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The Relationship between Sport Participation following Revision Anterior Cruciate Ligament Reconstruction and Two-Year Patient Reported Outcome Measures

MARS Group

Abstract

Background: ACL revision cohorts continually report lower outcome scores on validated knee questionnaires than primary ACL cohorts at similar time points following surgery. It is unclear how these outcomes are associated with physical activity following physician clearance for return to recreational or competitive sports after ACL revision surgery.

Hypotheses: Participants who return to either multiple sports or a singular sport following revision ACL surgery will report decreased knee symptoms, increased activity level and improved knee function as measured by validated patient-reported outcome measures (PROMs) compared to no sport participation. Multi-sport participation compared to singular sport participation will result in similar increased PROMs and activity level.

Study Design: Cross-sectional Study, Level X

Methods: A total of 1205 patients whom underwent a revision ACL reconstruction were enrolled by 83 surgeons at 52 clinical sites. At the time of revision, baseline data collected included: demographics, surgical characteristics, previous knee treatment and PROMs, the International Knee Documentation Committee (IKDC) questionnaire, Marx activity score, Knee Outcomes and Osteoarthritis Score (KOOS) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). A series of multivariate regression models were used to evaluate the association of IKDC, KOOS, WOMAC and MARX scores at two years following revision surgery by sport participation category, controlling for known significant covariates.

Results: Two-year follow-up was obtained on 82% (986/1205) of the original cohort. Patients who reported not participating in sports after revision surgery had lower median PROMs both at baseline and at 2 years, compared to patients who participated in either a single sport or multi-sports. Significant differences were found in the change of scores between groups on the IKDC ($P<0.0001$), KOOS-Symptoms ($P=0.01$), KOOS-Sports & Recreation ($P=0.04$), and KOOS-Quality of Life ($P<0.0001$) scales. Patients with no sport participation were 2.0 to 5.7 times more likely to report significantly lower PROMs compared to multiple sport participants, dependent upon the specific outcome measure assessed, and 1.8 to 3.8 times more likely than single sport participants (except for the WOMAC-Stiffness scale; $P=0.18$) after controlling for known covariates.

Conclusion: Participation in either a single or multiple sports in the two years following ACL revision surgery were found to be significantly associated with higher PROMs across multiple

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validated self-reported assessment tools. During follow-up appointments, surgeons should continue to expect patients who report returning to physical activity after surgery will self-report better functional outcomes, regardless of baseline activity levels.

Keywords

anterior cruciate ligament; outcomes; revision ACL; sport participation

Introduction

Return to sport is one of the key indicators of a successful outcome for patients who undergo a revision ACL reconstruction.[1, 20] However, compared to primary anterior cruciate ligament (ACL) reconstruction, individuals undergoing revision surgery have reported lower patient reported outcome measures (PROMs) during two and six year follow-up windows.[6, 10, 26] The Multicenter ACL Revision Study (MARS) cohort, a large, multi-center, prospective longitudinal cohort, provides the best opportunity to assesses short- and long-term predictors of improved revision ACL treatment outcomes, and identify risk factors affecting patient-reported functional status, pain, and performance.[16] In the same report, PROMs improved from baseline (i.e., time of revision surgery), but activity levels declined two-years post-operatively. While activity levels declined, it is unclear if was associated with reported sport participation following revision surgery.

Following primary ACL reconstruction, IKDC scores were significantly higher in patients who returned to their pre-injury sports compared to no sports.[23] Additionally, in another large multi-center prospective cohort study (MOON Study), individuals were able to maintain high sport function and quality of life measurements ten years after the initial reconstruction even as reported activity levels declined.[21] It is unknown how sport participation following revision surgery compared to no sport participation is associated with PROMs following return to activity. There may be benefit to providers and patients to understand whether participation type -- specifically multiple sports versus singular sport -- following revision surgery influences the magnitude of PROM scores over time. Compared to multi-sport participation, singular sport specialization is known to increase the risk of injury in youth athletes, yet the effect of single or multiple sport participation in older individuals and ACL revision cohorts is unknown.[18]

The objective of this analysis was to determine whether sports participation is associated with patient reported outcomes related to sports function, activity level, and knee symptom scores at two years following revision ACL surgery. We hypothesized that patients who did not return to sport participation following revision ACL reconstruction surgery would have decreased sports-related function, lower activity levels and increased knee symptoms two years post-operatively compared to patients who returned to sport, after controlling for their baseline sport participation and activity status. We further hypothesized that multi-sport athletes would have similar gains in PROMs compared to single-sport athletes.

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Materials and Methods

Study Population and Setting

The MARS group is a collaboration of 83 sports-medicine fellowship-trained surgeons who represent an approximately 50:50 mix of practitioners from private and academic sites (N = 52 sites). Surgeon inclusion criteria included: maintenance of institutional review board approval; completion of a training session of articular cartilage and meniscus agreement studies; and review of the study design, patient inclusion criteria, and surgeon questionnaire.

Site enrollment began in 2006, once approval was received from each institution's respective institutional review board, and ended in 2011. Patients were included if they were between the ages of 12 and 65 years of age while undergoing a revision of a failed primary ACL reconstruction by a participating MARS surgeon. Failure of the previous ACL reconstruction was determined through either an arthroscopic surgery, orthopedic clinical examination, or magnetic resonance imaging that has been previously described elsewhere.[11] Exclusion criteria included patients who presented with prior infection, multi-ligament reconstruction, complex regional pain syndrome or arthrofibrosis. Additionally, patients who did not successfully complete the two-year follow-up questionnaire were excluded for this particular study.

Data Sources and Measurement

Once informed consent was obtained, all patients completed a 13-page questionnaire to collect demographic information, sport participation, injury mechanism, comorbidities, and knee injury history.[12, 14] A series of previously-validated PROMs were completed by each patient that measured general and knee-specific outcomes at the time of revision: [24, 25] International Knee Documentation Committee (IKDC) questionnaire; Marx activity rating scale; Knee injury and Osteoarthritis Outcome Score (KOOS); and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), which was calculated from the KOOS questionnaire.[13] Additionally, surgeons completed a 48-page questionnaire including physical examination findings, surgical procedures and implants, arthroscopic findings, and the management of any current meniscal or chondral damage to the injured knee.[11]

Completed data forms were mailed to the data coordinating center by each participating site. Data was abstracted from both the patient and surgeon's questionnaire through TeleForm software (Cardiff Software, Vista, CA) using optical character recognition. Abstracted data was verified and transferred to a master database. Multiple quality control checks were performed prior to data analyses.

Patient Follow-up

Patients completed the same questionnaire at baseline (i.e., time of revision surgery) and at two-year follow-up. PROMs were returned via mailed questionnaires and, additionally, study participants were contacted by phone to determine if any successive surgeries were performed on either knee since their initial ACL revision. Operative reports were obtained when possible to verify subsequent injury and treatment.

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Statistical Analysis

To describe the characteristics of the study sample, continuous variables were summarized as percentiles (i.e., 25th, 50th and 75th) and categorical variables as frequencies and percentages. One-way analysis of variances with a Bonferroni correction was used to compare sports participation groups at both time intervals (baseline and 2-year follow-up) and the change in score between groups. Multivariate regression analyses were used to study which baseline risk factors were independently associated with each outcome variable. The primary outcome variables of interest were two-year PROMs scores from the IKDC, KOOS, MARX activity scale, WOMAC and their respective sub-scales. Linear regression models were used, as all of our primary outcome variables were treated as continuous variables. Results were reported as odds ratios and 95% confidence intervals indicating odds of having a worse outcome.

The primary exposure of interest was sport participation following ACL revision surgery. Sport participation variables were defined from the questions: “What sport have you participated in most in the last two years?” and “What second sport have you participated in most in the last two years?” from the patient questionnaire administered at two year follow-up. Potential responses included: none, basketball, baseball/softball, football, gymnastics, skiing, soccer, volleyball and “other”. Activities included in the “other” category from previous MARS data included: cycling, cheerleading, dancing, frisbee, hockey, lacrosse, martial arts, roller skating, rugby, tennis, track and field, and trampolining.[16] “Multi-sport” participants were defined as patients who participated in a primary sport plus a different, secondary, sport during the last two years. “Single sport” participants were defined as patients who self-reported playing a primary sport and no secondary sport, or who reported the same sport for both responses. Participants who reported no sport participation (i.e., “none”) to both sports participation questions were coded as “no sport.”

All models controlled for the following covariates: demographics (age, sex, Body Mass Index [BMI], smoking status, education level, baseline sport specialization in the two years prior to revision ACL, and baseline activity level); revision ACL surgical details (revision number, time since last ACL reconstruction procedure in years, and history of medial and lateral meniscal surgical treatment, articular cartilage surgery, and/or contralateral knee ACL reconstruction); current surgical findings (mechanism of injury, graft type, meniscal injury [medial, lateral], articular cartilage injury [medial femoral condyle, lateral femoral condyle, medial tibial plateau, lateral tibial plateau, patella, and trochlea]) and baseline PROM scores. Previous articular cartilage surgery, current meniscal injuries and articular cartilage injuries were treated as binary variables (yes/no) due to low frequency counts. Categorical variables were fit per their degrees of freedom (i.e., n-1). All continuous variables were fit with a linear effect as there was little to no evidence of a nonlinear relationship through non-linear testing.

Previous reports have identified minimal clinically important differences (MCIDs) in the PROMS used: 11 points for the IKDC,[7] eight to ten points for the KOOS[19] and WOMAC,[24, 25] as well as two points for the MARX activity scale.[26] Additionally, the level of sport participation was self-reported (Recreational, Amateur [team or club], High School, College [Division I & non-Division I], Semi-Pro/Professional), but demonstrated collinearity with

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level of sport participation; therefore, level of sport participation was excluded. Statistical analysis was performed with STATA 14 (StataCorp LLC, College Station, TX).

Results

Revision ACL reconstruction was performed on 1205 patients during the enrollment period. Approximately 58% of the cohort were males and the median age was 26 years of age (range, 12-63 years). Descriptive statistics of the cohort at baseline have been described in-depth in previous reports.[11, 15, 16]

Overall, 82% (986/1205) of participants completed the follow-up questionnaire at two years. Baseline characteristics of participants who completed the two-year follow-up are provided in Table 1. At baseline, 71% of participants reported playing multiple sports, 18% reported playing a single sport, and 11% reported no sports participation. At two-year follow-up, 58% (n=568) of patients reported playing multiple sports, 21% (n=205) reported playing a single sport, and 21% (n=207) reported playing no sports in the two years since their revision ACL surgery.

Patient-Reported Outcome Scores

Table 2 summarizes each PROM by sport participation and compares median scores within each group at baseline and at two-year follow-up. A significant difference ($p < 0.001$) was found between groups throughout each PROM and during both time intervals. Patients who reported no sports participation had lower median PROMs compared to single sport and multi-sport participants, both at baseline and two-year follow-up. At baseline, the largest magnitude of difference was seen on the KOOS-Pain subscale, where the median score for no sport participants was 66 points (IQR: 53-81), and 78 points for single sport (IQR: 61-86) and multiple sport (IQR: 64-89) participants. At two-year follow-up, those patients who reported no sport participation continued to have lower PROMs compared to the other groups. The biggest difference between groups was seen on the median IKDC score: no sport participants: 60 points (IRQ: 39-76), single sport participants: 77 points (IQR: 60-86) and multi-sport participants: 82 points (IQR: 69-89) which was greater than the 11 points established as the MCID for the IKDC). The lack of an active lifestyle by no sport participants may have contributed to the severity of knee injury. Individuals who reported no sport participation at two years were found to be older (median age = 30) and obese (median BMI = 30 kg/m^2).

Table 3 summarizes the change in PROM score from baseline to two years and compares them between sport participation groups. Overall, PROMs significantly improved from baseline to 2 years in all groups on the IKDC, KOOS, and WOMAC and their respective sub-scales, except for the WOMAC-Stiffness scale. On this scale, no change in median score from baseline was reported in the no sport and single sport participation groups, while the multi-sport participants were found to have an increase in their median score by 12.5 points. Significant differences were found in the change of scores between groups on the IKDC ($P < 0.0001$), KOOS-Symptoms ($P = 0.01$), KOOS-Sports and Recreation ($P = 0.04$), and KOOS-Quality of Life ($P < 0.0001$) subscales. Noting scores do improve within all sport participation groups; however, the lack of physical activity in the no sport group may be

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associated with their ability to reach higher PROMS. These results show that individuals who did not play sports were less active at baseline, before revision ACL surgery, which could have influenced the severity of their knee injury.

Regarding MCIDs, all groups passed the threshold for improvement in their scores on the IKDC, KOOS-PAIN, KOOS-Sports and Recreation, and KOOS-Quality of Life scales indicating that revision surgery had a significant impact on their functional outcomes. Compared to no-sport and single-sport participants, only multi-sports participants improved their WOMAC-Stiffness score over the MCID threshold. Regardless of sport participation type, scores did not reach the threshold for significance in KOOS-ADL, WOMAC-Pain, and WOMAC-ADL subscales. As expected, all groups reported a decrease in their activity levels on the MARX activity scale relative to pre-injury baseline; however, no significant differences were found in the decrease in activity level scores between sport participation groups (P = 0.22).

Influence of Sports Participation on Two-Year Outcomes

No sports participation (no sports vs. single sport participation vs. multi-sport participation) in the two years after revision surgery was found to be significantly associated with lower PROMs at two years following revision ACL reconstruction. Additionally, other patient demographic factors, previous surgical information, current meniscal and articular cartilage injuries at the time of revision were also associated with lower outcome scores. The odd ratios for sport participation variables and co-variates that were significantly associated with lower outcome scores are reported in Table 4.

IKDC.—Sport participation was found to be a significantly associated with higher IKDC scores at two years. Not participating in sports after a revision ACL revision reconstruction was significantly associated with higher odds of lower IKDC scores compared to participation in multiple sports (P < 0.0001, OR = 3.73, 95% CI: 2.64-5.28). IKDC scores in multi-sport participants were 12 points higher than no sports participants (P < 0.001, 95% CI: 9.12-15.70). Single-sport participants were found to score 9 points higher on the IKDC scale (P < 0.001, 95% CI: 4.92-12.30), which approached the MCID. Similarly, multi-sport participants had significantly higher IKDC scores at two years compared to single-sport participants (P = 0.024); however, the results did not reach the 11-point threshold of change for MCID (P = 0.024, Difference = 3.8 points, 95% CI: 0.96-6.64). Other covariates found to be significant predictors of worse outcomes on the two-year IKDC were lower baseline IKDC score, female sex, lower baseline activity scores, higher BMI, less time since the previous ACL reconstruction, previous lateral meniscectomy, or an unstable lateral meniscus repair, and a current grade two or higher articular cartilage injury.

KOOS.—Throughout the KOOS sub-scales, no sport participants were found to have significantly higher odds of reporting lower scores across sub-scales compared to multi-sport participants (P < 0.0001, OR range, 2.25-3.29, 95% CI: 1.60-4.67). Individuals who participated in multiple sports scored, on average, 8 points higher on the KOOS-Symptoms scale (P < 0.0001); 12 points higher on the KOOS-Sports and Recreation scale (P < 0.0001); and 14 points higher on the KOOS-Quality of Life scale (P < 0.0001) compared to single-

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sport participants at two-years. Again, similar results were found for no sport participants compared to single sport participation (P = 0.006, OR range, 1.77-2.70, 95% CI: 1.18-4.03). Participating in a single sport compared to no sports was associated with an increase of 12 points (P < 0.0001, 95% CI: 7.30-16.65) on the KOOS-Quality of Life subscale. While participating in a single sport compared to multiple sports was associated with higher KOOS Sports and Recreation scores (P = 0.006, OR = 1.79, 95% CI: 1.19-2.70). Other covariates that were associated with worse outcomes on the two-year KOOS sub-scales were similar to those on the two-year IKDC, with the addition of participants who were current smokers or having a previously excised medial meniscus.

WOMAC.—Not participating in sports at two years post-operatively was significantly associated with increased odds of having lower (i.e., worse) WOMAC scores compared to multi-sport participation across WOMAC subscales at the two-year follow-up (P < 0.0001, OR range, 1.99-2.39, 95% CI: 1.37-3.41. On the WOMAC stiffness subscale, multi-sport participants scored 8 points higher than single sport participants (P < 0.001, 95% CI: 4.17-11.84) on their two-year score. Additionally, participating in only a single sport compared to multi-sport participation increased the odds of reporting lower scores on the WOMAC stiffness subscale at two years (P = 0.019, OR = 1.48, 95% CI: 1.07-2.06). Additional factors associated with poorer outcomes across all WOMAC subscales were: lower baseline outcome scores, less time since a previous ACL reconstruction, and a previous lateral meniscus repair that is unstable or not healed. Having a previous lateral meniscus repair that was found to be unstable or not healed was associated with lower scores across the WOMAC subscales by 10 to 13 points at two-year follow-up (P ≤ 0.05, 95% CI: −0.06 – 24.03).

MARX Activity Level.—As expected, participation in sports after revision ACL reconstruction was significantly associated with increased activity levels. No sports participation was significantly associated with higher odds of reporting lower MARX scores when compared to multi-sport (P < 0.0001, OR = 5.68, 95% CI: 3.93-8.21) and single sport participants (P < 0.0001, OR = 3.77, 95% CI: 2.48-5.75).

No sport participation was associated with lower MARX scores by 3 points compared to single sport participation, and by 4 points compared to multi-sport athletes. While significant (P = 0.003), the difference in associated MARX scores between single- and multi-sport participants did not meet the threshold for MCID. Other co-variates that were significantly associated with lower MARX scores are reported in Table 4; however, none of these scores reached the 2 points threshold required for a MCID on the MARX activity scale.

Discussion

Results from our analysis indicate that two-year patient reported outcomes vary depending on the level of sports participation following revision ACL surgery after taking into account baseline activity levels, previous surgical and current revision injury characteristics. These findings support our hypothesis that individuals who participated in any combination of sports following revision ACL surgery would be associated with higher outcomes across all sub-scales compared to individuals who did not participate in any sports. These findings

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confirm intuited thoughts that in the short-term, sport participation following ACL revision surgery is associated with higher PROMs at two-years.

Participants with no sport participation were 2.0 to 5.7 times more likely to report significantly lower PROMs compared to multiple sport participants depending on the specific outcome measure, and 1.8 to 3.8 times more likely than single-sport participants (except for the WOMAC-Stiffness scale; P = 0.18) after controlling for co-variates in each model. Our statistical approach allows for the assessment of post-surgical sport participation independent of a patient's pre-injury activity level and PROM scores. One possible explanation for the difference in PROMs is overall activity levels of the cohort. Primary analysis of the MARS cohort found that two-year MARX activity levels to be lower than other primary ACL cohorts at the same follow-up period. Leaving it unclear whether the overall decrease were due to the condition of the knee or intentional to the patient's perceived intent to lower their risk of future injury.[11] We found no significant difference in the change of MARX scores between participation groups (P = 0.22), suggesting the change in activity level may resemble the natural decline of activity seen as individuals age in this population.[11] Long-term follow-up of primary ACL reconstructions have found stable KOOS, IKDC and WOMAC scores at ten-year follow-up even as MARX activity scores declined over-time.[21]

Overall, MARX activity level scores still declined by 3 points for single-sport and 4 points for multi-sport participants, after controlling for baseline MARX activity level, baseline PROMs, previous surgical treatment, and current surgical findings. While the MARX scale has been validated[17] to measure activity of different functions (running, cutting, deceleration, etc.) that occur in various sports, recent evidence has called into question the extrapolation of physical activity based on the questionnaire. Recent studies in the ACL reconstruction literature found self-reported MARX scores to be unrelated to objective moderate-to-vigorous physical activity (MVPA) measurements.[5, 8] Additionally, ACL reconstruction individuals matched to healthy controls based on activity level, age and sex were found to have lower step counts and decreased MVPA.[5] Grouping sport participation based on the self-reported count of sports participated in does not address the frequency nor intensity of sport participation. This is a key limitation of the (MARS) study data as we do not have any objective physical activity measurement or self-reported measurement of the intensity of sports activity following surgery. Our findings provide preliminary evidence that even as ACL revision patients are cleared and return to sports, they may not participate at the same intensity or frequency level in their chosen sports.

Our results cannot explain why individuals did not pursue sport participation post-operatively. The condition of the knee may be compromised in individuals who do not participate in sports following their revision surgery. As we saw across KOOS, WOMAC, IKDC scores at two-years, there was an increased association of lower reported scores in individuals who did not play sports. These results remained consistent after controlling for secondary injuries (meniscal, articular cartilage, ligament, etc) to the knee. Nevertheless, we can simply state engagement in sports after ACL revision surgery is correlated with higher outcomes at two-year follow-up.

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Return to sports and participation level are considered key indicators of successful ACL surgery. Results of the current study support the goal of a successful return to activity following ACL revision surgery. Previous reports have found that return to sports were similar between primary ACL reconstructions (91%) and revision ACL reconstructions (87%) at one-year follow-up.[9] However, at two-year follow-up, only 45% of individuals reported returning to their pre-injury level of participation.[3, 4] Similarly, a recent systematic review found 57% of ACL revision subjects do not return to the same level of sports activity following surgery.[2] While individuals may not be able to return to their specific level of sport or the same pre-injury sport, the current study emphasizes that continued activity following revision surgery is associated with a significant increase in function, quality of life, decreased pain and stiffness at two years. It is still unclear if being active through sport participation leads to an increase in function or if patients with better function are able to participate in sports. Future analysis should examine if individuals whom were actively engaged in sports before revision surgery, but ceased participation after, report different PROMs than patients who return to sports.

In the current study, two-year IKDC scores were higher in individuals who participated in sports and lower among those who did not compared to other reported cohorts.[1, 26] Anand et al found median a IKDC score of 73 in a revision ACL cohort for individuals who returned to sports and 65 for those who did not at five years following the initial revision.[1] Multi-sport participants (82) and single-sport participants (77) had similar or slightly higher median IKDC scores compared to primary ACL reconstruction patients at -two-year (75) and -six-year (77) follow-up.[22] Previous analyses of the MARS cohort found that KOOS subscale measurements were significantly lower than in a primary ACL reconstruction cohort at two years.[11, 22] Our results substantiate prior reports, and supplement them by stratifying by sports participation level. In the KOOS-Quality of Life and KOOS Sports and Recreation outcome measures, scores in the sport participation groups were lower than reported findings in the literature and significantly lower in those who did not participate in sports. Anada et al reported a median KOOS-Quality of Life score of 73 in individuals who returned to sports compared to those who during their five-year follow-up which was in contrast to both single sport and multiple sport MARS participants who had median KOOS-Quality of Life scores of 63.[1] The difference in scores could be attributed to the length of follow-up between the two studies. Following primary ACL reconstruction, median KOOS-Quality of Life scores increased from 75 to 81 at two- to six-year follow-up intervals.[22] These results indicate even if individuals were able to return to sport participation following revision ACL reconstruction, they may not have the same level of self-reported sports function compared to primary ACL reconstruction patients. Contrary to our hypothesis, few clinically meaningful differences were seen between participants who participated in multiple sports compared to a single sport. Multi-sport participants had higher odds of increased activity levels on the MARX activity scale and on the WOMAC-Stiffness subscale, compared to single-sport participants. These results could suggest a gradient effect between sport participation levels, in which diversifying sports activities -- even among the older MARS cohort (median age = 26 years) -- was associated with improved PROMs, compared to single-sport participation. Yet, the number of sports participated in may simply reflect personal preference of an individual following revision surgery and not as a surrogate

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of knee function. Further research is needed to determine if participating in multiple sports reduces the risk of injury in adult athletes, at various levels of sport participation, and is protective against future re-injury.

The MARS cohort is the largest known prospective longitudinal study of revision ACL patients. This study established that sports participation is associated with higher PROMs than no sport, but did not take into account the sport participation level (e.g., recreational versus collegiate). Interestingly, single sport participants were more likely to have higher outcome scores on the KOOS-Sports and Recreation subscale compared to multi-sport athletes. This may be due to the type of sporting events single-sport patients participated in or the level of sport for this cohort. Level of sport participation was collinear with the MARX activity scale and, as a result, we did not include this variable in our model. Only one other analysis of the MARS cohort analyzed the influence of sport type and level of sport activity on determining graft choice in revision ACL reconstruction found no association.[12] Future studies should aim to better understand how modifications of the level of sport participation affect short- and long-term PROMs. For translation to clinical practice, these results suggest that surgeons may only need simple questions on the return to physical activity in determining the health of the knee during follow-up visits.

Although this study relies upon self-reported measures, the PROMs collected are well validated and reported. While our statistical approach controlled for previously reported predictors of decreased PROMs, we did not address the amount of time an individual had been cleared for sport participation as a potential confounder. Six and ten-year follow-up data planned for the MARS cohort can be used to assess the longitudinal impact of sport participation on PROMs.

Conclusion

Participation in either a single or multiple sports in the two years following ACL revision surgery were found to be significantly associated with higher PROMs across multiple validated self-reported assessment tools. The causal mechanism as to why individuals who don’t participate in sport reported lower PROMs remains unknown. During follow-up appointments, surgeons should expect patients reporting returning to physical activity (organized or unorganized) will have good functional outcomes, regardless of baseline activity levels. Diversifying the number of activity’s participated in following clearance from revision surgery may reflect the individual’s personal preference and does not significantly change associated PROMs. Lastly, the decline in MARX scores across groups may not represent declining physical activity, but rather a change in the intensity of activities pursued within the sport. Further work is needed to determine how limiting physical activity following revision surgery influences long term outcomes.

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Appendix

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What is known about the subject: Patients undergoing revision ACL reconstruction continue to report sub-optimal patient reported outcome measures compared to those undergoing primary ACL reconstruction. Prior cohort studies have identified surgical characteristics, meniscal, and articular cartilage injuries to be associated with lower two-year PROMs.

What this study adds to existing knowledge: While return to sport and activity levels following ACL revision surgery have been documented in the literature, no studies have examined what affect post-operative sport participation has on PROMs. It is known that certain sports increase the risk for further injury in revision ACL patients and individuals are at an increased risk for developing osteoarthritis. This study attempts to evaluate the relationship between single- and multi-sport participation following revision ACL reconstruction in a large, multicenter, prospective longitudinal cohort. This study aims to inform expectations for knee-related pain and functional outcomes among patients for whom returning to sport is a key consideration when deciding to undergo ACL revision surgery.

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Table 1:

Baseline Characteristics of Cohort who Completed a Two-year Follow-Up[a] (N=9S6)

	Value
Baseline Patient Demographics	
Sex	
Male	545 (55)
Age, y	26 (20, 35)
Body mass index	25 (23, 28)
Baseline activity level (range, 0 – 16)	11 (4, 16]
Smoking status[b]	
Never	767 (78)
Quit	122 (13)
Current	84 (9)
Primary sport participation in the two years before revision ACL surgery[b]	
No Sport	111 (11)
Baseball/softball	60 (6)
Basketball	142 (14)
Football	85 (9)
Gymnastics	13 (1)
Skiing	66 (7)
Soccer	160 (16)
Volleyball	51 (5)
Other[c]	293 (30)
Secondary sport participation in the two years before revision ACL surgery[b]	
No Sport	288 (29)
Baseball/softball	66 (7)
Basketball	125 (13)
Football	41 (4)
Gymnastics	7 (1)
Skiing	56 (6)
Soccer	68 (7)
Volleyball	41 (4)
Other[c]	290 (30)
Sport participation in the two years before revision ACL surgery[b,d]	
No sport participation	180 (19)
Single sport participation	689 (70)
Multi-sport participation	110 (11)
Previous Surgical Information	
Previous graft type[b,e]	
Allograft-BJB	113 (11)

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	Value
Allograft-soft tissue	106 (11)
Autograft-BTB	411 (42)
Autograft-soft tissue	263 (27)
Both autograft + allograft	18 (2)
Other/unknown	74 (7)
Time since last ACL reconstruction, years	3.6 (1.4, 9.0)
Revision number	
1	871 (88)
2	96 (10)
3 or more	19 (2)
Previous medial meniscus surgery[b]	
Yes, repair healed/stable	293 (30)
Yes, repair not healed/stable	26 (3)
Yes, excision	49 (5)
Previous lateral meniscus surgery[b]	
Yes, repair healed/stable	146 (15)
Yes, repair not healed/stable	21 (2)
Yes, excision	17 (2)
Previous articular cartilage surgery	113 (12)
Previous ACL reconstruction on contralateral knee	106 (11)
Mechanism of Injur[b]	
Nontraumatic gradual onset	266 (27)
Nontraumatic sudden onset	60 (6)
Traumatic noncontact	119 (12)
Traumatic contact	539 (55)
Current Surgical Information	
Current graft type[b,d]	
Allograft-BTB	237 (24)
Allograft-soft tissue	241 (24)
Autograft-BTB	269 (27)
Autograft-soft tissue	207 (21)
Other/unknown	31 (3)
Current medial meniscal injury	446 (45)
Current lateral meniscal injury	351 (36)
Current articular cartilage injury	
Medial femoral condyle	424 (43)
Lateral femoral condyle	279 (28)
Medial tibial plateau	101 (10)
Lateral tibial plateau	165 (17)
Patella	295 (30)
Trochlea	209 (21)

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	Value
Post-Revision Sport Participation Information	
Primary sport participation in the two-years fallowing revision ACL surgery[b]	
No Sport	209 (21)
Baseball/softball	60 (6)
Basketball	110 (11)
Football	29 (3)
Gymnastics	7 (1)
Skiing	56 (6)
Soccer	100 (10)
Volleyball	42 (4)
Other[c]	363 (37)
Secondary sport participation in the two-years following revision ACL surgery[b]	
No Sport	403 (41)
Baseball/softball	46 (5)
Basketball	97 (10)
Football	33 (3)
Gymnastics	3 (<1)
Skiing	60 (6)
Soccer	50 (5)
Volleyball	32 (3)
Other[c]	252 (26)
Sport participation two years after revision ACL surgery[b,d]	
No sport participation	207 (21)
Single sport participation	203 (21)
Multi-sport participation	564 (58)

[a]Categorical data is reported as n (%) of nonmissing values or as median (lower quartile, upper quartile) for continuous variables.

[b]Catergory contains missing data that represents <5% of the total population.

[c]Other sports were self-reported by patients to include: biking, cheerleading, dancing, frisbee, hockey, lacrosse, martial arts, roller skating, rugby, tennis, track and field, and trampolining.

[d]No sport participation were individuals who reported no primary or secondary sport participation, single sport participation were individuals who only reported a single sport participation. Multi-sport participation were individuals who reported more than one sport or other sport in their primary and secondary sport participation.

[e]All previous and current surgical information were determined by the patient's individual surgeon.

ACL, Anterior cruciate ligament; BTB, bone-tendon-bone

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Table 2

Median 2-Year PROM Scores by Sport Participation at Two-Year Follow-Up[a] (N = 930)

		Baseline Score[b]			2-Year Follow Up Score[b]		
		No Sport Participation	Single Sport Participation	Multi-Sport Participation	No Sport Participation	Single Sport Participation	Multi-Sport Participation
PROMs	**Scale**	**n = 207**	**r = 205**	**r = 568**	**n = 207**	**n = 205**	**n = 568**
IKDC	0-100	44 (30, 57)	53 (39, 63)	54 (42, 66)	60 (39, 76)	77 (60, 86)	82 (69, 89)
KOOS							
Symptoms	0-100	60 (46, 79)	68 (54, 82)	68 (54, 82)	71 (54, 86)	79 (64, 93)	82 (68, 89)
Pain	0-100	66 (53, 31)	78 (61, 86)	78 (64, 89)	81 (61, 92)	92 (75, 97)	92 (81, 97)
ADL	0-100	78 (59, 91)	85 (69, 97)	90 (74, 97)	91 (72, 99)	97 (90, 100)	97 (92, 100)
Sport and Recreation	0-100	35 (15, 55)	45 (25, 55)	50 (30, 70)	60 (20, 80)	75 (55, 90)	80 (60, 90)
QoL	0-100	25 (13, 38)	32 (19, 44)	38 (19, 50)	44 (25, 56)	63 (44, 75)	63 (44, 75)
WOWAC							
Stiffness	0-100	63 (50, 75)	75 (50, 88)	75 (50, 88)	75 (50, 88)	75 (63, 100)	75 (63, 100)
Pain	0-100	75 (60, 35)	85 (70, 95)	85 (75, 95)	85 (65, 95)	95 (80, 100)	95 (85, 100)
ADL	0-100	78 (59, 91)	85 (69, 97)	90 (74, 97)	91 (72, 98)	97 (90, 100)	97 (93, 100)
MARX activity score	0-16	5 (0, 11)	11 (4, 16)	12 (7, 16)	1 (0, 4)	6 (2, 12)	9 (4, 12)

[a] Data reported as median and inter-quantile ranges (25^{th} and 75^{th} percentiles)

[b] Significance level for all PROMs within sub-groups at each time point was <0.001

ADL, Activities of Daily Living; IKDC, International Knee Documentation Committee subjective form; KOOS, Knee injury and Osteoarthritis Outcome Score; PROMs, Patient Reported Outcome Measures; QoL, quality of Life; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index

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Table 3:

Median Difference in PROMs by Sport Participation Group at Two-Year Follow-Up (N = 980)[a]

		Difference in Scores from Baseline			
		No Sport Participation	Single Sport Participation	Multi-Sport Participation	
PROMs	**Scale**	**n = 207**	**n = 205**	**n = 568**	**P-value**
IKDC	0-100	12 (0, 25)	20 (7, 32)	23 (10, 37)	<0.0001
KOOS					
Symptoms	0-100	7 (−4, 17)	7 (−4, 21)	10 (0, 25)	0.01
Pain	0-100	8 (−3, 19)	8 (0, 20)	11 (0, 25)	0.12
ADL	0-100	7 (0, 19)	7 (0, 18)	6 (0, 18)	0.74
Sport and Recreation	0-100	20 (−5, 39)	25 (5, 45)	25 (5, 45)	0.04
QoL	0-100	12.5 (0, 31)	25 (6, 43)	25 (6, 43)	<0.0001
WOMAC					
Stiffness	0-100	0 (−12.5, 25)	0 (−12.5, 25)	12.5 (0, 25)	0.07
Pain	0-100	5 (−5, 20)	5 (0, 15)	5 (0, 15)	0.89
ADL	0-100	7 (0, 19)	7 (0, 18)	6 (0, 18)	0.73
Marx activity score	0-16	−2 (−8, 0)	−1 (−6, 1)	−2 (−6, 0)	0.22

[a]Data reported as median and inter-quantile ranges (25th and 75th percentiles)

ADL, Activities of Daily Living; IKDC, International Knee Documentation Committee subjective form; KOOS, Knee injury and Osteoarthritis Outcome Score; PROMs, Patient Reported Outcome Measures; QoL, Quality of Life; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index

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Table 4:

Significant Odd Ratios for Explanatory and Co-Variates in Model (IKDC and KOOS PROMs)[a]

				KOOS				
Patient Demographics	**Comparison**	**Worse Outcome**	**IKDC (n=937)**	**Symptoms (n=937)**	**Pain (n=935)**	**ADL (n=937)**	**Sports/Rec (n=911)**	**QoL (n=940)**
Two-year sport participation[b]	Multi-sport vs No sport	No sport	3.73 (2.64-5.28) P < .0001	2.25 (1.62-3.15) P < .0001	2.28 (162-3.19) P < .0001	2.39 (167-3.41) P < 0.0001	2.31 (160-3.35) P < .0001	3.29 (2.31-4.67) P < .0001
	Single sport vs No sport	No sport	2.41 (1.62-3.58) P < .0001	1.77 (1.18-2.64) P = .005	1.94 (1.32-2.87) P = .001	1.98 (1.34-2.94) P = .001	1.79 (1.19-2.70) P = .006	2.70 (1.31-4.03) P < .0001
Baseline sport participation[b]	Multi-sport vs Single sport	Single Sport					0.61 (0.43-0.86) P = 0.005	
Baseline outcome score		Lower To Score	1.04 (1.04-1.05) P < .0001	1.04 (1.04-1.05) P < .0001	1.05 (1.04-1.06) P < .0001	1.05 (1.04-1.06) P < .0001	1.03 (102-1.03) P < .0001	1.03 (102-1.04) P < .0001
Baseline activity score (MARK activity scale)		Lower activity level	1.04 (1.02-1.08) P = .001				1.03 (1.01-1.06) P = .021	1.03 (1.01-1.06) P = .019
Sex		Female	1.44 (1.11-1.87) P = .006					
BMI		Higher BMI	0.96 (0.92-0.99) P = .012			0.96 (093-1.00) P = .027		
Time since last ACLR, y		Less time since ACLR	1.05 (1.02-1.08) P = .001	1.07 (1.04-1.09) P < .0001	1.06 (1.3-1.09) P < .0001	1.06 (1.03-1.10) P < .0001	1.06 (1.03-1.09) P < .0001	
Smoking	Never vs Current	Current smoker						1.54 (103-2.30) P = .037
Meniscal Treatment (previous)								
Medial	No tear vs excised	Excised		1.32 (1.01-175) P = .046	1.39 (103-1.87) P = .030			
Lateral	No tear vs excised	Excised	1.50 (1.03-2.20) P = .036	1.81 (1.27-2.59) P = .001	1.52 (1.07-2.17) P = .020		1.48 (1.02-2.15) P = .041	1.79 (1.24-2.59) P = .002
	No tear vs unstable, not healed repair	Unstable, not healed repair	2.17 (1.03-4.55) P = .041	2.82 (1.18-6.79) P = .021	3.04 (1.33-6.96) P= .003	2.60 (120-5.62) P = .015		2.04 (1.03-4.05) P = .042

				KOOS				
	Comparison	**Worse Outcome**	**IKDC (n=937)**	**Symptoms (n=937)**	**Pain (n=935)**	**ADL (n=937)**	**Sports/Rec (n=911)**	**QoL (n=940)**
Articular cartilage injury (current)								
Lateral femoral condyle	Normal/G1 vs Injury/G2-G4[c]	Normal/G1				1.36 (1.01-1.84) P = .045		
Trochlear	Normal/G1 vs Injury/G2-G4[c]	injury/G2-G4	1.41 (102-1.97) P = .038		1.47 (1.03-2.12) P = .035	1.83 (1.32-2.56) P < .0001	1.45 (1.04-2.03) P = .029	