Knee Surgery, Sports Traumatology, Arthroscopy
https://doi.org/10.1007/s00167-020-06254-4

KNEE

Arthroscopic anterior cruciate ligament reconstruction is a reliable option to treat knee instability in patients over 50 years old

Jordan Ovigue[1] · Nicolas Bouguennec[1] · Nicolas Graveleau[1]

Received: 24 June 2019 / Accepted: 21 August 2020

Abstract

Purpose To evaluate return to sport and clinical outcomes with at least 2 years followup after arthroscopic reconstruction ACL in population over 50 years-old. Methods: eighty-one patients aged 50 years or older underwent isolated, primary ACL reconstruction with hamstring autograft between 2014 and 2016. In all patients, a period of conservative treatment had failed (minimum 6 months), and they complained of functional instability and/or limitation during daily activity. Patients were assessed preoperatively and at the latest follow-up with a physical examination, return to sports activity, the Lysholm score, the International Knee Documentation Committee scoring system, the Knee injury and Osteoarthritis Outcome Score, and the Tegner activity scale. Data regarding complications and revision surgeries were collected at 2-year follow-up.

Results At the last follow-up, significant improvement in outcome scores from pre- to postoperative assessments was found. The mean overall IKDC score increased from a preoperative mean of 54.4–82.9 ($p < 0.001$). Mean preoperative Lysholm score increased from a preoperative mean of 67.4–90.4 ($p < 0.001$). The mean overall KOOS score increased from a preoperative mean ($p < 0.001$). Median preoperative Tegner score was 5 (range 2–8) and median postoperative score was 5 (range 1–7). 86% of patients returned to the sport, 51% to their preinjury sports level. Tegner score, before accident, was the only positive influencing factor a return to pre-injury level of the sport.

Conclusion Arthroscopic reconstruction ACL in patients over 50 years-old resulted in excellent functional outcomes, with most patients returning to sport and at the same level they had before the injury.

Level of evidence Level IV.

Keywords Anterior cruciate ligament · 50 years · Return to sport · ACL reconstruction

Introduction

The incidence of Anterior Cruciate Ligament (ACL) injuries is increasing in the general population due to the evolution of sports practices and to the fact that people continue to practice sports as they grow older. People aged 50 years and older represented approximately 36% of the French population in 2018. For patients over 50, maintaining a healthy musculoskeletal system is essential for staying independent in daily activities. Physical activity also prevents two significant diseases associated with aging: sarcopenia and osteoporosis [19, 28, 29, 50]. An optimal management strategy for patients over 50 years of age with ACL injury is still far from clear. Two opposing treatments are available: conservative management or surgical reconstruction of the ACL. In this particular population, conservative treatment is the rule [7, 18]. A failure rate of non-operative rehabilitation programs nevertheless exists, with joint instability that leads to decreasing sports activity, unsatisfactory knee function, and an increased risk of associated meniscal lesions [16, 27]. As far as the authors are aware, there are only a few published studies that determined results and return to sport after ACL reconstruction in a population over 50 years of age, and the rate of return to sport for this specific population remains unknown [41]. The purpose of this study was, therefore, to evaluate return to sport and clinical outcomes with at least 2 years follow-up after arthroscopic ACL reconstruction in patients over 50 years of age. The hypothesis of the study was that a higher sports level before ACL injury would be associated with a return to the pre-injury level of sport after primary reconstruction.

✉ Jordan Ovigue
Jordan06021990@hotmail.fr

[1] Sports Clinic of Bordeaux-Merignac, 33700 Mérignac, France

Published online: 04 September 2020

Materials and methods

This study was a single-center, retrospective review of consecutive primary ACL reconstruction performed between 2014 and 2016. The Ethics and Research Committee of Clinique du Sport, Bordeaux–Merignac, France, approved the study, and consent was obtained from all patients for the research. The population included 81 knees in 81 patients that underwent anatomic ACL reconstruction using an autogenous hamstring graft. For all patients, a period of conservative treatment with rehabilitation had failed (minimum of 6 months). Rehabilitation was considered a failure when patients remained symptomatic, and complained of mechanical instability and/or limitation during daily activity. Inclusion criteria were patients older than 50 at the time of surgery and having their first ACL reconstruction procedure, with a minimum of 2 years of follow-up. Patients were excluded if they had bilateral ACL injuries, revision ACL reconstruction, multi-ligament injuries, or osteoarthritis more than Ahlback grade I.

Surgical procedure

All patients underwent a single-bundle ACL reconstruction by five senior surgeons. Reconstruction was performed with the patient under general anesthesia. An air tourniquet was applied at the proximal part of the limb with a pressure of 300 mm Hg, to obtain an arthroscopic image of acceptable quality during the procedure. Two surgical techniques were performed: using a four-strand semitendinosus and gracilis tendon graft (4STG) or a four-strand semitendinosus graft (4ST). The hamstrings (semitendinosus and gracilis) were harvested through one short incision medial to the tibial tuberosity.

The graft was prepared with the help of a graft preparation table. The short graft was prepared with two adjustable suspensory fixation devices (PULLUP®, SBM, Lourdes). The standard graft was prepared with an adjustable suspensory fixation device (PULLUP®, SBM, Lourdes) on the femoral side and a biodegradable interference screw (LIGAFIX®, SBM, Lourdes) on the tibial side. The ACL reconstruction aimed at reconstructing anteromedial (AM) fibers [35, 39]. Graft sizes spanned from 7.5 to 9.0 mm. The aimer of the tibial director drill guide was introduced through the AM portal and the tip of the guide placed at the center of the ACL tibial footprint. A full tibial tunnel was drilled from outside-in. The femoral ACL reconstruction tunnel was drilled through the anteromedial portal in all patients, using the capsular line reference as a reliable and reproducible arthroscopic landmark to position the tunnel [9, 32]. A complete bone tunnel was drilled using a 4.5-mm drill. Next, a socket was drilled using a drill bit of the same size as the graft. The recommended socket length of 20-mm was drilled. The graft was then introduced from the tibia to the femur. The knee was flexed at 20 degrees, and the suspensory fixation device on the femur was tensioned. It was fixed on the tibial side with a bioabsorbable interference screw (LIGAFIX®, SBM, Lourdes) that was 1 mm larger in diameter than the tunnel for the standard graft, or with an adjustable suspensory fixation device (PULLUP®, SBM, Lourdes) for the short graft.

Evaluation

Clinical examination was performed in all patients after 6 months and 1 year of follow-up. All patients were interviewed at a minimum of 2 years after surgery by an independent fellowship-trained examiner (J.O.). For these last follow-up visits, participants were initially contacted via their mobile phone for clinical evaluation at the clinic. People who did not respond were contacted by email that directed them to the website of our facility and a link to the electronic version of the survey. Patient demographics were recorded including age, gender, BMI, sporting activity, presence and nature of associated injuries. Patients were assessed pre- and post-operatively with the subjective International Knee Documentation Committee (IKDC) evaluation form, Tegner activity scale, Lysholm score and Knee injury and Osteoarthritis Outcome Score (KOOS) [40]. The activity levels were determined to evaluate the return to pre-injury level of sport performance. All participants were asked about their sports activities at the time of completing the survey, and whether they practiced a pivoting sport. If subjects reported that their current activity level was worse than their pre-injury activity level, then those patients were asked whether their change in activity level was due to knee injury, a change in lifestyle, or a combination of both. Data on knee damage, including the presence of a meniscal tear, an irreparable meniscal tear requiring meniscectomy or meniscus suture repair, and chondral damage (according to the International Cartilage Repair Society [ICRS] criteria), were extracted from the operative report to research predictive factors for return to sport.

Surgical management of meniscus lesions

In terms of traumatic tears, the first-line choice is non-removal or repair with an all-inside technique, especially for longitudinal vertical tears in the red-white or red-red zones, with a rim smaller than 4 mm and a lesion longer than 10 mm on MRI [30, 51]. Arthroscopic partial meniscectomy is proposed for traumatic tears if there is a heterogeneous signal of the meniscus fragment on MRI, localization in white–white zones, or complex tearing, indicative of an

arthroscopically irreparable meniscus [26, 30]. Degenerative meniscus lesion (DML) is different. DMLs develop slowly and typically involve a horizontal cleavage. MRI of these lesions identified a linear intra-meniscal signal, often communicating with the articular surface, which indicated ongoing mucoid degenerative changes. Non-operative treatment was the first-line choice, and arthroscopic partial meniscectomy was performed during ACL reconstruction in case of failure after a minimum of 3 months of conservative treatment [2].

Rehabilitation protocol

The rehabilitation protocol was the same for all patients. Partial weight-bearing was allowed after surgery using two crutches and a removable brace with progression to full weight-bearing at 2 weeks. Muscle-strengthening exercises were started with isometric quadriceps contraction. The range of motion was limited to 120 degrees for 6 weeks. Jogging and gradually increasing the activity level was permitted after 3 months. At 6 months, isokinetic and functional tests were used to evaluate the dynamic stability of the knee joint and the quality of the rehabilitation outcome. This examination included range of motion, the Lachman test, and side-to-side laxity testing with a GNRB® arthrometer. Return to sports activity was allowed once sufficient recovery of muscle strength, proprioception, and flexibility were achieved.

Statistical analysis

Statistical analysis was performed with the free online application EasyMedStat (www.easymedstat.com, Neuilly-Sur-Seine, France). For all tests, the level of significance was taken as $p < 0.05$. Quantitative (measurable) variables are presented as both the number of observations (n) and the percentage (%). Since most of the variables had a non-normal distribution, non-parametric tests were used. The Wilcoxon test for consecutive pairs was used to compare two dependent samples that were pre- and postoperative scores. A second statistical analysis was carried out between the "return to the same sport level" and "no return to the same sport level" groups: the Mann–Whitney U test was used for these two independent samples. The distribution by sex, by IRCS stage, and by meniscectomy incidence were compared using the Chi 2 test between these two groups.

Results

Eighty-one patients who met the inclusion criteria were identified. Of these 81 patients, 75 (93%) had a complete follow-up at a minimum of 2 years following surgery. Six (7%) patients were lost to follow-up despite attempts to contact them by telephone and email. Thirty-four (67.5%) were women, and 41 (45.3%) were men. The mean age was 53.9 years (range 50–65). Mean follow-up was 28 months (range 24–34 months) (Table 1). The primary mechanism of injury was skiing (39 knees), followed by non-contact sports ($n = 11$), falls ($n = 10$), work accident ($n = 6$), motor vehicle accident ($n = 5$) and contact sports ($n = 4$). Thirteen percent of patients did not practice any sports activity before ACL rupture. There were 43 patients with meniscus tears, 23 had traumatic tears and 20 had degenerative meniscal lesions. Of these 23 patients with traumatic tears, 10 were treated by suture repair, and 9 underwent partial meniscectomies. In four stable asymptomatic lesions, the choice was non-removal. For degenerative injuries, 17 partial meniscectomies were performed.

At the last follow-up, the mean overall IKDC score increased from a preoperative mean of 54.4 ± 21.9 (median 54, range 9–92) to 82.9 ± 13.1 (median 86, range 56–100), showing a statistically significant difference ($p < 0.001$). Mean preoperative Lysholm score was 67.4 ± 22.2 (median 72, range 16–99) and mean postoperative Lysholm score was 90.4 ± 12.1 (median 93, range 56–100) ($p < 0.001$). The mean overall KOOS score increased from a preoperative mean, showing a statistically significant difference ($p < 0.001$) (Fig. 1). The median preoperative Tegner score was 5 (2–8) and the median postoperative score was 5 (1–7) (Table 2).

Table 3 shows the IKDC, Tegner, and Lysholm scores after the final follow-up per up of meniscal tear. There was not a statistically significant difference between mean scores

Table 1 Demographic Data ($n = 75$ Patients)[a]

Sex (number)	
Male	41
Female	34
Age (years)	53.9 (50–65)
Follow-up (months)	28.3 (24–38)
Graft (number)	
4ST (short graft)[b]	58
4STG (standard graft)[c]	17
Type of sport (%)	
Pivoting, noncontact[d]	64
Nonpivoting[e]	36
Time between accident and surgery (months)	13.3 (5–77)

[a]Data are reported as mean

[b]Four-strand Semitendinosus Grafts (4ST)

[c]Four-strand semitendinosus and gracilis tendon grafts (4STG)

[d]Pivoting, noncontact sports: volleyball, skiing, tennis, and badminton

[e]Nonpivoting sports: cycling, running, swimming

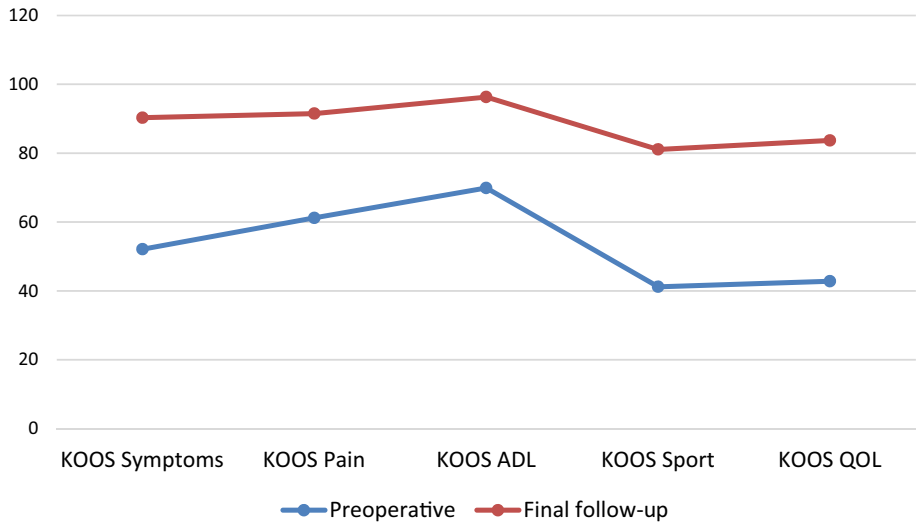

Fig. 1 Median KOOS item scores according to preoperative and postoperative. ($p < 0.001$ for all items)

Table 2 Comparison between pre-injury or preoperative and postoperative clinical outcomes

	Pre-injury	Final follow-up	*p* value
Tegner score[a]	5 (2–8)	5 (1–7)	
	Preoperative	Final follow-up	
Subjective IKDC score	54.4 ± 21.9	82.9 ± 13.1	< 0.001
Lysholm score	67.4 ± 22.2	90.4 ± 12.1	< 0.001

Data are reported as mean ± SD

IKDC International Knee Documentation Committee

[a]Data are reported as median + range

for meniscal repair, meniscectomy and those patients with normal menisci undergoing ACL reconstruction (n.s.).

The most frequent postoperative complications in the first week were hematomas (2%), which were successfully treated with conservative measures. At the latest follow-up, the graft failure rate was 8%, and 7% of patients had second surgery. One patient was operated for a cyclops syndrome, and four patients underwent secondary partial meniscectomy after ACL reconstruction. Among failures, resection of the meniscal segments primarily repaired occurred for two medial tears: in one patient with a symptomatic degenerative lesion, and in one patient because of insufficient resection of the initial lesion.

At the final follow-up, 86% of patients had returned to sport, 51% to their preinjury sports level, 20% at a lower level, and 15% changed sports. No difference in time to return to sport was found between the different groups of meniscal tears (n.s.) (Table 3). Among the sports studied, there was a higher rate of return to the same level in the skiing group (54.5%) versus non skiing group (45.3%). Compared with the non skiing group, the skiing group had higher preoperative and postoperative Tegner scores ($p < 0.05$). Preoperative IKDC, KOOS sport, KOOS symptoms, and Lysholm scores did not differ significantly between the skiing and non skiing groups (n.s.) but postoperative IKDC and Lysholm scores differed significantly ($p < 0.05$). Furthermore, 72.3% of patients in the skiing group returned to the same level or a lower level of play than the one they had previous to the injury versus 58.6% in the other group. The main reasons for changing sports activity were fear of reinjury (48%), less time for participating in the previous sport

Table 3 Participant demographics

	ACL-only ($n = 39$)	Meniscal repair ($n = 10$)	Meniscectomy ($n = 26$)	*p* value
Subjective IKDC postoperative[a]	83.5 ± 12.2	81.9 ± 13.1	82.7 ± 10.1	n.s
Tegner postoperative[b]	5 (1–7)	5 (1–7)	5 (1–7)	n.s
Lysholm postoperative[c]	91.5 ± 12.1	88.2 ± 11.4	89.4 ± 10.1	n.s
Return to sport (months)[d]	7.2 ± 1.2	7.4 ± 1.0	6.9 ± 1.3	n.s

Comparison of mean or median score following menisectomy, meniscal suture and ACL only

IKDC International Knee Documentation Committee

[a,c,d]Data are reported as mean ± SD. [b]Data are reported as median + range

(26%), knee instability (9%) and pain (17%). New sports that were chosen were low impact joint friendly sports: long walks/trekking (36%), cycling (34%), gym activities (21%), and swimming (9%).

Univariate analysis demonstrated that patients who returned to their average performance level were those with a significantly higher pre-injury sports level. The mean pre-injury Tegner score was 6 (range 2–8) in the group which returned to the usual level of sport versus 5 (range 3–6) in the other group ($p < 0.05$). Sex, cartilage injury at the time of surgery, a lateral or medial meniscal injury, IKDC, Lysholm, and KOOS scores before the operation were not found to be significantly correlated with a return to preinjury sports level.

Discussion

The main result of this study was that arthroscopic ACL reconstruction in patients aged 50 years and older resulted in excellent functional outcomes.

This study showed that at the last follow-up, the mean overall IKDC score, KOOS score, and Lysholm score increased, with a statistically significant difference. The results obtained were similar to those observed in patients over 50 years of age in the literature [4, 11, 22, 41–43, 48]. Figueroa et al. [15] reported that after 2 years of follow-up in patients over 50 years of age after ACL reconstruction, the IKDC score and Lysholm score increased from 42.9 to 90.9 and 50.1 to 93.7 ($p < 0.001$). Furthermore, these results seem to be match with previously published results in patients over the age of 40 years as well as younger patients [6, 12, 20, 33, 37, 45]. In studies by Cinque et al. [8] as well as Iorio et al. [21], outcome scores do not seem to differ between a younger (age 20–30 years) and older (age 50–75 years) patient cohort, with bone-tendon-bone or hamstring grafts. A low rate of complications and repeat operations was observed in this study. The graft failure rate was of only 8%, and 7% of patients had a second surgery. In a recent systematic review, Costa et al. reported results that are analogous to those in younger patients [10]. These results suggest that the advantages of ACL reconstruction outweigh the non-operative rehabilitation programs when comparing clinical outcomes.

The current study demonstrates that overall, at 24 months after surgery, 86% of patients had returned to sport though not necessarily the same, and 51% had returned to their preinjury sports level. This seems to support the meta-analysis by Ardern et al. [1] who showed that the return to sport was 82% and 63% at the same level after a mean 41.5 months follow-up. Gerometta et al. [17] reports that 92% of patients return to sport but only 38% of these athletes return to preinjury levels after 2 years. The difference in the return to preinjury levels can be explained by the fact that the majority of patients in our study were considered recreational athletes, whereas many of the patients in the Gerometta et al. study practiced at a competitive level. The return-to-sport rate is not always clearly reported in the literature, between 30 and 100% depending on the studies [13, 23, 36]. Toanen et al. reported the rate of return to preinjury level of sport in patients 50 years and older [41]. Panisset et al. showed that time to return to sports and resumed levels were similar to those in patients under 40 years of age [31]. In this study, the return-to-sport rate was 83%, and the rate of return to the preinjury level of sport was 50%. Here, we retrospectively assessed the rates of return to sports in a population with high-demand activities (skiing). In the skiing group, 72.3% returned to their previous sports after ACL reconstruction. Work, lifestyle, and family greatly influence the decision to continue playing the game at a preinjury level after surgery in these populations. Therefore, ACL reconstruction is a viable surgical option in patients 50 years and older, especially among patients who enjoy athletic activities.

In the present study, ten patients had longitudinal vertical traumatic tears, in the red-white or red-red zones. No ramp lesion was found. In this case, the first-line choice is to repair. In four traumatic tears, the decision was the non-removal for stable asymptomatic lateral meniscal tears in conjunction with anterior cruciate ligament reconstruction. Meniscus preservation, if possible, is particularly crucial in ACL injured knees. Meniscus preservation (repair or non-removal) in combination with ACL reconstruction protects the articular cartilage and the ACL graft, reducing residual laxity. ACL reconstruction also protects the meniscus repair. Meniscus repair outcomes with an ACL tear are now well-established. Even if the short-term clinical results ($\leq$ 1-year follow-up) for ACLR with concomitant meniscal surgery are better for meniscal resection, meniscal repairs have better long-term patient-reported outcomes and better activity levels than meniscectomy [25, 34, 38, 49]. Melton et al. reported that good long-term outcomes could be obtained in patients up to over 12 years after combined ACL reconstruction and meniscal repair when compared with ACL reconstruction and meniscectomy [26]. Lepley et al. reported that concomitant meniscectomy or meniscal repair did not affect the time when individuals returned to sport following ACL reconstruction [25]. 23 patients had typically degenerative meniscal lesions, with a horizontal cleavage of the meniscus. The most common location was the posterior horn of the medial meniscus. For 17 patients, arthroscopic partial meniscectomy was proposed after 3 months and persistent pain and/or mechanical symptoms related to a DML with normal Radiograph but an abnormal MRI [2, 3]. Fayard et al. reported that rigorous patient selection is mandatory,

as radiologic signs of medial tibiofemoral osteoarthritis indicate a risk of poor outcome [14]. The main message remains: save the meniscus.

In this study, a return to the pre-injury level of sport after a primary ACL reconstruction was correlated with a high sports level before ACL injury. The pre-injury Tegner score was the only factor influencing a return to the pre-injury level of sport in univariate analysis. The results confirmed the findings of several previous studies. Lai et al. [24] in a recent systematic review reported that elite athletes had a 94% rate of return to play, with the same or higher competition level. Higher performance players return to play and return to prior performance at higher rates. However, the rate of sport participation can decline over time. Walden et al. [44] reported a return to sport in professional soccer at a mean of 90% after 12 months, with only 65% still playing at 3 years after ACLR. It might be interesting to see if this evolution follows the same curve in patients over 50 years old. However, our study was limited to a shorter-term follow-up. This means that we cannot comment on sports participation in the long term, but we believe that 2 years is an appropriate interval at which to evaluate return to play. 48% of patients in our study who did not return to sports reported fear of re-injury as the main reason. The psychological component has been investigated with ACL-RSI score in the literature [5, 46], and it should be understood that psychological readiness and fear of reinjury influence the probability of an athlete returning to play [47].

Some limitations of this study should be mentioned. First, the study is retrospective and without a control group. The outcome assessment was done at a minimum follow-up of 2 years with a minimum number of patients lost to follow-up, which is difficult in this active and mobile population. Second, we did not perform a sample size calculation, and the study could was underpowered to detect a difference in some of the outcomes analyzed. Finally, there were no radiographs at follow-up, which would have been useful to evaluate the relationship with clinical results.

Conclusion

ACL reconstruction is a viable surgical option in patients aged 50 years and older, especially among patients who enjoy athletic activities. Overall, complication rates are low. The rate of patients who returned to sport after surgery was 86%, of which 51% returned to the same or higher performance level. A higher sport level before ACL injury is associated with a return to the pre-injury level of sport after primary reconstruction.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Funding No funding was received for this study.

Ethical approval The Ethics and Research Committee of Clinique du Sport, Bordeaux-Merignac, France approved the study (No. 03.2018.12.).

References

1. Ardern CL, Webster KE, Taylor NF, Feller JA (2011) Return to sport following anterior cruciate ligament reconstruction surgery: a systematic review and meta-analysis of the state of play. Br J Sports Med 45:596–606
2. Beaufils P, Becker R, Kopf S, Englund M, Verdonk R, Ollivier M, Seil R (2017) Surgical management of degenerative meniscus lesions: the 2016 ESSKA meniscus consensus. Knee Surg Sports Traumatol Arthrosc 25:335–346
3. Beaufils P, Becker R, Kopf S, Matthieu O, Pujol N (2017) The knee meniscus: management of traumatic tears and degenerative lesions. EFORT Open Rev 2:195–203
4. Blyth MJG, Gosal HS, Peake WM, Bartlett RJ (2003) Anterior cruciate ligament reconstruction in patients over the age of 50 years: 2- to 8-year follow-up. Knee Surg Sports Traumatol Arthrosc 11:204–211
5. Bohu Y, Klouche S, Lefevre N, Webster K, Herman S (2015) Translation, cross-cultural adaptation and validation of the French version of the anterior cruciate ligament-return to sport after injury (ACL-RSI) scale. Knee Surg Sports Traumatol Arthrosc 23:1192–1196
6. Brandsson S, Kartus J, Larsson J, Eriksson BI, Karlsson J (2000) A comparison of results in middle-aged and young patients after anterior cruciate ligament reconstruction. Arthroscopy 16:178–182
7. Ciccotti MG, Lombardo SJ, Nonweiler B, Pink M (1994) Nonoperative treatment of ruptures of the anterior cruciate ligament in middle-aged patients. Results after long-term follow-up. J Bone Joint Surg Am 76:1315–1321
8. Cinque ME, Chahla J, Moatshe G, DePhillipo NN, Kennedy NI, Godin JA, LaPrade RF (2017) Outcomes and complication rates after primary anterior cruciate ligament reconstruction are similar in younger and older patients. Orthop J Sports Med 5:2325967117729659
9. Colombet P, Silvestre A, Bouguennec N (2018) The capsular line reference, a new arthroscopic reference for posterior/anterior femoral tunnel positioning in anterior cruciate ligament reconstruction. J Exp Orthop 5:9
10. Costa GG, Grassi A, Perelli S, Agrò G, Bozzi F, Lo Presti M, Zaffagnini S (2019) Age over 50 years is not a contraindication for anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 27:3679–3691
11. Dahm DL, Wulf CA, Dajani KA, Dobbs RE, Levy BA, Stuart MA (2008) Reconstruction of the anterior cruciate ligament in patients over 50 years. J Bone Joint Surg Br 90:1446–1450
12. Desai N, Björnsson H, Samuelsson K, Karlsson J, Forssblad M (2014) Outcomes after ACL reconstruction with focus on older patients: results from The Swedish National Anterior Cruciate Ligament Register. Knee Surg Sports Traumatol Arthrosc 22:379–386

13. Fabbriciani C, Milano G, Mulas PD, Ziranu F, Severini G (2005) Anterior cruciate ligament reconstruction with doubled semitendinosus and gracilis tendon graft in rugby players. Knee Surg Sports Traumatol Arthrosc 13:2–7
14. Fayard J-M, Wein F, Ollivier M, Paihle R, Ehlinger M, Lustig S, Panisset J-C, French Arthroscopic Society (2019) Factors affecting outcome of ACL reconstruction in over-50-year-olds. Orthop Traumatol Surg Res 105:S247–S251
15. Figueroa D, Figueroa F, Calvo R, Vaisman A, Espinoza G, Gili F (2014) Anterior cruciate ligament reconstruction in patients over 50 years of age. Knee 21:1166–1168
16. Frobell RB, Roos EM, Roos HP, Ranstam J, Lohmander LS (2010) A randomized trial of treatment for acute anterior cruciate ligament tears. N Engl J Med 363:331–342
17. Gerometta A, Lutz C, Herman S, Lefèvre N, Dromzee E, Dubrana F, Fazilleau F, Thoreux P, Yaoub B, Miletic B, Girard J, Pasquier G, Bohu Y, Henry M, Sauleau V, Khiami F (2014) Étude multicentrique française : reprise du sport après ligamentoplastie du ligament croisé antérieur chez les sportifs de pivot et pivot contact. Journal de Traumatologie du Sport 31:171–178
18. Herrington L, Fowler E (2006) A systematic literature review to investigate if we identify those patients who can cope with anterior cruciate ligament deficiency. Knee 13:260–265
19. Ho-Le TP, Pham HM, Center JR, Eisman JA, Nguyen HT, Nguyen TV (2018) Prediction of changes in bone mineral density in the elderly: contribution of "osteogenomic profile". Arch Osteoporos 13:68
20. Hu J, Qu J, Xu D, Zhou J, Lu H (2013) Allograft versus autograft for anterior cruciate ligament reconstruction: an up-to-date meta-analysis of prospective studies. Int Orthop 37:311–320
21. Iorio R, Iannotti F, Ponzo A, Proietti L, Redler A, Conteduca F, Ferretti A (2018) Anterior cruciate ligament reconstruction in patients older than fifty years: a comparison with a younger age group. Int Orthop 42:1043–1049
22. Kim DK, Park G, Kuo L-T, Park WH (2019) Patients older than 50 years had similar results of knee strength and anteroposterior stability after ACL reconstruction compared to younger patients. Knee Surg Sports Traumatol Arthrosc 27:230–238
23. Kvist J, Ek A, Sporrstedt K, Good L (2005) Fear of re-injury: a hindrance for returning to sports after anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 13:393–397
24. Lai CCH, Ardern CL, Feller JA, Webster KE (2018) Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: a systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. Br J Sports Med 52:128–138
25. Lepley LK, Wojtys EM, Palmieri-Smith RM (2015) Does concomitant meniscectomy or meniscal repair affect the recovery of quadriceps function post-ACL reconstruction? Knee Surg Sports Traumatol Arthrosc 23:2756–2761
26. Melton JTK, Murray JR, Karim A, Pandit H, Wandless F, Thomas NP (2011) Meniscal repair in anterior cruciate ligament reconstruction: a long-term outcome study. Knee Surg Sports Traumatol Arthrosc 19:1729–1734
27. Mihelic R, Jurdana H, Jotanovic Z, Madjarevic T, Tudor A (2011) Long-term results of anterior cruciate ligament reconstruction: a comparison with non-operative treatment with a follow-up of 17–20 years. Int Orthop 35:1093–1097
28. Montero-Fernández N, Serra-Rexach JA (2013) Role of exercise on sarcopenia in the elderly. Eur J Phys Rehabil Med 49:131–143
29. Moreira LDF, de Oliveira ML, Lirani-Galvão AP, Marin-Mio RV, dos Santos RN, Lazaretti-Castro M (2014) Physical exercise and osteoporosis: effects of different types of exercises on bone and physical function of postmenopausal women. Arq Bras Endocrinol Metabol 58:514–522
30. Nourissat G, Beaufils P, Charrois O, Selmi TAS, Thoreux P, Moyen B, Cassard X, French Society of Arthroscopy (2008) Magnetic resonance imaging as a tool to predict reparability of longitudinal full-thickness meniscus lesions. Knee Surg Sports Traumatol Arthrosc 16:482–486
31. Panisset J-C, Gonzalez J-F, de Lavigne C, Ode Q, Dejour D, Ehlinger M, Fayard J-M, Lustig S, French Society of Arthroscopy (2019) ACL reconstruction in over-50 year-olds: comparative study between prospective series of over-50 year-old and under-40 year-old patients. Orthop Traumatol Surg Res 105:S259–S265
32. Pearle AD, McAllister D, Howell SM (2015) Rationale for strategic graft placement in anterior cruciate ligament reconstruction: I.D.E.A.L. Femoral Tunnel Position Am J Orthop 44:253–258
33. Saper M, Pearce S, Shung J, Zondervan R, Ostrander R, Andrews JR (2018) Outcomes and return to sport after revision anterior cruciate ligament reconstruction in adolescent athletes. Orthop J Sports Med 6:2325967118764884
34. Sarraj M, Coughlin RP, Solow M, Ekhtiari S, Simunovic N, Krych AJ, MacDonald P, Ayeni OR (2019) Anterior cruciate ligament reconstruction with concomitant meniscal surgery: a systematic review and meta-analysis of outcomes. Knee Surg Sports Traumatol Arthrosc 27:3441–3452
35. Shen W, Fu FH (2008) Anterior cruciate ligament insertion site anatomy. Arthroscopy 24:850–851
36. Smith FW, Rosenlund EA, Aune AK, MacLean JA, Hillis SW (2004) Subjective functional assessments and the return to competitive sport after anterior cruciate ligament reconstruction. Br J Sports Med 38:279–284
37. Sonnery-Cottet B, Saithna A, Cavalier M, Kajetanek C, Temponi EF, Daggett M, Helito CP, Thaunat M (2017) Anterolateral ligament reconstruction is associated with significantly reduced ACL graft rupture rates at a minimum follow-up of 2 years: a prospective comparative study of 502 patients from the SANTI study group. Am J Sports Med 45:1547–1557
38. Stein T, Mehling AP, Welsch F, von Eisenhart-Rothe R, Jäger A (2010) Long-term outcome after arthroscopic meniscal repair versus arthroscopic partial meniscectomy for traumatic meniscal tears. Am J Sports Med 38:1542–1548
39. Tashman S, Kopf S, Fu FH (2008) The kinematic basis of ACL reconstruction. Oper Tech Sports Med 16:116–118
40. Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 198:43–49
41. Toanen C, Demey G, Ntagiopoulos PG, Ferrua P, Dejour D (2017) Is There any benefit in anterior cruciate ligament reconstruction in patients older than 60 years? Am J Sports Med 45:832–837
42. Trojani C, Sané J-C, Coste J-S, Boileau P (2009) Four-strand hamstring tendon autograft for ACL reconstruction in patients aged 50 years or older. Orthop Traumatol Surg Res 95:22–27
43. Ventura A, Legnani C, Terzaghi C, Borgo E (2012) Single- and double-bundle anterior cruciate ligament reconstruction in patients aged over 50 years. Arthroscopy 28:1702–1709
44. Waldén M, Hägglund M, Magnusson H, Ekstrand J (2016) ACL injuries in men's professional football: a 15-year prospective study on time trends and return-to-play rates reveals only 65% of players still play at the top level 3 years after ACL rupture. Br J Sports Med 50:744–750
45. Wang H, Ao Y, Gong X, Wang Y, Wang J, Ma Y, Liu Y, Jiang Y, Zhang J, Cheng J, Yu J (2015) Comparison of clinical results between middle-aged patients and young patients after anterior cruciate ligament reconstruction. Zhonghua Yi Xue Za Zhi 95:3529–3532

46. Webster KE, Feller JA, Lambros C (2008) Development and preliminary validation of a scale to measure the psychological impact of returning to sport following anterior cruciate ligament reconstruction surgery. Phys Ther Sport 9:9–15
47. Webster KE, Nagelli CV, Hewett TE, Feller JA (2018) Factors associated with psychological readiness to return to sport after anterior cruciate ligament reconstruction surgery. Am J Sports Med 46:1545–1550
48. Wolfson TS, Epstein DM, Day MS, Joshi BB, McGee A, Strauss EJ (2013) Jazrawi LM (2014) Outcomes of anterior cruciate ligament reconstruction in patients older than 50 years of age. Bull Hosp Joint Dis 72:277–283
49. Xu C, Zhao J (2015) A meta-analysis comparing meniscal repair with meniscectomy in the treatment of meniscal tears: the more meniscus, the better outcome? Knee Surg Sports Traumatol Arthrosc 23:164–170
50. Xu J, Lombardi G, Jiao W, Banfi G (2016) Effects of exercise on bone status in female subjects, from young girls to postmenopausal women: an overview of systematic reviews and meta-analyses. Sports Med 46:1165–1182
51. Zimmerer A, Sobau C, Nietschke R, Schneider M, Ellermann A (2018) Long-term outcome after all inside meniscal repair using the FasT-Fix system. J Orthop 15:602–605