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The effect of meniscal pathology and management with ACL reconstruction on patient-reported outcomes, strength, and jump performance ten months post-surgery

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Running Title: Meniscal intervention with ACLR

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The effect of meniscal pathology and management with ACL reconstruction on patient-reported outcomes, strength, and jump performance ten months post-surgery

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Background

The purpose of this study was to examine the differences in patient-reported outcome measures, isokinetic strength, plyometric ability and ability to meet return to play criteria ten months after anterior cruciate ligament (ACL) reconstruction surgery between those who underwent meniscectomy, those who underwent meniscal repair and those with no meniscal intervention alongside ACL reconstruction surgery.

Methods

Three hundred and thirteen athletes with clinically and radiologically confirmed ACL ruptures were included in this study. Participants were grouped according to their intra-operative procedures (isolated ACL reconstruction surgery n=155, ACL reconstruction surgery with meniscectomy n=128, ACL reconstruction surgery with meniscal repair n=30). Participants completed patient-reported outcome measures questionnaires (Marx Activity Rating Scale, the ACL Return to Sport after Injury and the International Knee Documentation Committee Score) and completed a battery of objective functional testing including isokinetic dynamometry and jump performance testing (countermovement jump and drop jump) between 9 and 11 months after surgery.

Results

No significant between-group differences were identified in any metric relating to patient-reported outcome measures (p =.611), strength and jump measures (p =.411) or the ability to achieve symmetry-based return to play criteria (p = .575).

Conclusions

Clinically, these results suggest that concomitant meniscal surgery has no significant effects on patient-reported outcome measures, strength and jump metrics at the return to play stage post-operatively and can inform the pre-operative counselling of those awaiting ACL reconstruction surgery with likely meniscal intervention.

Keywords: Anterior Cruciate Ligament, Anterior Cruciate Ligament Reconstruction, Isokinetic Dynamometry, Countermovement Jump, Return to Play

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1.1 Introduction

Anterior cruciate ligament (ACL) injury is the most common orthopaedic knee ligament injury and primarily affects young, active individuals [1]. ACL tears can result in impaired function of the knee and affect quality of life [2] and surgical ACL reconstruction (ACLR) is commonly used to restore stability to the knee [2-4]. ACL injuries usually occur during activities that involve pivoting, twisting and multidirectional movement [1] and can occur with concomitant damage to other structures of the knee [5, 6], most frequently the menisci [6-8]. The role of the menisci is to distribute load and to protect the articular cartilage from excessive axial, rotational and shearing forces [9, 10]. Injured menisci can be either left in situ, partially or wholly resected (meniscectomy) or repaired using sutures [11]. Management of concomitant meniscal injuries varies depending on the type and location of the injury [11, 12]. Increased efforts are being made to repair menisci where appropriate, in light of the increased risk of knee osteoarthritis (OA) following meniscectomy [13-15]. However, meniscectomy is still 2-3 times more prevalent than meniscal repair [16].

Given how commonly meniscal injury occurs alongside ACL rupture [6] it is important to understand the impact meniscal intervention has on outcomes after ACL reconstruction and the ability of participants to return to sport. Long-term investigations have demonstrated a significantly increased risk of OA in patients after meniscectomy and partial meniscectomy relative to those who have not undergone meniscal intervention [13, 15]. Outcomes after meniscal repair yield high success rates in both adults and adolescents, making it an attractive option to protect the long-term health of the knee [15, 17, 18]. However the decision to perform a meniscal repair is influenced by many factors [19] and post-operative rehabilitation protocols vary in relation to restricted range of motion through bracing and restricted weightbearing [20, 21]. The long-term impact of meniscal intervention alongside ACLR is well investigated with respect to osteoarthritis, however the effect on the patients' short term outcomes and ability to meet a return to play criteria is unclear.

Return to play after ACL reconstruction is a decision made by various stakeholders in the management of an athlete after ACLR. At present, the best evidence suggests that achieving >90% symmetry in quadriceps and hamstring strength, >90% symmetry in plyometric ability alongside optimising neuromuscular function before returning to play, combined with increased time from surgery reduces risk of further knee injury [22-24]. Isokinetic dynamometry has been shown to be a reliable and valid measure of quadriceps and hamstring strength [25] and has been previously reported in a post-ACLR population to measure the recovery of strength in the ACLR limb and quantify between-limb asymmetries [4, 26]. Jump testing, for example, countermovement jump (CMJ) and drop jump (DJ) testing are important measures of reactive and explosive strength [27], both of which are qualities needed for multidirectional sports [28, 29]. In addition to this, previous research in patients after ACLR demonstrate biomechanical differences in how jumping tasks are executed alongside performance asymmetries between limbs on single leg jumping tasks [24, 30]. The single-leg CMJ has been identified as the most sensitive and valid jump test for assessing restoration of normal function after ACLR [30].

Previous research has yielded mixed results with respect to how these measures are affected by meniscal intervention. Patient-reported outcome measures (PROMs) are an important tool in monitoring the progress of rehabilitation and readiness to return to play. When comparing short term subjective findings after isolated ACLR, ACLR with partial meniscectomy and ACLR with meniscal repair, studies have shown equivocal subjective results at 2 years for meniscectomy with ACLR and isolated ACLR [31]. However, patients who underwent meniscal repair with ACLR demonstrated poorer short term results when compared to ACLR with meniscectomy and isolated ACLR in relation to subscales of the Knee Injury and Osteoarthritis Outcomes Score (KOOS) across a range of timescales from 6 months to 2 years [31-33]. Functional tests including isokinetic dynamometry, isometric strength and hopping tasks have demonstrated no significant differences between patients after isolated ACLR, ACLR with meniscectomy and ACLR with meniscal repair across timescales of 6 months to 2 years though methods have been heterogenous [4, 26, 34].

Findings to date have thus provided mixed conclusions on how PROMs, strength and functional testing is affected by meniscal pathology in the short term, and there are no studies incorporating a testing battery that assesses all of the qualities needed to return to playing a multidirectional sport at a return to play stage. Results from previous studies are also difficult to compare due to the variety of methodologies, time-points and metrics used. It is therefore unclear how meniscal intervention affects rehabilitation post ACLR and whether it hinders the athlete’s ability to meet return to play criteria. This information is important for clinicians and patients alike, enabling clinicians to provide informed education on the expected short-term prognosis of the various meniscal procedures, particularly for athletes aiming to return to sport, and allowing for accurate expectation management post-operatively. A combination of the above measures would assess the fundamental subjective qualities, objective qualities and functional outcomes needed to return to play, reducing the risk of further knee injury [22-24], so a testing battery that incorporates all of these measures and provides a comparison across those who underwent an isolated ACLR, ACLR with meniscectomy and ACLR with meniscal repair is needed.

The aim of this study was to investigate PROMs, isokinetic strength, plyometric ability and the ability to meet return to play criteria 9-11 months after surgery across patients who underwent meniscectomy, meniscal repair and no meniscal intervention at the time of ACLR. We hypothesised that subjective and objective outcomes would be lower among those who underwent ACLR with meniscal repair compared to those who underwent ACLR with meniscectomy or an isolated ACLR.

1.2 Methods

1.2.1 Participants

This study was a level II cohort study involving 313 participants from a single institution. ACL injury was confirmed clinically and on MRI at the Sports Surgery Clinic, Dublin, Ireland. Participants included were male, multidirectional athletes between the ages of 16-35 years undergoing primary ACL reconstruction with a bone-patella tendon-bone autograft. Multi-directional sports require frequent and consistent sagittal plane movement and running as well as lateral shuffling, cutting and jumping [11]. The primary sports included in this study were Gaelic football (52%), soccer (18%), hurling (16%) and rugby (14%).

Participants were only eligible for to participate in this study if they underwent testing 9-11 months after ACLR as part of a standardised return to play assessment protocol.

Surgery was carried out using arthroscopic and surgical techniques: bone–patellar tendon–bone (BPTB) autografts, with graft and tunnel placement within anatomic footprints and with graft selection guided by case history and surgeon preference. Allograft-based surgical reconstructions were not included in this study. BPTB grafts were secured with metal interference screws (Softsilk; Smith & Nephew). Routine arthroscopy was performed and co-existing pathology and managed at the discretion of the surgeon . All intraoperative data were recorded at the time of surgery in an ACL registry.

Exclusion criteria were revision ACL surgery and multi ligament reconstruction. Participants undergoing partial meniscectomy or repair of both compartments were included and were placed in the appropriate meniscectomy and repair groups .Those who underwent a meniscectomy in one compartment of the knee but also underwent meniscal repair in the other compartment (n=2) were also excluded from the study. Participants were divided into 3 groups: ACLR with meniscal repair (n=30), ACLR with partial meniscectomy (n=128) and a control group who had an isolated ACLR (n=155). A breakdown of the meniscal tears in the meniscectomy and meniscal repair groups is provided. (Table 1). The control group also included those with meniscal tears that were deemed stable by the surgeon and left in situ (medial meniscal tears left in situ n=26, lateral meniscus tears left in situ n=43).

Post-operatively, participants were given two elbow crutches, advised to weight bear as tolerated for two weeks, and provided with rehabilitation guidelines. Given the geographical spread of participants, rehabilitation was led by local clinicians and therapists in the majority of cases. Informed written consent was obtained prior to study enrolment. Ethical approval was granted by the hospital ethics committee and this trial was registered with https://clinicaltrials.gov/ (NCT02771548).

Table 1. Breakdown of meniscal injuries into meniscectomy and repair groups

	Meniscectomy	Meniscal repair
Management of medial and lateral meniscal tears	16 medial 114 lateral	16 medial 17 lateral
Location of tear	64 posterior 62 middle 9 anterior	26 posterior 6 middle 2 anterior
Type of tear	64 cleavage tears 62 beak tears 9 bucket tears	26 cleavage tears 6 beak tears 2 bucket tears

1.2.2 Testing procedures

Testing took place 9-11 months after ACLR surgery. Prior to all testing, participants completed a standardised warm up consisting of a two-minute jog, five bodyweight squats and five double-legged countermovement jumps. Exercise familiarisation was then completed prior to data collection for each movement task, in the form of two submaximal repetitions. The testing protocol comprised single-leg counter-movement jumps (SLCMJ), followed by single leg drop jumps (SLDJ) from a 20cm box. During SLCMJ testing, patients were asked to keep their hands on their iliac crests and jump as high as they could, with the knees fully-extended during the flight phase. During SLDJ testing, participants were instructed to drop off the box and jump as high in the air as possible whilst also minimizing ground contact time, keeping their hands on their iliac crests. Three valid (apparent maximal effort and full foot contact on force plate) attempts were recorded from each leg. The non-operated side was tested first for each task. Participants then completed additional jumping and change of direction exercises as part of a clinical assessment and broader study [24, 36]. Prior to testing, retroreflective markers (14 mm diameter) were placed at bony landmarks on the lower limbs, pelvis, and trunk as per a modified Vicon Plug-in-Gait (Vicon Motion Systems, Oxon, UK) marker set [37]. Data were recorded with an 8-camera motion analysis system (Bonita-B10; Vicon Motion Systems) at 200 Hz synchronized (Vicon Nexus 1.8) with two force platforms (BP400600; AMTI, MA, USA) sampling at a frequency of 1000 Hz.

Participants then completed isokinetic dynamometry knee strength testing (Cybex NORM, Computer Sports Medicine Inc., MA, USA). This consisted of concentric knee extension and flexion torque, assessed at an angular velocity of 60◦/s through the range 0-100 degrees knee flexion. Participants completed a total of 3 sets of 5 repetitions of knee flexion and extension. The first set was used as a warmup of increasing effort from 60-90%, finishing with 1 attempt at maximal effort. Participants then completed 2 sets of maximal flexion and extension repetitions with a 60-second rest period between each set. The non-operated limb was tested first.

Three validated PROM questionnaires, completed on the same day as the physical testing, were used to assess subjective knee function. The measures chosen were the Marx Activity Rating Scale, the Anterior Cruciate Ligament Return to Sport after Injury (ACL-RSI) and the International Knee Documentation Committee Score (IKDC).

1.2.3 Data processing

Marker trajectory and ground reaction force (GRF) data were filtered using a low-pass fourth-order zero-lag Butterworth filter with a cut-off frequency of 15 Hz [38]. The position of the centre of mass (COM) was calculated on a frame-by-frame basis from segment kinematics and anthropometric properties (Vicon Nexus 2.7) Jump height was calculated from the vertical displacement of the COM from the instant of take-off to its maximum height during the flight phase. Contact time was calculated using a GRF threshold of 20 N. For the two jumping tasks, the mean of the three collected trials on each leg was used for further analysis. The isokinetic dynamometry set with the highest gravity-corrected knee extensor peak torque and coefficient of variation <0.1 was selected for analysis [39]. Peak torques relative to body mass during knee extension and flexion were extracted from this set.

The Limb Symmetry Index (LSI) was used to quantify symmetry between the operated and non-operated limb for all analysed variables. LSI was calculated by taking the test score of the operated limb, dividing by the non-operated limb, and multiplying by 100 to obtain a percentage difference between limbs:

$$LSI = \frac{Operated\ limb}{Nonoperated\ limb} \times 100$$

1.2.4 Statistical Analysis

All statistical analyses were performed using JASP version 0.12.2 for Windows. Descriptive statistics are reported as mean +/- standard deviation. No significant between group differences were seen in age (p = .623), bodyweight (p = .188) and time from surgery to testing (p = .067). One-way ANOVA was used to identify between-group differences in isokinetic strength metrics and jump performance metrics. Between-group differences in PROMS were analysed using the Kruskal-Wallis test due to the non-parametric nature of the data. Both LSI and results from the operated limb were analysed. Significance was accepted at $\alpha = 0.05$ and effect size was calculated as eta-squared. Results were interpreted using the following thresholds: *ES* > 0.1 = small; *ES* > 0.25 = moderate; *ES* > 0.37 = large [40, 41]. Chi-squared goodness of fit testing was used to identify the proportion of each group that met the overall return to play criteria to ascertain whether meniscal intervention influenced the participants' ability to meet these criteria. Return to play criteria were defined as >90% inter-limb symmetry in objective measures (Grindem et al., 2016): knee extensor peak torque, knee flexor peak torque, SLCMJ height, and SLDJ height and SLDJ contact time. This was also broken down to assess whether meniscal intervention influenced the participants' ability to meet return to play criteria in strength and jump performance outcome measures separately. To determine the magnitude of difference between each individual meniscal intervention group and the control group, and between meniscal intervention groups, effect size (ES) was calculated using Cohen's d. The results were interpreted using the following thresholds: *ES* > .1 = trivial *ES* > 0.2 = small; *ES* > 0.5 = moderate; *ES* > 0.8 = large [42].

1.3 Results

There were no significant between-group differences in age, body mass or time from surgery to testing (Table 2).

Table 2. Descriptive statistics-mean, standard deviation

Group	N	Age (years)	Body Mass (kg)	Time from surgery to testing (weeks)
Control	155	23.33 +/- 5.0	81.41 +/- 9.5	43.15 +/- 2.3
Meniscectomy	128	22 +/- 5.4	82.71 +/- 12.6	42.65 +/- 2.3
Repair	30	23.75 +/- 5.6	85.1 +/- 9.3	42.28 +/- 2.6

There were no statistically significant between-group differences were identified for any PROM, strength or jump performance outcome metric (Table 3).

Table 3. PROMs

	Control Median (IQR)	**Meniscectomy Median (IQR)**	**Repair Median (IQR)**	**p**	**n^2**
MARX SCORE	12.00 (4.00)	12.00 (3.00)	12.00 (2.00)	.181	.011
IKDC SCORE	85.42 (10.42)	85.42 (12.50)	84.38 (13.80)	.749	.002
ACL RSI	75.38 (24.17)	80.00 (25.00)	82.50 (19.38)	.310	.008

Table 4. Strength and jump performance metrics

	Control Mean (SD)	**Meniscectomy Mean (SD)**	**Repair Mean (SD)**	**p**	**n^2**

EXTENSOR LSI	83.5 (14.6)	82.6 (13.6)	85 (14.3)	.691	.002
FLEXOR LSI	100.2 (13.08)	97.6 (15.1)	98.2 (11.4)	.271	.008
SLCMJ LSI	85.9 (16.2)	85.1 (11.3)	84.5 (10.9)	.810	.001
SLDJ JH LSI	79.7 (19.3)	80.6 (14.3)	77.8 (12.7)	.708	.002
SLDJ CT LSI	105.2 (13.2)	106.6 (12.5)	107 (.4)	.576	.004
EXTENSOR STRENGTH OPERATED SIDE	186.5 (39.1)	179.8 (38.1)	188.3 (32.3)	.269	.008
FLEXORSTRENGTH OPERATED SIDE	128.2 (24.8)	125.4 (27.5)	128.7 (21.4)	.612	.003
SLCMJ OPERATED SIDE	12.3 (3.2)	12.5 (3)	12.3 (2.5)	.780	.002
SLDJ JH OPERATED SIDE	11.3 (3.3)	12 (3.2)	11.6 (2.5)	.276	.008
SLDJ CT OPERATED SIDE	.38 (.11)	.37 (.09)	.39 (.1)	.465	.005

SLCMJ LSI-Single leg countermovement jump limb symmetry index, SLDJ JH LSI-Single leg drop jump jump height limb symmetry index, SLDJ CT LSI-Single leg drop jump contact time limb symmetry index

1.3.1 Return to play criteria

Of the 313 participants in the study, 3% of participants achieved >90% symmetry in all metrics tested, therefore meeting the return to play criteria, 27% achieved >90% symmetry in all isokinetic strength metrics and 10% achieved >90% symmetry in jump metrics (Table 4). The proportion of athletes achieving the return to play criteria for all metrics, strength metrics and jump metrics did not differ between the three groups ($p = .611$, $p = .411$, $p = .575$).

Table 5. Return to play criteria achievement

	Total % of participants	Control	Meniscectomy	Repair
Achieved >90% symmetry in all metrics	3	5	4	0
Achieved >90% symmetry in isokinetic strength measures	27	40	32	11

Achieved >90% symmetry in jump metrics	10	18	11	2

1.4 Discussion

This study examined the differences in PROMs, isokinetic strength and plyometric ability between those who underwent ACL reconstruction with and without two different forms of meniscal intervention. We hypothesised that subjective and objective outcomes would be lower in the ACLR with meniscal repair group compared to the ACLR with meniscectomy and isolated ACLR groups but this hypothesis was not supported by our findings.

1.4.1 PROMS

The results indicated similar levels of perceived impairment and patient confidence in the ability to return to play across the three groups. Previous literature has suggested that patients with isolated ACLR and ACLR with meniscectomy display equivocal PROM scores two years post-operatively [31]. These results have been replicated in this study at the earlier stage of 9-11 months, around the time of return to play. It is reported that removal of meniscal tissue increases the risk of OA in the long-term [43], however the results of this study suggest that short term outcomes are not different regardless of surgical management.

Our findings do not correspond with those of previous studies reporting that patients who have undergone ACLR with meniscal repair demonstrate poorer PROM scores at 6 months, 1 year and 2 years post-operatively relative to their counterparts who undergo isolated ACLR or ACLR with partial meniscectomy [32, 33]. This could be attributed to the heterogeneity in the reported rehabilitation programmes and more conservative approach to early post-operative management in comparison with that experienced by our study's participants; Svantesson, Cristiani, Senorski, Forssblad, Samuelsson, Stålman [32] used a hinged brace with restricted range of motion in the early post-operative period, [4] prescribed partial weight-bearing for four weeks to all participants and the rehabilitation guidelines in LaPrade, Dornan, Granan, LaPrade, Engebretsen [33] are not described. The rehabilitation guidelines provided in the current study were to weight bear as tolerated for two weeks with elbow crutches and a protocol provided to their physiotherapist. There was no use of bracing post-operatively. The difference in PROM results between our meniscal repair cohort and the cohorts in the aforementioned studies may thus be attributed to a rehabilitation protocol that allowed unrestricted knee range of motion and encouraged a normal gait pattern, which is thought to cause compression of some meniscal tear types and promote healing of the repair [44-46]. It is important to note that the current study focuses on post-operative PROMs and doesn't provide analysis on pre-operative PROMs. The lack of preoperative PROMs is a limitation to this study as it does not allow for analysis of changes in score from the preoperative state that may have found differences in the degree of improvement postoperatively among the three groups.

1.4.2 Strength and jump testing

The results of this study suggest that there are no significant differences in knee strength, SLCMJ height, SLDJ height and SLDJ contact time between those who underwent an ACLR, ACLR with meniscectomy and ACLR with meniscal repair 9-11 months after surgery. There were also no significant between-group differences in LSI for strength or jump performance, and no between-group differences in the ability to achieve >90% symmetry return to play criteria across jump and strength metrics.

In this study, <3% of participants met 90% symmetry across the variables tested, however previous research has shown performance deficits persist beyond 9 months post-operatively across many variables [24, 36, 39, 47, 48]. Variables often tested include strength [47, 48], jump performance [24] and biomechanics [36, 39] and in all three areas, patients post-ACLR underperform compared to their non-ACLR counterparts. The causes of this are likely to be multi-factorial and could be attributed to both physical and psychological readiness [49] to return to play but also the timepoint at which our participants were tested. There is some evidence to suggest that differences in limb symmetry index reduce 1 year post-ACLR [50] but this study tested participants at 9-11 months post-operatively. However, this study demonstrates that the presence of these deficits is not related to meniscal intervention intra-operatively but does add to the literature highlighting the persistence of deficits in strength and performance metrics post-operatively.

The results of this study are also in line with those of previous studies comparing patients who underwent isolated ACLR vs those who underwent ACLR with meniscal intervention. Both Lepley, Wojtys, Palmieri-Smith [26] and Øiestad, Holm, Engebretsen, Risberg [4] found no significant difference in quadriceps strength as measured by isokinetic dynamometry at 6 months, 1 year and 2 years post-operatively. Similarly, [Øiestad, Holm, Engebretsen, Risberg [4]] reported no significant differences in jump hop and stair hop test scores between those who underwent ACLR with and without meniscal intervention. However, the current study is the first to investigate both strength and a variety of single leg jump metrics across patients with isolated ACLR, ACLR with meniscal repair and ACLR with meniscectomy at the key return to play timepoint of ten months post-operatively. Meniscectomy results in a change to the biomechanical loading of the knee joint [51-53] and the removal of shock-absorbing cartilage [54]. Despite this significant interruption to the structure of the joint, our study shows it has no impact on participants' ability to achieve between-limb strength and jump score symmetry at this stage after ACLR.

1.4.3 Clinical implications

The clinical implications of this study revolve around preoperative counselling and expectation management for patients undergoing ACLR with concomitant meniscal intervention. It is well accepted that ACLR with meniscectomy results in a higher risk of OA in long-term studies [15, 43], however these differences are not evident in subjective or objective outcomes in the first post-operative year [4, 31]. Sarraj, Coughlin, Solow, Ekhtiari, Simunovic, Krych, MacDonald, Ayeni [31] demonstrated favourable outcomes in the meniscectomy cohort relative to the meniscal repair cohort at two years, however this effect is reversed at four years when results favour the meniscal repair group in terms of arthrometric data and IKDC scores. Our results also highlight that early range of motion and weightbearing post-operatively may negate the poorer PROM scores and functional outcomes seen in previous studies [32, 34]. This study suggests that concomitant meniscal surgery has no significant effects on PROMs, strength and jump metrics at the return to play stage post-operatively. These findings suggest that clinicians and patients can be counselled to expect to achieve similar levels of recovery of strength and jump performance and PROMs in the short term after ACLR, regardless of meniscal intervention.

1.5 Conclusion

This study reports a range of outcomes after isolated ACLR, ACLR with meniscectomy and ACLR with meniscal repair in multi-directional athletes ready to return to play. We show that concomitant meniscal intervention with ACLR has no significant effect on PROMs, strength scores and jump scores at 9 months post-operatively. Clinically, these results can inform the pre-operative counselling of those awaiting ACLR with likely meniscal intervention.

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