse HRQL as measured by the mDPA-PSC (<0.001) and mDPA-MSC (p=0.018), higher levels of fear-avoidance beliefs (FABQ-PA: p<0.001. FABQ-Sport: p=.001), and lower levels of resilience compared to those participants in the non-symptomatic group (p=0.030, Table 2). There were no differences in current physical activity or change in physical activity levels between the two groups (Table 2).

DISCUSSION

The purpose of this study was to examine differences in HRQL and psychological outcomes in participants with a history of ACLR that were classified as symptomatic compared to those classified as non-symptomatic according to the Englund criteria.[10] The hypothesis was confirmed as participants with symptomatic knees had lower HRQL, higher fear-avoidance beliefs and lower resilience compared to the non-symptomatic group. Furthermore, the authors identified differences in BMI between groups, with participants with symptomatic knees having a higher BMI than those with non-symptomatic knees. While these differences identified are not causal, and are limited in their application based on study design, these results are foundational to the development of effective intervention strategies to address osteoarthritis symptomology in people with a history of ACLR.

The results of this cross-sectional analysis present an interesting, potential cyclical cascade of outcomes that are of primary concern for the long-term health of patients with a history of ACLR as presented in Figure 1. The results of this study align with previous research demonstrating decreased HRQL after knee surgery[33] and in individuals with symptomatic knees.[34] While the authors did not attempt to quantify specific symptoms in this sample, previous studies have identified that knee pain, stiffness, and weakness in surrounding musculature are common in those with symptomatic knees.[34] It is likely that changes in knee symptoms negatively impact other aspects of life as previous literature has identified links between HRQL, BMI, and physical activity participation. For example, individuals with symptomatic knees after ACLR often present with increased BMI[34] which align with the results of the present study. Additionally, higher BMI has been associated with decreased HRQL in the general population,[35] adolescent populations,[36] and older adults (>65 years).[37] However, based on the study design, it is unable to be determined whether those with symptomatic knees had higher BMI at time of injury or

Table 2. Summary of dependent variables for included participants (median (interquartile range).

Variable	Symptomatic Participants (n=17)	Non-Symptomatic Participants (n=12)	p-value
Brief Resilience Scale	3.7 (0.50)	4.0 (0.83)	0.030*
Modified Disablement in the Physically Active Scale- Physical Summary Component	13 (16.0)	0.0 (2.5)	<0.001*
Modified Disablement in the Physically Active Scale- Mental Summary Component	2.0 (4)	0.0 (1)	0.018*
Fear-Avoidance Beliefs Questionnaire- Physical Activity	22 (30)	1 (4)	<0.001*
Fear-Avoidance Beliefs Questionnaire- Sport	15 (10)	0.0 (6)	0.001*

* significantly different between groups, p<0.05

surgery or whether these differences are associated with factors experienced between ACLR and participation in this study.

Individuals with symptomatic knees also reported increased fear avoidance beliefs compared to individuals with non-symptomatic knees. Fear avoidance refers to the avoidance of activities that could illicit pain, potentially cause reinjury, or any other negative stimuli.[38] The Fear Avoidance Model suggests that increased perceptions of fear and increased incidence of avoidance will lead to disuse, dysfunction, and depression.[39] Similarly, pain catastrophizing, kinesiophobia[15] and fear of reinjury[40,41] are common psychological factors that have been observed post-ACLR. Qualitative evidence demonstrates that fear of reinjury is a primary barrier for returning to activity after ACLR and many patients self-limit and/or avoid physical activities to avoid reinjury.[40,41] We did not identify significant differences in physical activity measured by current Tegner scores between our two groups; however, we did see that the symptomatic participants scored one point lower on the Tegner activity scale than the group that had non-symptomatic knees and had a larger change from baseline. While we are not able to report differences in physical activity between the groups or a cause-and-effect relationship between ACLR, decreased HRQL, higher BMI and decreased activity, we do believe that these findings are of interest for future research investigations. Fear-avoidance beliefs have been associated previously with physical activity in people with a history of ACLR.[4] Individuals with a history of ACLR participate in less MVPA compared to non-injured peers.[2] This is problematic as physical activity has been found to be the most effective intervention for treating pain in patient with knee osteoarthritis,[42] and is known to be beneficial for weight loss,[43] potentially decreasing a person's BMI. Additionally, it has been demonstrated that individuals who participate in greater MVPA report higher HRQL even when they report increased knee symptomology.[44] Lastly, it is also important to note that all 5 participants that reported having a history of 2 ACLR were included in the symptomatic group.

Finally, the symptomatic group demonstrated lower resilience scores compared to the non-symptomatic group. Resilience, as operationally defined by Liu et al.,[16] is the process by which an individual adjusts and responds to challenges. Resilience has been sparsely examined as a psy-
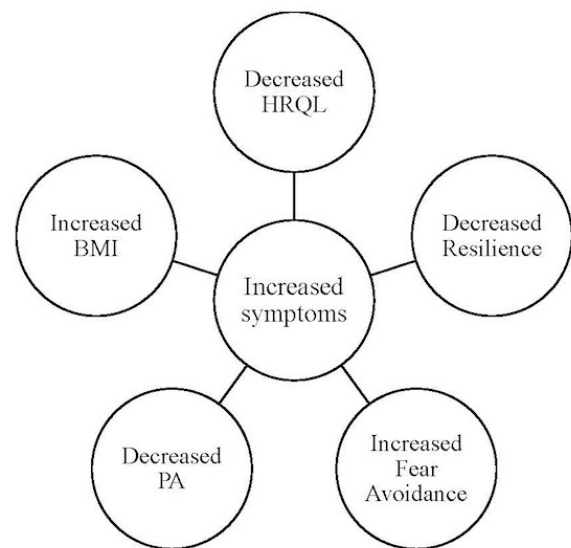

Figure 1. Proposed model depicting the cascade of events associated with increased symptoms in individuals with a history or ACL reconstruction.

HRQL= health related quality of life, BMI= body mass index, PA= physical activity

chological factor associated with outcomes after ACLR; however, qualitative evidence has identified resilience as a key theme.[45] Johnson et al. concluded that patients that were more resilient had better outcomes after ACLR,[17] while Disantis et al.[46] revealed that individuals that viewed recovery as an opportunity to 'overcome adversity' experienced personal growth as a result of their injury. It has been suggested that cognitive behavioral therapies and resilience training can improve coping strategies and decrease psychological distress in patients undergoing knee surgery.[47] This, in turn, may have positive effects on other psychological factors (e.g., fear avoidance), physical activity adherence, and HRQOL (Figure 1).

LIMITATIONS

This study was not without limitations. All data associated with this investigation are self-reported and were captured via electronic survey. Participants may not have understood every question presented and were not able to ask clarifying questions based on this study design. Methods used for pa-

tient classification were also limited to patient self-reports. No additional clinical criteria (i.e., radiographs) associated with the determination of a symptomatic knee were used, other than the completion of the KOOS survey. It is possible that the symptoms identified by completion of the KOOS could have been from origins other than osteoarthritis. Furthermore, the results of this study cannot be considered evidence of a cause and effect relationship. This was a cross-sectional study design that was only able to determine differences between the two groups of participants. These results are preliminary in nature, and are intended to support future investigations to determine the progression of osteoarthritis symptoms, quality of life, physical activity and fear-avoidance beliefs. Given the cross-sectional nature of this investigation, we are unable to determine if these outcomes preceded the ACL injury, reconstruction, and now symptomatic knee. The authors are also unable to determine if participants underwent any other lower extremity surgery after their ACLR but within the inclusionary time frame. Future investigations into the development of these outcomes should be longitudinal in nature to better understand the cascade of events. Lastly, these data were captured during COVID-19 in a small sample. It is possible that restrictions associated with the pandemic could have impacted participant responses on the surveys and responder bias may have influenced those who chose to complete the survey.

CONCLUSION

In conclusion, differences in BMI, HRQL, fear-avoidance beliefs and resilience were identified between participants with symptomatic knees and those with non-symptomatic knees. This series of relationships may be a cascade of events that can negatively impact health outcomes across the lifespan for this post-ACLR population. It is necessary for future longitudinal investigations to examine these outcomes after ACLR and as these individuals progress after rehabilitation and beyond clearance from formal rehabilitation. Should it be warranted, clinicians may consider patient education with a focus on the importance of physical activity for decreasing pain and other symptoms associated with symptomatic knees. Clinicians may consider exercise as a prescription for symptomatic joints after injury, but must include an overall assessment of the patient's psychological variables (e.g. fear-avoidance beliefs and resilience) and consider additional treatment strategies as warranted.

REFERENCES

1. Kuenze C, Lisee C, Pfeiffer KA, et al. Sex differences in physical activity engagement after ACL reconstruction. *Phys Ther Sport*. 2019;35:12-17. doi:10.1016/j.ptsp.2018.10.016

2. Bell DR, Pfeiffer KA, Cadmus-Bertram LA, et al. Objectively measured physical activity in patients after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2017;45(8):1893-1900. doi:10.1177/0363546517698940

3. Lisee CM, Montoye AHK, Lewallen NF, Hernandez M, Bell DR, Kuenze CM. Assessment of free-living cadence using ActiGraph accelerometers between individuals with and without anterior cruciate ligament reconstruction. *J Athl Train*. 2020;55(9):994-1000. doi:10.4085/1062-6050-425-19

4. Hoch JM, Houston MN, Baez SE, Hoch MC. Fear-avoidance beliefs and health-related quality of life in post-ACL reconstruction and healthy athletes: a case-control study. *J Sport Rehabil*. 2020;29(6):772-776. doi:10.1123/jsr.2018-0491

5. Grassi A, Pizza N, Al-Zu'bi BBH, Fabbro GD, Lucidi GA, Zaffagnini S. Clinical outcomes and osteoarthritis at very long-term follow-up after ACL reconstruction: a systematic review and meta-analysis. *Orthop J Sports Med*. 2022;10(1):23259671211062238. doi:10.1177/23259671211062238

6. Whittaker JL, Losciale JM, Juhl CB, et al. Risk factors for knee osteoarthritis after traumatic knee injury: a systematic review and meta-analysis of randomised controlled trials and cohort studies for the OPTIKNEE Consensus. *Br J Sports Med*. 2022;56(24):1406-1421. doi:10.1136/bjsports-2022-105496

7. Webster KE, Hewett TE. Anterior cruciate ligament injury and knee osteoarthritis: an umbrella systematic review and meta-analysis. *Clin J Sport Med*. 2022;32(2):145-152. doi:10.1097/jsm.0000000000000894

8. Bijlsma JW, Berenbaum F, Lafeber FP. Osteoarthritis: an update with relevance for clinical practice. *Lancet*. 2011;377(9783):2115-2126. doi:10.1016/s0140-6736(11)60243-2

9. Mahmoudian A, Lohmander LS, Mobasheri A, Englund M, Luyten FP. Early-stage symptomatic osteoarthritis of the knee — time for action. *Nat Rev Rheumatol*. 2021;17(10):621-632. doi:10.1038/s41584-021-00673-4

10. Englund M, Roos EM, Lohmander LS. Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: a sixteen-year followup of meniscectomy with matched controls. *Arthritis Rheum*. 2003;48(8):2178-2187. doi:10.1002/art.11088

11. Harkey MS, Baez S, Lewis J, et al. Prevalence of early knee osteoarthritis illness among various patient-reported classification criteria after anterior cruciate ligament reconstruction. *Arthritis Care Res (Hoboken)*. 2022;74(3):377-385. doi:10.1002/acr.24809

12. Pietrosimone B, Blackburn JT, Padua DA, et al. Walking gait asymmetries 6 months following anterior cruciate ligament reconstruction predict 12-month patient-reported outcomes. *J Orthop Res*. 2018;36(11):2932-2940. doi:10.1002/jor.24056

13. Hoch JM, Sinnott CW, Robinson KP, Perkins WO, Hartman JW. The examination of patient-reported outcomes and postural control measures in patients with and without a history of ACL reconstruction: a case control study. *J Sport Rehabil*. 2018;27(2):170-176. doi:10.1123/jsr.2016-0105

14. Gay C, Chabaud A, Guilley E, Coudeyre E. Educating patients about the benefits of physical activity and exercise for their hip and knee osteoarthritis. Systematic literature review. *Ann Phys Rehabil Med*. 2016;59(3):174-183. doi:10.1016/j.rehab.2016.02.005

15. Baez SE, Hoch MC, Hoch JM. Psychological factors are associated with return to pre-injury levels of sport and physical activity after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(2):495-501. doi:10.1007/s00167-019-05696-9

16. Liu JJW, Ein N, Gervasio J, Battaion M, Reed M, Vickers K. Comprehensive meta-analysis of resilience interventions. *Clin Psychol Rev*. 2020;82:101919. doi:10.1016/j.cpr.2020.101919

17. Johnson U, Ivarsson A, Karlsson J, Hägglund M, Waldén M, Börjesson M. Rehabilitation after first-time anterior cruciate ligament injury and reconstruction in female football players: a study of resilience factors. *BMC Sports Sci Med Rehabil*. 2016;8(1):20. doi:10.1186/s13102-016-0046-9

18. Hsieh CM, Chiu AF, Huang CH. Association between psychological resilience and self-rated health in patients with knee osteoarthritis. *Healthcare*. 2023;11(4):529. doi:10.3390/healthcare11040529

19. ResearchMatch. Frequently Asked Questions. Accessed March 30, 2023. https://www.researchmatch.org/researchers/faq#a100

20. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. *J Biomed Inform*. 2019;95:103208. doi:10.1016/j.jbi.2019.103208

21. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381. doi:10.1016/j.jbi.2008.08.010

22. Briggs KK, Lysholm J, Tegner Y, Rodkey WG, Kocher MS, Steadman JR. The reliability, validity, and responsiveness of the Lysholm Score and Tegner Activity Scale for Anterior Cruciate Ligament Injuries of the knee: 25 years later. *Am J Sports Med*. 2009;37(5):890-897. doi:10.1177/0363546508330143

23. Windle G, Bennett KM, Noyes J. A methodological review of resilience measurement scales. *Health Qual Life Outcomes*. 2011;9(1):8. doi:10.1186/1477-7525-9-8

24. Smith BW, Dalen J, Wiggins K, Tooley E, Christopher P, Bernard J. The brief resilience scale: assessing the ability to bounce back. *Int J Behav Med*. 2008;15(3):194-200. doi:10.1080/10705500802222972

25. Houston MN, Hoch JM, Van Lunen BL, Hoch MC. The development of summary components for the Disablement in the Physically Active scale in collegiate athletes. *Qual Life Res*. 2015;24(11):2657-2662. doi:10.1007/s11136-015-1007-6

26. Vela LI, Denegar CR. The Disablement in the Physically Active Scale, part II: the psychometric properties of an outcomes scale for musculoskeletal injuries. *J Athl Train*. 2010;45(6):630-641. doi:10.4085/1062-6050-45.6.630

27. Waddell G, Newton M, Henderson I, Somerville D, Main CJ. A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. *Pain*. 1993;52(2):157-168. doi:10.1016/0304-3959(93)90127-b

28. Piva SR, Fitzgerald GK, Irrgang JJ, et al. Associates of physical function and pain in patients with patellofemoral pain syndrome. *Arch Phys Med Rehabil*. 2009;90(2):285-295. doi:10.1016/j.apmr.2008.08.214

29. Houston MN, Cross KM, Saliba SA, Hertel J. Injury-related fear in acutely injured interscholastic and intercollegiate athletes. *Athletic Training and Sports Health Care*. 2013;6(1):15-23. doi:10.3928/19425864-20131120-01

30. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)—development of a self-administered outcome measure. *J Orthop Sports Phys Ther*. 1998;28(2):88-96. doi:10.2519/jospt.1998.28.2.88

31. Salavati M, Akhbari B, Mohammadi F, Mazaheri M, Khorrami M. Knee injury and Osteoarthritis Outcome Score (KOOS); reliability and validity in competitive athletes after anterior cruciate ligament reconstruction. *Ostearthr Cartil*. 2011;19(4):406-410. doi:10.1016/j.joca.2011.01.010

32. Collins NJ, Prinsen CAC, Christensen R, Bartels EM, Terwee CB, Roos EM. Knee Injury and Osteoarthritis Outcome Score (KOOS): systematic review and meta-analysis of measurement properties. *Osteoarthr Cartil*. 2016;24(8):1317-1329.

33. Kleis RR, Simon JE, Turner M, Vela LI, Thomas AC, Gribble PA. Differences in Health-Related Quality of Life Among Patients After Knee Injury. *Int J Athl Ther Train*. 2020;25(5):247-253. doi:10.1123/ijatt.2019-0054

34. Filbay SR, Ackerman IN, Dhupelia S, Arden NK, Crossley KM. Quality of life in symptomatic individuals after anterior cruciate ligament reconstruction, with and without radiographic knee osteoarthritis. *J Orthop Sports Phys Ther*. 2018;48(5):398-408. doi:10.2519/jospt.2018.7830

35. Yan H, Guo J, Zhou W, Dong C, Liu J. Health-related quality of life in osteoarthritis patients: a systematic review and meta-analysis. *Psychol Health Med*. 2022;27(8):1859-1874. doi:10.1080/13548506.2021.1971725

36. De Beer M, Hofsteenge GH, Koot H, Hirasing R, Delemarre-van de Waal H, Gemke R. Health-related-quality-of-life in obese adolescents is decreased and inversely related to BMI. *Acta Paediatrica*. 2007;96(5):710-714. doi:10.1111/j.1651-2227.2007.00243.x

37. Yan LL, Daviglus ML, Liu K, et al. BMI and Health-Related Quality of Life in Adults 65 Years and Older. *Obesity Res*. 2004;12(1):69-76. doi:10.1038/oby.2004.10

38. Baez SE, Hoch JM, Cramer RJ. Social Cognitive Theory and the Fear-Avoidance Model: An explanation of poor health outcomes after ACL reconstruction. *Athl Train Sports Health Care*. 2019;11(4):168-173. doi:10.3928/19425864-20181002-02

39. Vlaeyen JW, Kole-Snijders AM, Rotteveel AM, Ruesink R, Heuts PH. The role of fear of movement/(re)injury in pain disability. *J Occup Rehabil.* 1995;5(4):235-252. doi:10.1007/bf02109988

40. Burland JP, Toonstra J, Werner JL, Mattacola CG, Howell DM, Howard JS. Decision to return to sport after anterior cruciate ligament reconstruction, part I: A qualitative investigation of psychosocial factors. *J Athl Train.* 2018;53(5):452-463. doi:10.4085/1062-6050-313-16

41. Disanti J, Lisee C, Erickson K, Kuenze C, Bell D, Shingles M. Perceptions of rehabilitation and return to sport among high school athletes with anterior cruciate ligament reconstruction: A qualitative research study. *J Orthop Sports Phys Ther.* 2018;48(12):951-959. doi:10.2519/jospt.2018.8277

42. Ferreira RM, Torres RT, Duarte JA, Gonçalves RS. Non-Pharmacological and non-surgical interventions for knee osteoarthritis: a systematic review and meta-analysis. *Acta Reumatol Port.* 2019;44(3):173-217.

43. U.S. Department of Health and Human Services. *Physical Activity Guidelines for Americans.* 2nd ed. U.S. Department of Health and Human Services; 2018.

44. Davis-Wilson HC, Thoma LM, Longobardi L, et al. Quality of life associates with moderate to vigorous physical activity following anterior cruciate ligament reconstruction. *J Athl Train.* 2022;57(6):532-539. doi:10.4085/1062-6050-0670.20

45. Ezzat AM, Brussoni M, Whittaker JL, Emery CA. A qualitative investigation of the attitudes and beliefs about physical activity and post-traumatic osteoarthritis in young adults 3–10 years after an intra-articular knee injury. *Phys Ther Sport.* 2018;32:98-108. doi:10.1016/j.ptsp.2018.05.001

46. DiSanti J, Lisee C, Erickson K, Bell D, Shingles M, Kuenze C. Perceptions of rehabilitation and return to sport among high school athletes with anterior cruciate ligament reconstruction: a qualitative research study. *J Orthop Sports Phys Ther.* 2018;48(12):951-959. doi:10.2519/jospt.2018.8277

47. Flanigan DC, Everhart JS, DiBartola AC, et al. Positive reframing: an important but underutilized coping strategy in athletes undergoing sport-related knee surgery. *J Athl Train.* 2021;56(12):1334-1339. doi:10.4085/1062-6050-0618.20