Recent Trends in Concomitant Meniscal Procedures During Anterior Cruciate Ligament Reconstruction

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Background: The chondroprotective effect and secondary stabilizing role of the meniscus has been well-established. Meniscal preservation during anterior cruciate ligament reconstruction (ACLR) has been advocated in the literature and supported by advancements in surgical techniques.

Purpose: To examine the recent trends in concomitant partial meniscectomy and meniscal repair procedures with ACLR.

Study Design: Descriptive epidemiological study.

Methods: Patients who underwent arthroscopic meniscectomy (Current Procedural Terminology [CPT] codes 29880, 29881), meniscal repair (CPT codes 29882, 29883), and ACLR (CPT code 29888) between 2010 and 2018 were identified using the National Surgical Quality Improvement Program database. We calculated the proportion of patients who underwent each surgery type, stratified by year and by patient age and body mass index (BMI) groups. The Cochran-Armitage test for trend was used to analyze yearly proportions of concomitant meniscal surgery types.

Results: During the 9-year study period, 22,760 patients underwent either isolated ACLR (n = 10,562) or ACLR with concomitant meniscal surgery (either meniscectomy [n = 8931] or meniscal repair [n = 3267]). There was a gradual decrease in the proportion of meniscectomies (from 80.8% of concomitant procedures in 2010 to 63.8% in 2018), while the proportion of meniscal repairs almost doubled (from 19.2% in 2010 to 36.2% in 2018) (trend, $P < .001$). ACLR with meniscal repair increased in patients aged 35 to 44 years and 45 to 54 years (trend, $P = .027$) between 2010 and 2018; at the same time, the proportion of normal weight patients decreased by 17.7%, the proportion of overweight patients increased by 13.2%, and increases were seen in BMI groups corresponding to obesity classes 1 to 3 (trend, $P < .001$). In 2010, the average BMI of patients undergoing ACLR with meniscectomy versus meniscal repair differed by 2 ($P = .004$), but by 2018 the difference was nonsignificant (28.83 ± 5.80 vs 28.53 ± 5.73; $P = .113$).

Conclusion: Between 2010 and 2018, there was an upward trend in the proportion of meniscal repairs performed during ACLR, with notable increases in the proportion of repairs being performed on older, overweight, and obese patients.

Keywords: anterior cruciate ligament; knee; meniscus; knee; general; biology of cartilage

It is estimated that there are between 60,000 and 200,000 anterior cruciate ligament (ACL) injuries annually in the United States,[31] and 40% to 60% of patients who sustain an ACL tear will have a concomitant meniscal tear.[24,37] Historically, treatment of meniscal tears consisted of complete meniscectomy; however, detrimental long-term effects of meniscal loss have led to favoring the preservation of viable tissue. The chondroprotective effect of performing an arthroscopic meniscal repair, instead of a partial meniscectomy, with a concomitant ACL reconstruction (ACLR) has been demonstrated in multiple studies.[5,14,16,20,48,52,62] Even with restoration of knee stability, meniscectomy (when performed before, during, or after ACL surgery) has been shown to accelerate degenerative joint changes.[14,20,30,35,52] Therefore, the importance of meniscal preservation in ACLR is increasingly recognized.

Database publications between 2004 and 2015 have displayed trends of decreased meniscectomy rates with either

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stable or increasing meniscal repair rates.[4,16,48] These publications concluded that surgeons were performing more meniscal repairs, particularly on younger patients and those with lower body mass index (BMI). Evolving evidence and surgical procedures in favor of meniscal preservation has led to a diversification of surgical candidates undergoing meniscal repair. The 2019 European Society for Sports Traumatology, Knee Surgery and Arthroscopy consensus on the management of traumatic meniscal tears concluded that several patient factors are linked to higher failure rates including older age and increased BMI.[33] However, they concluded that neither of these factors were contraindications for meniscal repair.[33] A previous study, using the Great Britain National Hospital Episode statistics between 1997 and 2019, found the incidence of meniscal repair during ACLR increased by 2.4 times in the 30- to 39-year-old group and 1.3 times in the 40- to 49-year-old group.[3] Serial database publications have continued to demonstrate trends favoring meniscal preservation during ACLR, and the British literature has suggested a paradigm shift toward meniscal preservation in older patients. In the US literature, there remains a lack of particular focus on demographics, such as advancing age and BMI. There is undoubtedly an orthopaedic consensus on the value of meniscal preservation during ACLR, and surgeons are redefining their surgical selection criteria.

The purpose of our study was to evaluate how meniscal surgery during ACLR has evolved between 2010 and 2018. Specifically, we examined trends in (1) meniscectomy and meniscal repair during ACLR, (2) patient age, and (3) patient BMI.

METHODS

Database

This study utilized the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database. Data are collected for this database from over 700 participating hospitals by trained clinical reviewers and include demographics; comorbidities; diagnoses in International Classification of Diseases, Ninth and Tenth Revisions, codes; inpatient and outpatient surgical procedures in Current Procedural Terminology (CPT) codes; and surgical outcomes for 30 days postoperatively. The database does not include procedures from independent or separate ambulatory surgical centers not affiliated directly with partnering NSQIP hospitals. All patient data are deidentified of any protected health information; thus, the study was exempt from institutional review board approval.

Study Population

The NSQIP database was queried to identify all patients who underwent an ACLR as defined by the CPT code 29888, between January 1, 2010, and December 31, 2018.[1] A total of 30,375 patients were identified and then further subdivided by CPT codes into procedure type, which included (1) isolated ACLR (29888) (with no concomitant procedures) and (2) ACLR with concomitant meniscal surgery: (i) ACLR with concomitant partial meniscectomy (29880, 29881) and (ii) ACLR with concomitant meniscal repair (29882, 29883). During the 9-year study period, the database query yielded a total of 22,760 patients who underwent either isolated ACLR or ACLR with concomitant meniscal surgery (either partial meniscectomy or meniscal repair).

Patient Demographics and Statistical Analysis

Demographic parameters collected included age, sex, height, weight, and year of procedure. The proportion of each surgery type by year and within groups was calculated. BMI was calculated, with missing height or weight data noted in 158 (0.7%) cases of isolated ACLR and 131 (0.6%) cases of ACLR with meniscal surgery. Averages are reported as means with variability as 1 SD. The Cochran-Armitage test for trend was used to analyze yearly proportions of concomitant meniscal surgery types. Kendall tau-b was used to determine the relationship between increasing year and mean age and mean BMI for concomitant meniscal surgery and types. The Mann-Whitney *U* test was used for comparison of mean BMI between meniscectomy and meniscal repair in 2010 and 2018. The Jonckheere-Terpstra test was used to determine trend significance of changes in age and BMI groups across the study period. All statistical and graphical analyses were performed using SPSS Version 26 (IBM Corp).

RESULTS

During the study period, the total number of procedures collected per year increased from 697 to 4032 cases. There were 10,562 patients (46.4%) who underwent isolated ACLR, while 12,198 (53.6%) had concomitant meniscal surgery, either meniscectomy or meniscal repair. There were 8931 patients (73.2%) who underwent concomitant meniscectomy and 3267 (26.8%) who underwent concomitant meniscal repair (Table 1). Between 2010 and 2018, there was an overall decrease in meniscal procedures during ACLR, with increases in meniscal repair but decreases in meniscectomy (Figure 1). As a proportion of concomitant procedures, meniscal repair almost doubled from 19.2% to 36.2%, while meniscectomy decreased from 80.8% to 63.8% (trend, $P < .001$) (Table 1).

During the study period, the mean age of patients undergoing any meniscal procedure during ACLR decreased from 33.9 ± 11.9 years in 2010 to 31.5 ± 10.5 years in 2018 (trend, $P < .001$) (Table 2). For patients undergoing meniscectomy, this downward trend was from 35.2 ± 12.0 years in 2010 to 33.2 ± 11.0 years in 2018 ($P < .001$), and for patients undergoing meniscal repair, it was from 28.7 ± 9.9 in 2010 to 28.5 ± 8.7 years in 2018 ($P = .019$) (Table 2 and Figure 2).

The proportion of ACLRs with meniscal repair decreased slightly in the younger age groups but increased substantially in the older age groups (trend, $P = .027$) (Table 3 and Figure 3). Kendall tau-b demonstrated a positive correlation between increasing year and age for ACLR with any meniscal surgery ($\tau_b = 0.035$; $P < .001$), ACLR with

TABLE 1
ACLR by Year: Isolated and With Concomitant Meniscal Procedures[a]

Year	Study Population	Isolated ACLR	ACLR With Any Meniscal Surgery	ACLR with Meniscectomy[b,c]	ACLR with Meniscal Repair[b,c]
2010	697 (3.1)	291 (41.8)	406 (58.2)	328 (80.8)	78 (19.2)
2011	964 (4.2)	393 (40.8)	571 (59.2)	468 (82.0)	103 (18.0)
2012	1462 (6.4)	614 (42.0)	848 (58.0)	674 (79.5)	174 (20.5)
2013	1778 (7.8)	710 (39.9)	1068 (60.1)	836 (78.3)	232 (21.7)
2014	2618 (11.5)	1393 (53.2)	1225 (46.8)	942 (76.9)	283 (23.1)
2015	3158 (13.9)	1487 (47.1)	1671 (52.9)	1293 (77.4)	378 (22.6)
2016	3920 (17.2)	1823 (46.5)	2097 (53.5)	1508 (71.9)	589 (28.1)
2017	4131 (18.2)	1869 (45.2)	2262 (54.8)	1574 (69.6)	688 (30.4)
2018	4032 (17.7)	1982 (49.2)	2050 (50.8)	1308 (63.8)	742 (36.2)
Total	22,760 (100.0)	10,562 (46.4)	12,198 (53.6)	8931 (73.2)	3267 (26.8)

[a]Data are reported as n (%). ACLR, anterior cruciate ligament reconstruction.
[b]Cochran-Armitage trend test for increasing year since 2010; $P < .001$.
[c]Proportion of ACLRs with meniscal surgery by year is shown in parentheses.

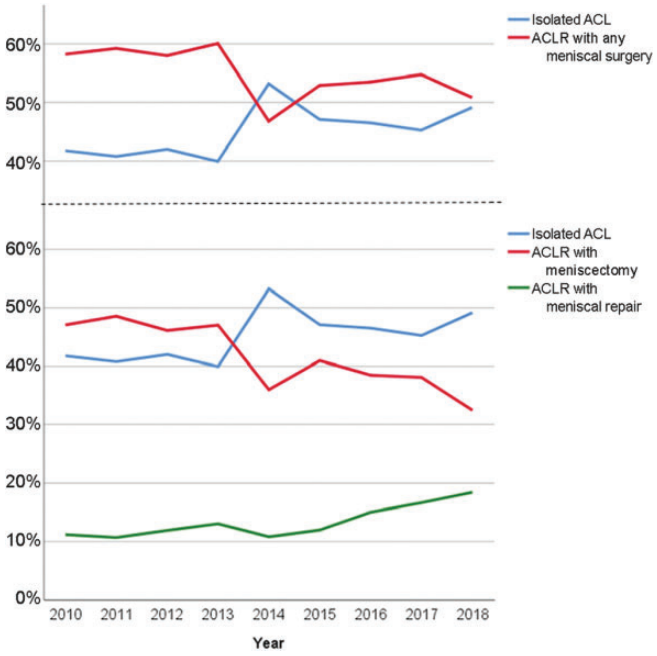

Figure 1. Proportion of ACLRs with concomitant meniscal surgery cases by year. ACLR, anterior cruciate ligament reconstruction.

meniscectomy ($\tau_b = 0.036$; $P < .001$), and ACLR with meniscal repair ($\tau_b = 0.064$; $P < .001$).

The mean BMI of patients undergoing ACLR with concomitant meniscal procedures showed an upward trend between 2010 (28.24 ± 5.92) and 2018 (28.72 ± 5.78) ($P < .001$) (Figure 4). In 2010, the average BMI of ACLR with meniscectomy (28.61 ± 5.96) and meniscal repair (26.65 ± 5.51) differed by 2 ($P = .004$), but by 2018 the difference was minimal (28.83 ± 5.80 vs 28.53 ± 5.73; $P = .113$) (Figure 4). The proportion of normal weight patients (BMI, 18.5-24.9) undergoing ACLR with meniscal repair decreased during the study period, while increases were seen in the proportion of overweight (BMI, 25.0-29.9) and obesity classes 1 (BMI, 30.0-34.9), 2 (BMI, 35.0-39.9), and 3 (BMI, ≥40.0) (trend, $P < .001$) (Figure 5).

DISCUSSION

The current study examined the characteristics of patients who underwent ACLR with concomitant meniscal procedures between 2010 and 2018. Previous studies have examined meniscal procedure trends up to 2015 but with a lack of focus on patient demographics. Our study showed that between 2010 and 2018, the proportion of ACLRs with meniscal repair increased from 19.2% to 36.2%, while the proportion of ACLRs with meniscectomy decreased from 80.8% to 63.8%. During this time, the proportion of patients aged 35 to 44 years who underwent meniscectomies decreased by 2.6% and who underwent meniscal repair increased by 3.4%. We suspect this trend reflects literature favoring meniscal preservation in patients aged over 40 years.[9,47] In the 9-year study period, the proportion of meniscal repairs performed on overweight patients increased by 13.2%, with increases seen in BMI groups corresponding to obesity classes 1 to 3. There was an anomalous decrease in ACLR with meniscal surgery between 2013 (60.1%) and 2014 (46.8%), followed by an increase in 2015 (52.9%). This trend was mainly seen in concomitant meniscectomies, and it may have been reflective of studies during that time demonstrating equivalent strength and clinical outcomes of all-inside techniques.[10,13,27,40] The proportion of ACLRs with meniscal repair increased steadily during the study period (Figure 1).

Advances in arthroscopic surgery, coupled with increased understanding of meniscal healing potential, have led to a shift from meniscal resection toward meniscal preservation.[43,46,55,56,59] Additionally, meniscal ramp lesions have received renewed interest in the literature,[6] with an estimated prevalence of 9.3% to 40% concurrently with ACL tears.[11,17,38,58] Because of studies supporting concomitant meniscal preservation, many authors have advocated for repair of ramp lesions at the time of ACLR.[18,19,49,60] These contemporary changes are reflected

TABLE 2
Age and BMI by Year for Patients Undergoing ACLR With Concomitant MS[a]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	*P* Value for Trend[b]
ACLR + MS										
Age, y	33.9 ± 11.9	34.3 ± 12.4	33.9 ± 11.5	32.4 ± 11.0	33.4 ± 11.7	32.7 ± 10.9	32.0 ± 11.0	31.8 ± 11.1	31.5 ± 10.5	<.001
BMI	28.24 ± 5.92	27.76 ± 5.30	27.90 ± 5.65	28.48 ± 6.05	28.35 ± 5.86	28.67 ± 5.79	28.56 ± 5.79	28.75 ± 5.76	28.72 ± 5.78	<.001
ACLR + MEC										
Age, y	35.2 ± 12.0	35.4 ± 12.7	34.5 ± 11.5	33.3 ± 11.0	34.4 ± 12.1	33.6 ± 11.1	33.4 ± 11.3	33.3 ± 11.4	33.2 ± 11.0	<.001
BMI	28.61 ± 5.96	28.14 ± 5.34	27.98 ± 5.57	28.80 ± 6.24	28.56 ± 5.97	28.90 ± 5.79	28.87 ± 6.03	29.21 ± 5.91	28.83 ± 5.80	<.001
ACLR + MR										
Age, y	28.7 ± 9.9	29.1 ± 9.7	31.4 ± 11.3	29.2 ± 10.3	30.0 ± 9.9	29.7 ± 9.4	28.6 ± 9.3	28.6 ± 9.5	28.5 ± 8.7	.019
BMI	26.65 ± 5.51	25.93 ± 4.70	27.61 ± 5.94	27.31 ± 5.16	27.64 ± 5.40	27.89 ± 5.73	27.76 ± 5.03	27.70 ± 5.26	28.53 ± 5.73	<.001

[a]Data are reported as mean ± SD. ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; MEC, meniscectomy; MR, meniscal repair; MS, any meniscal surgery.
[b]Kendall tau-b correlation with increasing years since 2010.

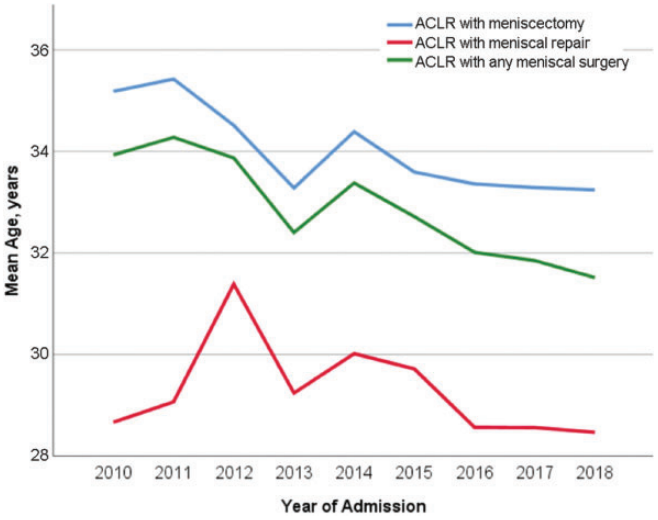

Figure 2. Mean patient age by year for patients undergoing ACLR with concomitant meniscal surgery. ACLR, anterior cruciate ligament reconstruction.

in the current study, which found increases in the proportion of meniscal repair with concomitant ACLR.[4,16,48] In a study by Abrams et al[4] between 2005 and 2011, the authors found a 48.3% overall increase in the number of meniscal repairs performed during ACLR; however, the overall incidence was not significantly changed. In a similar study by DeFroda et al[16] between 2010 and 2015, the number of ACLRs with concomitant meniscectomy was 2.9 times that with concomitant meniscal repairs; however, the incidence of meniscectomy decreased while the incidence of meniscal repair remained constant. We found a decrease in concomitant meniscal procedures during ACLR between 2013 and 2014, which we attribute to a decrease in meniscectomies, followed by an increase in 2015. DeFroda et al examined yearly trends of isolated meniscectomies and meniscal repairs and found a similar decrease between 2013 and 2014 among isolated meniscectomies, with minimal change in isolated meniscal repairs. This may be attributed to coincident literature at that time supporting improved outcomes with meniscal repair, in addition to the advent of a new generation of industry devices.[13,25,27,32,33,36,41,50]

Despite the support of concurrent meniscal repair with ACLR, some researchers have attempted to identify meniscal tears that may not necessarily require repair. In a study of ACLRs by Duchman et al,[22] lateral and medial meniscal tears left in situ did not require reoperation at the 6-year follow-up in 95.7% and 82.4% of patients, respectively. However, various studies have shown that approximately 50% of concomitant meniscal tears are amenable to repair and may heal with an increased rate of healing (compared with an isolated meniscal tear) owing to the biological environment created by tunnel drilling during ACLR.[4,6,12,44] With regard to concurrently repairing meniscal ramp lesions, some studies have advocated for nonoperative healing potential given the vascularity and location in the red-red zone.[22,38] The development of all-inside techniques, with reduced surgical times and neurovascular risks[60] and equivalent meniscal failure rates,[45] have also made concomitant meniscal repair a more feasible orthopaedic procedure.[22,63] Despite literature suggesting that not all meniscal tears require repair,[22] there is an overall consensus on the value of meniscal preservation during ACLR.

Meniscal repair rates in younger patients as well as those with a lower BMI have been consistently higher across numerous studies.[3,4,16,61] Conversely, a study by Abram et al,[3] using the UK Hospital Episode Statistics between 1997 and 2017, found that the incidence of meniscal repair during ACLR increased by 2.4 times in the 30- to 39-year age group and 1.3 times in the 40- to 49-year age group. Using the NSQIP database, we observed findings in the United States that paralleled this trend toward meniscal preservation in the older patients undergoing ACLR. We also noted increases in the proportion of overweight and obese patients undergoing concomitant meniscal repair with ACLR, although we found that by 2018 there was only

TABLE 3
Demographics of Patients Undergoing ACLR With Concomitant Meniscal Surgery by Year[a]

	2010	2011	2012	2013	2014	2015	2016	2017	2018	*P* Value for Trend[b]
ACLR + MEC										
Sex										
Female	114 (34.8)	155 (33.1)	210 (31.2)	291 (34.8)	325 (34.5)	430 (33.3)	493 (32.7)	484 (30.7)	403 (30.8)	
Male	214 (65.2)	313 (66.9)	464 (68.8)	545 (65.2)	617 (65.5)	863 (66.7)	1015 (67.3)	1090 (69.3)	905 (69.2)	
Age group, y										.001
<25	89 (27.1)	121 (25.9)	165 (24.5)	232 (27.8)	247 (26.2)	335 (25.90	418 (27.7)	430 (27.3)	342 (26.1)	
25-34	68 (20.7)	116 (24.8)	194 (28.8)	269 (32.2)	278 (29.5)	388 (30.0)	473 (31.4)	503 (32.0)	419 (32.0)	
35-44	90 (27.4)	113 (24.1)	173 (25.7)	173 (20.7)	211 (22.4)	338 (26.1)	319 (21.2)	357 (22.7)	324 (24.8)	
45-54	63 (19.2)	81 (17.3)	108 (16.0)	132 (15.8)	145 (15.4)	186 (14.4)	225 (14.9)	208 (13.2)	162 (12.4)	
55-64	16 (4.9)	25 (5.3)	26 (3.9)	28 (3.3)	51 (5.4)	38 (2.9)	66 (4.4)	62 (3.9)	56 (4.3)	
≥65	2 (0.6)	12 (2.6)	8 (1.2)	2 (0.2)	10 (1.1)	8 (0.6)	7 (0.5)	14 (0.9)	5 (0.4)	
BMI group										<.001
<18.50	0 (0.0)	3 (0.6)	9 (1.3)	2 (0.2)	2 (0.2)	1 (0.1)	6 (0.4)	4 (0.3)	4 (0.3)	
18.50-24.99	101 (30.8)	132 (28.2)	191 (28.3)	224 (26.8)	262 (27.8)	318 (24.6)	389 (25.8)	373 (23.7)	324 (24.8)	
25.00-29.99	120 (36.6)	197 (42.1)	279 (41.4)	332 (39.7)	385 (40.9)	527 (40.8)	604 (40.1)	619 (39.3)	522 (39.9)	
30.00-34.99	64 (19.5)	83 (17.7)	120 (17.8)	147 (17.6)	158 (16.8)	268 (20.7)	303 (20.1)	342 (21.7)	276 (21.1)	
35.00-39.99	26 (7.9)	33 (7.1)	44 (6.5)	67 (8.0)	77 (8.2)	98 (7.6)	123 (8.2)	151 (9.6)	111 (8.5)	
≥40.00	16 (4.9)	17 (3.6)	23 (3.4)	48 (5.7)	48 (5.1)	69 (5.3)	70 (4.6)	75 (4.8)	55 (4.2)	
ACLR + MR										
Sex										
Female	25 (32.1)	41 (39.8)	53 (30.5)	89 (38.4)	98 (34.6)	130 (34.4)	171 (29.0)	250 (36.3)	229 (30.9)	
Male	53 (67.9)	62 (60.2)	121 (69.5)	143 (61.6)	185 (65.4)	248 (65.6)	418 (71.0)	438 (63.7)	513 (69.1)	
Age group, y										.027
<25	32 (41.0)	42 (40.8)	52 (29.9)	105 (45.3)	102 (36.0)	139 (36.8)	256 (43.5)	304 (44.2)	300 (40.4)	
25-34	30 (38.5)	32 (31.1)	69 (39.7)	68 (29.3)	105 (37.1)	135 (35.7)	199 (33.8)	229 (33.3)	266 (35.8)	
35-44	11 (14.1)	21 (20.4)	30 (17.2)	37 (15.9)	48 (17.0)	75 (19.8)	86 (14.6)	99 (14.4)	130 (17.5)	
45-54	2 (2.6)	7 (6.8)	14 (8.0)	18 (7.8)	23 (8.1)	21 (5.6)	39 (6.6)	45 (6.5)	41 (5.5)	
55-64	3 (3.8)	1 (1.0)	8 (4.6)	2 (0.9)	5 (1.8)	7 (1.9)	9 (1.5)	8 (1.2)	5 (0.7)	
≥65	0 (0.0)	0 (0.0)	1 (0.6)	2 (0.9)	0 (0.0)	1 (0.3)	0 (0.0)	3 (0.4)	0 (0.0)	
BMI group										<.001
<18.50	0 (0.0)	0 (0.0)	0 (0.0)	2 (0.9)	2 (0.7)	1 (0.3)	2 (0.3)	2 (0.3)	2 (0.3)	
18.50-24.99	34 (43.6)	47 (45.6)	64 (36.8)	76 (32.8)	88 (31.1)	121 (32.0)	172 (29.2)	218 (31.7)	192 (25.9)	
25.00-29.99	23 (29.5)	36 (35.0)	64 (36.8)	96 (41.4)	116 (41.0)	153 (40.5)	271 (46.0)	284 (41.3)	317 (42.7)	
30.00-34.99	13 (16.7)	10 (9.7)	27 (15.5)	32 (13.8)	46 (16.3)	64 (16.9)	94 (16.0)	123 (17.9)	142 (19.1)	
35.00-39.99	4 (5.1)	5 (4.9)	9 (5.2)	9 (3.9)	18 (6.4)	19 (5.0)	29 (4.9)	34 (4.9)	46 (6.2)	
≥40.00	2 (2.6)	1 (1.0)	6 (3.4)	9 (3.9)	8 (2.8)	16 (4.2)	18 (3.1)	22 (3.2)	36 (4.9)	

[a]Data are reported as n (%). ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; MEC, meniscectomy; MR, meniscal repair.
[b]Jonckheere-Terpstra test trend with increasing years since 2010.

a minimal difference in average BMI between patients who had a meniscal repair and patients who had a partial meniscectomy.

According to the National Center for Health Statistics, between 1999 and 2018 the age-adjusted prevalence of obesity increased from 30.5% to 42.4%, and the prevalence of severe obesity increased from 4.7% to 9.2%.[28] In light of rising obesity trends, Sommerfeldt et al[57] studied the relationship between BMI and meniscal repair failure, concluding that although higher BMI increased the likelihood of a degenerative meniscal lesion,[21,26,34] patients with a higher BMI (up to 35) did not have a higher risk of repair failure. With regard to the expanding appreciation of meniscal extrusion (ie, root tears), authors have found medial meniscal extrusion to increase with advancing age[8] and higher BMI,[2] which gives further attribution to the increase in meniscal repair rates in such populations. The escalating obesity crisis parallels our observed increasing trends in meniscal preservation among patients with higher BMI, which raises questions regarding their hypothetical correlation. More importantly, the well-recognized obesity epidemic highlights the importance of future research as it pertains to meniscal preservation during ACLR.

Across the study period, there was an almost 6-fold increase in the number of ACLR cases (regardless of meniscal procedure), which resembles the increase in database participation among NSQIP hospitals. In 2004, there were 18 hospitals participating in the database,[29] whereas there are currently more than 700 hospitals.[1] The cumulative data now available in NSQIP are immense, with more than 5.5 million cases indexed in the total ACS NSQIP archive.[29] With regard to the increase in ACLR procedures, reports

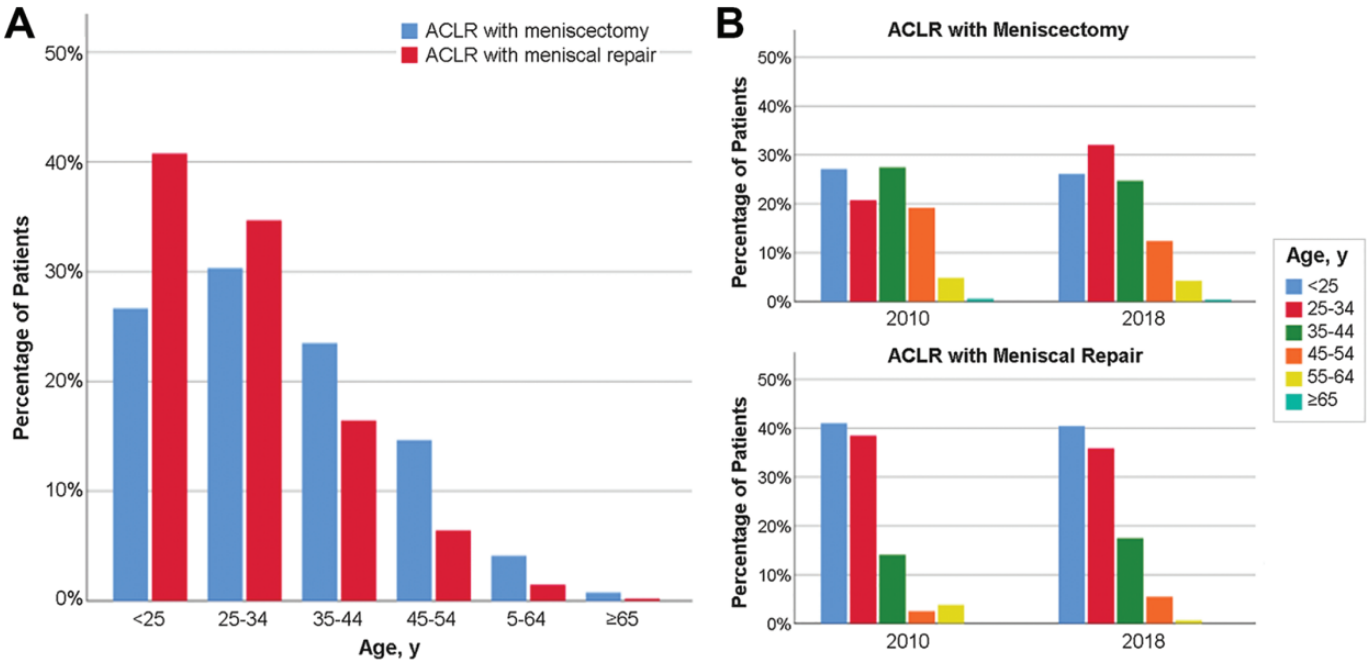

Figure 3. Percentage of patients who underwent ACLR with concomitant meniscal surgery according to age group (A) overall and (B) in 2010 and 2018. ACLR, anterior cruciate ligament reconstruction.

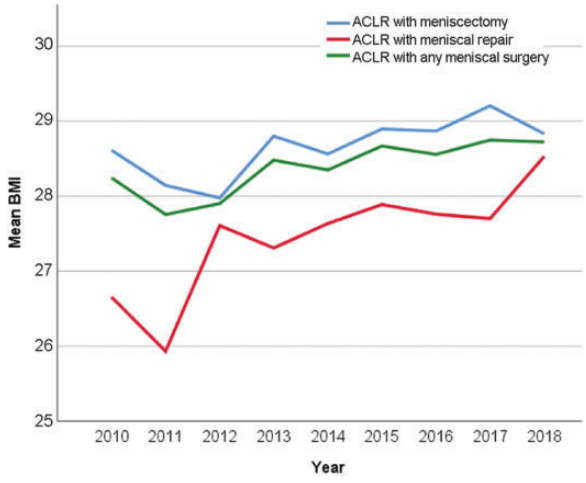

Figure 4. Mean patient body mass index by year for patients undergoing ACLR with concomitant meniscal surgery. ACLR, anterior cruciate ligament reconstruction; BMI, body mass index.

from large database registries have demonstrated similar trends between the early 1990s and the present.[15,39,42,53] However, it remains unclear whether the increase in surgical management of ACL tears is reflective of changes in injury patterns or simply changes in population incidence or operative indications over time.[53] In a study with a time frame similar to ours, the overall rate of ACLR increased by 22%, from 61.4 per 100,000 person-years in 2002 to 74.6 per 100,000 person-years in 2014.[31] Similarly, in the study by Abram et al,[3] the rate of ACLR in the United Kingdom increased 12-fold between 1997 and 2017. We believe that the dramatic increase in observed ACLR cases throughout our study is likely owed to the emerging participation of hospitals in the NSQIP. As the NSQIP participation stabilizes, future commensurate studies may help better define ACLR rates. Regardless, our intent to compare meniscal procedure trends within ACLRs was largely unaffected by this overlying trend.

Although our study benefited from a large number of surgical cases, certain limitations need to be considered. There are limitations inherent to the NSQIP database. CPT codes are used to identify patients in the NSQIP database, and when potential miscoding is considered, incomplete patient capture is a risk. In addition, the misclassification of data is a concern when using database information. However, interrater reliability disagreement within ACS NSQIP has previously been shown to be less than 1.8%.[1] Because the database is reported by individual hospitals, the case numbers may reflect the trends of the participating institutions rather than being a true representation of a larger population. However, with the increasing number of institutions submitting data, the trends become more generalizable. Additionally, the NSQIP database does not include independent ambulatory centers. Therefore, true ambulatory cases captured in the database are only reflective of "outpatient" cases performed at centers directly with NSQIP participating hospitals.[1] It is also important to note that the NSQIP database is limited to surgical outcomes for 30 days postoperatively. We focused on the proportions of total cases and on yearly changes, which allowed us to report variations in concomitant procedure type rather than on the absolute number of cases. Last, the study design inherently restricted the ability to clarify factors,

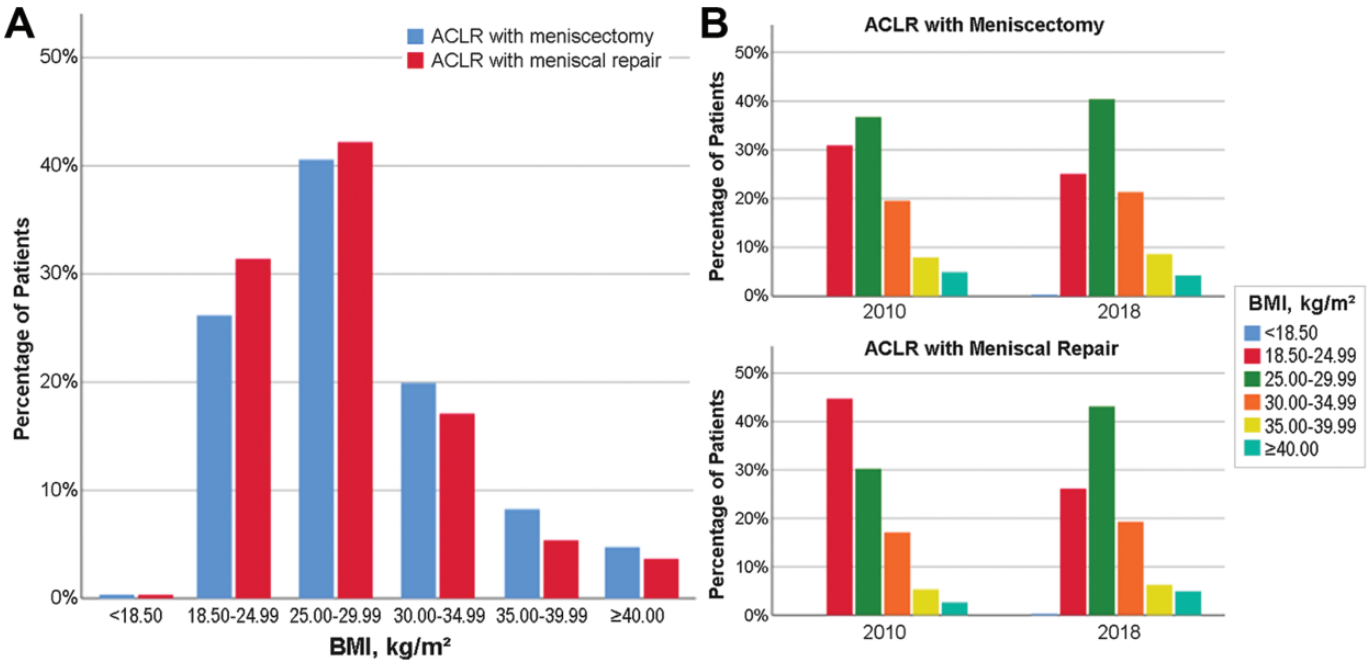

Figure 5. Percentage of patients who underwent ACLR with concomitant meniscal surgery according to BMI grouping (A) overall and (B) in 2010 and 2018. ACLR, anterior cruciate ligament reconstruction; BMI, body mass index.

such as tear characteristics (size, location, type, root involvement), failing to highlight their contribution to reparability as well as evaluation of postoperative outcomes. However, the intent of our investigation was to examine trends in recent practice with regard to available demographic data rather than to contribute strongly to current practice guidelines.

Our findings reflect trends in concomitant meniscal work between 2010 and 2018 that were influenced by evidence-based practice guidelines developed in part from literature published before and during that time frame. Similar database analyses in the future will likely be reflective of the contemporary literature on outcomes of meniscectomy versus meniscal repair during ACLR. A 2019 systematic review and meta-analysis of 25 studies compared meniscectomy and meniscal repair during ACLR using the Knee injury and Osteoarthritis Outcome Score at 2 years postoperatively.[54] The authors concluded that ACLR combined with meniscal resection rather than meniscal repair demonstrated better symptoms at 2 years. Conversely, their subanalysis of 8 studies including the long-term follow-up of $\geq$4 years favored meniscal repair, which demonstrated superior International Knee Documentation Committee scores. Additionally, medial meniscal resection showed significantly increased anterior tibial translation compared with medial meniscal repair.[54] Recent prospective studies have also suggested that lack of meniscus (medial or lateral) is associated with altered knee kinematics and subsequent ACLR failure.[7,51]

While most literature has favored meniscal preservation, one must not mitigate the potential risk of meniscal repair failure. A systematic review of outcome studies regarding meniscal repair in adults found a more than 5-year follow-up pooled risk failure of 20% to 24%,[45] with similar failure rates in a study with patients aged over 40 years.[23] In the latter study, repairs with concomitant ACLR had 10% fewer failures compared with meniscal repairs in patients with intact ACLs.[23] Last, given the chondroprotective effect of meniscal presence, repair attempts can be taken more aggressively in less favorable tear patterns in the younger population, as older patients have more feasible options in the face of arthritic sequelae (ie, total knee arthroplasty, high tibial osteotomy, unicondylar arthroplasty). We anticipate that future epidemiological studies examining these trends will be largely reflective of contemporary and future clinical research. As researchers further demonstrate the long-term clinical benefit of meniscal preservation during ACLR, continued trends toward increased meniscal repair rates will likely be reflected in future studies.

CONCLUSION

The current study showed that between 2010 and 2018, there was an upward trend in meniscal repairs performed during ACLR. Although ACLR with concurrent meniscal repair was still most commonly performed in patients younger than 25 years, the priority of meniscal preservation was highlighted by the increasing proportion of older patients and those with higher BMI who underwent the procedure. Technical improvements, evolving simplicity of use, and favorable outcomes will continue to make meniscal repair an attractive option for orthopaedic surgeons managing meniscal tears during ACLR.

REFERENCES

1. ACS NSQIP Participant Use Data File. Accessed January 15, 2020. https://www.facs.org/quality-programs/acs-nsqip/participant-use
2. Achtnich A, Petersen W, Willinger L, et al. Medial meniscus extrusion increases with age and BMI and is depending on different loading conditions. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(8):2282-2288.
3. Abram SGF, Price AJ, Judge A, Beard DJ. Anterior cruciate ligament (ACL) reconstruction and meniscal repair rates have both increased in the past 20 years in England: hospital statistics from 1997 to 2017. *Br J Sports Med*. 2020;54(5):286-291.
4. Abrams GD, Frank RM, Gupta AK, Harris JD, McCormick FM, Cole BJ. Trends in meniscus repair and meniscectomy in the United States, 2005-2011. *Am J Sports Med*. 2013;41(10):2333-2339.
5. Ahn JH, Bae TS, Kang KS, Kang SY, Lee SH. Longitudinal tear of the medial meniscus posterior horn in the anterior cruciate ligament-deficient knee significantly influences anterior stability. *Am J Sports Med*. 2011;39(10):2187-2193.
6. Ahn JH, Yoo JC, Yang HS, Kim JH, Wang JH. Second-look arthroscopic findings of 208 patients after ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(3):242-248.
7. Akpinar B, Thorhauer E, Irrgang JJ, Tashman S, Fu FH, Anderst WJ. Alteration of knee kinematics after anatomic anterior cruciate ligament reconstruction is dependent on associated meniscal injury. *Am J Sports Med*. 2018;46:1158-1165.
8. Balazs GC, Greditzer HG IV, Wang D, et al. Ramp lesions of the medial meniscus in patients undergoing primary and revision ACL reconstruction: prevalence and risk factors. *Orthop J Sports Med*. 2019;7(5):2325967119843509.
9. Barrett GR, Field MH, Treacy SH, Ruff CG. Clinical results of meniscus repair in patients 40 years and older. *Arthroscopy*. 1998;14(8):824-829.
10. Bogunovic L, Kruse LM, Haas AK, Huston LJ, Wright RW. Outcome of all-inside second-generation meniscal repair: minimum five-year follow-up. *J Bone Joint Surg Am*. 2014;96(15):1303-1307.
11. Bollen SR. Posteromedial meniscocapsular injury associated with rupture of the anterior cruciate ligament: a previously unrecognised association. *J Bone Joint Surg Br*. 2010;92(2):222-223.
12. Cannon WD, Vittori JM. The incidence of healing in arthroscopic meniscal repairs in anterior cruciate ligament-reconstructed knees versus stable knees. *Am J Sports Med*. 1992;20(2):176-181.
13. Choi NH, Kim TH, Victoroff BN. Comparison of arthroscopic medial meniscal suture repair techniques: inside-out versus all-inside repair. *Am J Sports Med*. 2009;37(11):2144-2150.
14. Cohen M, Amaro JT, Ejnisman B, et al. Anterior cruciate ligament reconstruction after 10 to 15 years: association between meniscectomy and osteoarthrosis. *Arthroscopy*. 2007;23(6):629-634.
15. Csintalan R, Inacio M, Funahashi T. Incidence rate of anterior cruciate ligament reconstructions. *Perm J*. 2008;12(3):17-21.
16. DeFroda SF, Yang DS, Donnelly JC, Bokshan SL, Owens BD, Daniels AH. Trends in the surgical treatment of meniscal tears in patients with and without concurrent anterior cruciate ligament tears. *Phys Sportsmed*. 2019;1:1-7.
17. DePhillipo NN, Cinque ME, Chahla J, Geeslin AG, Engebretsen L, LaPrade RF. Incidence and detection of meniscal ramp lesions on magnetic resonance imaging in patients with anterior cruciate ligament reconstruction. *Am J Sports Med*. 2017;45(10):2233-2237.
18. DePhillipo NN, Cinque ME, Kennedy NI, et al. Inside-out repair of meniscal ramp lesions. *Arthrosc Tech*. 2017;6(4):e1315-e1320.
19. DePhillipo NN, Moatshe G, Brady A, et al. Effect of meniscocapsular and meniscotibial lesions in ACL-deficient and ACL-reconstructed knees: a biomechanical study. *Am J Sports Med*. 2018;46(10):2422-2431.
20. Diamantopoulos A, Tokis A, Tzurbakis M, Patsopoulos I, Georgoulis A. The posterolateral corner of the knee: evaluation under microsurgical dissection. *Arthroscopy*. 2005;21(7):826-833.
21. Ding C, Martel-Pelletier J, Pelletier JP, et al. Meniscal tear as an osteoarthritis risk factor in a largely non-osteoarthritic cohort: a cross-sectional study. *J Rheumatol*. 2007;34(4):776-784.
22. Duchman KR, Westermann RW, Spindler KP, et al. The fate of meniscus tears left in situ at the time of anterior cruciate ligament reconstruction: a 6-year follow-up study from the MOON Cohort. *Am J Sports Med*. 2015;43(11):2688-2695.
23. Everhart JS, Higgins JD, Poland SG, Abouljoud MM, Flanigan DC. Meniscal repair in patients age 40 years and older: a systematic review of 11 studies and 148 patients. *Knee*. 2018;25(6):1142-1150.
24. Fetzer GB, Spindler KP, Amendola A, et al. Potential market for new meniscus repair strategies: evaluation of the MOON cohort. *J Knee Surg*. 2009;22(3):180-186.
25. Fillingham YA, Riboh JC, Erickson BJ, Bach BR, Yanke AB. Inside-out versus all-inside repair of isolated meniscal tears: an updated systematic review. *Am J Sports Med*. 2017;45(1):234-242.
26. Ford GM, Hegmann KT, White GL, Holmes EB. Associations of body mass index with meniscal tears. *Am J Prev Med*. 2005;28(4):364-368.
27. Haas AL, Schepsis AA, Hornstein J, Edgar CM. Meniscal repair using the FasT-Fix all-inside meniscal repair device. *Arthroscopy*. 2005;21(2):167-175.
28. Hales CM, Fryar CD, Carroll MD, Freedman DS, Ogden CL. Prevalence of obesity and severe obesity among adults: United States, 2017-2018. *NCHS Data Brief*. 2020;360:1-8.
29. Hall BL, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program: an evaluation of all participating hospitals. *Ann Surg*. 2009;250(3):363-376.
30. Hertel P, Behrend H, Cierpinski T, Musahl V, Widjaja G. ACL reconstruction using bone-patellar tendon-bone press-fit fixation: 10-year clinical results. *Knee Surg Sports Traumatol Arthrosc*. 2005;13(4):248-255.
31. Herzog MM, Marshall SW, Lund JL, Pate V, Mack CD, Spang JT. Trends in incidence of ACL reconstruction and concomitant procedures among commercially insured individuals in the United States, 2002-2014. *Sports Health*. 2018;10(6):523-531.
32. Konan S, Haddad FS. Outcomes of meniscal preservation using all-inside meniscus repair devices. *Clin Orthop Relat Res*. 2010;468(5):1209-1213.
33. Kopf S, Beaufils P, Hirschmann MT, et al. Management of traumatic meniscus tears: the 2019 ESSKA meniscus consensus. *Knee Surg Sports Traumatol Arthrosc*. 2020;28(4):1177-1194.
34. Laberge MA, Baum T, Virayavanich W, et al. Obesity increases the prevalence and severity of focal knee abnormalities diagnosed using 3T MRI in middle-aged subjects-data from the Osteoarthritis Initiative. *Skeletal Radiol*. 2012;41(6):633-641.
35. Laible C, Stein DA, Kiridly DN. Meniscal repair. *J Am Acad Orthop Surg*. 2013;21(4):204-213.
36. LaPrade CM, Dornan GJ, Granan LP, LaPrade RF, Engebretsen L. Outcomes after anterior cruciate ligament reconstruction using the Norwegian Knee Ligament Registry of 4691 patients: how does meniscal repair or resection affect short-term outcomes? *Am J Sports Med*. 2015;43(7):1591-1597.
37. Levy AS, Meier SW. Approach to cartilage injury in the anterior cruciate ligament-deficient knee. *Orthop Clin North Am*. 2003;34(1):149-167.
38. Liu X, Zhang H, Feng H, Hong L, Wang XS, Song GY. Is it necessary to repair stable ramp lesions of the medial meniscus during anterior cruciate ligament reconstruction? A prospective randomized controlled trial. *Am J Sports Med*. 2017;45(5):1004-1011.
39. Lyman S, Koulouvaris P, Sherman S, Do H, Mandl L, Marx R. Epidemiology of anterior cruciate ligament reconstruction trends, readmissions, and subsequent knee surgery. *J Bone Joint Surg Am*. 2009;91:2321-2328.
40. Lynch TS, Parker RD, Patel RM, Andrish JT, Spindler KP. The impact of the Multicenter Orthopaedic Outcomes Network (MOON) research on anterior cruciate ligament reconstruction and orthopaedic practice. *J Am Acad Orthop Surg*. 2015;23(3):154-163.

41. Majeed H, Karuppiah S, Sigamoney KV, Guetjens G, Straw RG. All-inside meniscal repair surgery: factors affecting the outcome. *J Orthop Traumatol*. 2015;16(3):245-249.
42. Mall N, Chalmers P, Moric M. Incidence and trends of anterior cruciate ligament reconstruction in the United States. *Am J Sports Med*. 2014;42(10):2363-2370.
43. McGinty JB. The importance of the meniscus. *Am J Knee Surg*. 1996; 9(3):109.
44. Melton JTK, Murray JR, Karim A, Pandit H, Wandless F, Thomas NP. Meniscal repair in anterior cruciate ligament reconstruction: a long-term outcome study. *Knee Surg Sports Traumatol Arthrosc*. 2011; 19(10):1729-1734.
45. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years. *J Bone Joint Surg Am*. 2012;94(24): 2222-2227.
46. Northmore-Ball MD, Dandy DJ, Jackson RW. Arthroscopic, open partial, and total meniscectomy: a comparative study. *J Bone Joint Surg Br*. 1983;65(4):400-404.
47. Noyes FR, Barber-Westin SD. Treatment of meniscus tears during anterior cruciate ligament reconstruction. *Arthroscopy*. 2012;28(1): 123-130.
48. Parker B, Hurwitz SR, Spang JT, Creighton RA, Kamath GV. Surgical trends in treatment of meniscus tears: analysis of data from the American Board of Orthopaedic Surgery certification examination database. *Am J Sports Med*. 2015;44(7):1717-1723.
49. Peltier A, Lording T, Maubisson I, Ballis R, Neyret P, Lustig S. The role of the meniscotibial ligament in posteromedial rotational knee stability. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(10):2967-2973.
50. Pujol N, Tardy N, Boisrenoult P, Beaufils P. Long-term outcomes of all-inside meniscal repair. *Knee Surg Sports Traumatol Arthrosc*. 2013;23(1):219-224.
51. Robb C, Kempshall P, Getgood A, et al. Meniscal integrity predicts laxity of anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(12):3683-3690.
52. Salmon LJ, Russell VJ, Refshauge K, et al. Long-term outcome of endoscopic anterior cruciate ligament reconstruction with patellar tendon autograft: minimum 13-year review. *Am J Sports Med*. 2006; 34(5):721-732.
53. Sanders TL, Maradit Kremers H, Bryan AJ, et al. Incidence of anterior cruciate ligament tears and reconstruction: a 21-year population-based study. *Am J Sports Med*. 2016;44(6):1502-1507.
54. Sarraj M, Coughlin RP, Solow M, et al. Anterior cruciate ligament reconstruction with concomitant meniscal surgery: a systematic review and meta-analysis of outcomes. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(11):3441-3452.
55. Simpson DS, Bellenger CR, Ghosh P, Numata Y, Little C. The effect of total meniscectomy versus caudal pole hemimeniscectomy on the stifle joint of the sheep. *Vet Comp Orthop Traumatol*. 1999;12(1): 56-63.
56. Sofu H, Yildirim T, Gürsu S, Issin A, Şahin V. Short-term effects of partial meniscectomy on the clinical results of anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2014; 23(1):184-187.
57. Sommerfeldt MF, Magnussen RA, Randall KL, et al. The relationship between body mass index and risk of failure following meniscus repair. *J Knee Surg*. 2016;29(8):645-648.
58. Sonnery-Cottet B, Conteduca J, Thaunat M, Gunepin FX, Seil R. Hidden lesions of the posterior horn of the medial meniscus: a systematic arthroscopic exploration of the concealed portion of the knee. *Am J Sports Med*. 2014;42(4):921-926.
59. Stein T, Mehling AP, Welsch F, Von Eisenhart-Rothe R, Jäger A. Long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. *Am J Sports Med*. 2010;38(8):1542-1548.
60. Stephen JM, Halewood C, Kittl C, Bollen SR, Williams A, Amis AA. Posteromedial meniscocapsular lesions increase tibiofemoral joint laxity with anterior cruciate ligament deficiency, and their repair reduces laxity. *Am J Sports Med*. 2016;44(2):400-408.
61. Suchman KI, Behery OA, Mai DH, Anil U, Bosco JA. The demographic and geographic trends of meniscal procedures in New York State: an analysis of 649,470 patients over 13 years. *J Bone Joint Surg Am*. 2018;100(18):1581-1588.
62. Tuman J, Haro MS, Foley S, Diduch D. All-inside meniscal repair devices and techniques. *Expert Rev Med Devices*. 2012;1(5):438-444.
63. Turman KA, Diduch DR, Miller MD. All-inside meniscal repair. *Sports Health*. 2009;1(5):438-444.