The Knee 29 (2021) 222–232

Contents lists available at ScienceDirect

The Knee

journal homepage:

Age, activity level and meniscus injury, but not tear location, tibial slope or anterolateral ligament injury predict coping with anterior cruciate ligament injury

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A R T I C L E I N F O

Article history:
Received 9 October 2020
Revised 4 January 2021
Accepted 25 January 2021

Keywords:
Anterior cruciate ligament
Copers
Tibial slope
Anterolateral ligament
Tear location
Proximal tear

A B S T R A C T

Introduction: Early recognition of potential predictors on the success of conservative treatment of anterior cruciate ligament (ACL) is important, as appropriate treatment can be applied to each individual patient. The goal of this study is to assess the patient demographic and radiological parameters that predict coping with ACL injuries.
Methods: All patients presenting with a complete ACL injury between 2014 and 2018 at our clinic were included. The role of patient demographics (age, gender, activity level, meniscus injury and time from injury to clinic), and ACL tear location, bone bruises, tibial slope, and anterolateral ligament (ALL) injury were assessed on the success of conservative treatment using univariate and multivariate analyses.
Results: Sixty-five patients (32%) were copers and 141 (68%) were non-copers. Univariate analysis showed that copers were significantly older (40 vs. 27 years, $P < 0.001$), had lower preinjury activity level (Tegner 5.7 vs. 6.5, $P < 0.001$) and less often lateral meniscus tears (16% vs. 5%, $P = 0.019$) but not medial meniscus tears (17% vs. 14%, $P = 0.609$) than non-copers. Multivariate analysis revealed that increasing age ($P < 0.001$), Tegner level ≤ 6 ($P = 0.003$) and no meniscus injury ($P = 0.045$) were independent predictors of coping with ACL deficiency.
Conclusions: Older age, participation in lower activity sports levels and absence of meniscus injury were predictive of coping with ACL deficiency, whereas there was no such role for tear location, tibial slope, lateral bone bruise presence, ALL injury or gender. These findings might help to identify potential copers and guide surgeons early in the optimal treatment for patients with ACL injury.

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https://doi.org/10.1016/j.knee.2021.01.027
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1. Introduction

Anterior cruciate ligament (ACL) injury is a common injury with an estimated incidence of more than 200,000 injuries in the USA [1–3], and these ACL injuries can either be treated operatively or conservatively. With conservative treatment [4,5], patients will undergo neuromuscular training (NMT) under the guidance of a physical therapist [4,6,7], and will only undergo ACL reconstruction if persistent knee instability is present (so called 'non-copers'). Studies have shown that approximately 40–50% of patients can be successful with NMT and are considered 'copers' with their ACL deficiency [4–6,8,9].

This approach of initial conservative treatment has the advantage that surgery is only performed in patients that truly need surgical stabilization. This not only reduces surgical costs, but also prevents potential surgical complications for patients [5]. Conversely, there are also disadvantages with this approach. If ACL reconstruction is needed after failed conservative treatment, this will be performed in the delayed setting which increases the risk of additional meniscal and cartilage damage [10–12], it will delay the total time from injury to return to sports due to the months of failed conservative treatment, and will have higher indirect costs when compared with early ACL reconstruction [13]. It is therefore important to identify early which patients are potential copers and potential non-copers with their ACL deficiency.

Some studies have assessed the role of patient demographics on the success of conservative treatment of ACL injuries [6,8,9], but no studies have assessed the role of potential imaging factors, such tear location, tibial slope or injury to the anterolateral ligament (ALL) on this. First, ACL tear location could play a role on coping with ACL injury as studies have shown that there is better vascularity [14] and healing potential in the proximal part of the ACL [15], and therefore some groups have advocated to primarily repair proximal tears [16–21]. As primary repair is performed in the acute setting, patients do not have the possibility to undergo conservative treatment and it is possible that these patients with proximal tears respond well to NMT treatment, as the ligament might have sufficient distal remnant length to reattach to the notch [15,22] or femoral insertion [23–25] and provide stability that results in coping. It is therefore important to assess whether tear location plays a predictive role in the success of conservative treatment. Furthermore, several studies have shown that large lateral posterior tibial slope has a predictive role on ACL injury [26–29], on graft rupture following ACL reconstruction [30,31] and ACL revision surgery [32], and it is therefore also possible that tibial slope plays a role on coping with ACL deficiency with conservative treatment [33]. However, this has not yet been assessed in clinical studies [34]. Another factor that has recently been shown to play a role in knee stability in the setting of ACL deficiency and ACL reconstruction is ALL injury [35–37], and it is possible that presence of ALL injury predicts the failure of conservative treatment but this has also not been assessed in clinical studies. Finally, it has been suggested that different bone bruise patterns exist with different injury mechanisms [38] but no studies have assessed the correlation between bone bruising patterns and coping with ACL deficiency.

Early recognition of these potential predictors on the success of conservative treatment of ACL injuries is important, as this might help surgeons to start patient-specific treatment for potential copers and non-copers. The goal of this study was thus to assess the role of tear location, ALL injury and tibial slope, along with other patient characteristics on the success of conservative treatment of acute ACL injuries. We hypothesized that older age, lower activity level and absence of meniscal injury along with presence of proximal tears, of lateral bone bruises and absence of ALL injury and less posterior slope were correlated with success of conservative treatment.

2. Materials and methods

2.1. Study design

For this retrospective study, institutional board approval was obtained. All patients presenting to our orthopaedic surgery department between 1 January 2014 and 31 May 2018 with an ACL injury within 3 months of their injury were identified, and patients were excluded for not undergoing conservative treatment, poor quality or no magnetic resonance imaging (MRI), multi-ligamentous knee injury, and if treatment decision was influenced by skeletally maturity status (details in Fig. 1). This resulted in a group of 206 skeletally mature patients with an MRI-confirmed, complete, isolated ACL injury within 3 months of presentation and that were initially treated with conservative treatment. The baseline characteristics of the included versus excluded patients are shown in Table 1.

2.2. Conservative treatment

Conservative treatment under the guidance of a physical therapist was based on the principle of NMT, as is widely described [4,6,7], and consisted of three phases. In the first phase, the goal was to restore range of motion (ROM), control swelling and start isometric muscle training. In the second phase, the goal was to further improve muscle strength, progress to light sport-specific exercises, obtain $\geq$ 80% of the quadriceps and hamstring muscle strength when compared with the contralateral side and $\geq$80% for hop tests. In the third phase, the goal was to advance to have symmetric patterns of running and sport-specific exercises, improve $\geq$ 90% of strength and hop tests compared with the contralateral side, and return to sports. Patients were seen in clinic at 6 weeks and 3 months after start of conservative treatment and were assessed for pain, stability, giving way and progress of NMT. If symptoms were mild, no or rare giving way occurred and patients were satisfied with NMT progress, patients continued conservative treatment and were seen back 6 weeks later or were discharged from

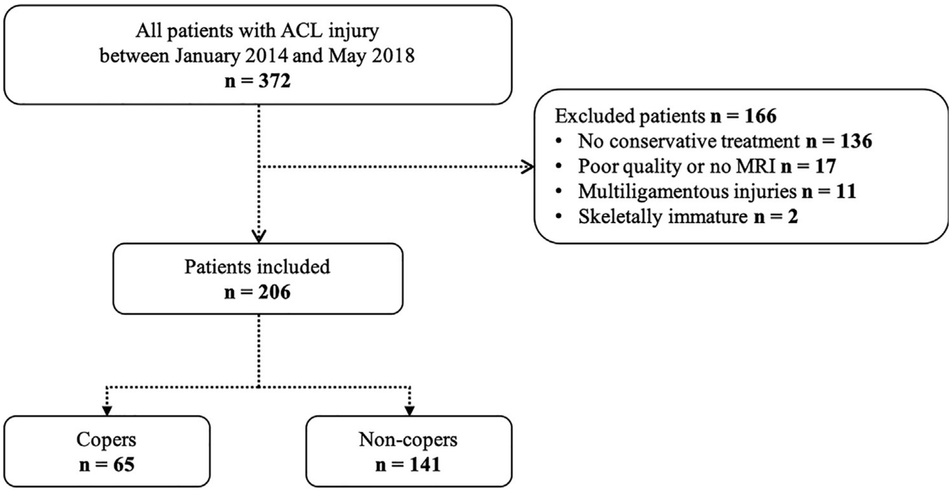

Fig. 1. Flowchart of inclusion and exclusion of this study.

Table 1
Patient demographics for included and excluded patients.

	Study cohort n = 206	Excluded patients n = 166	Included vs. excluded
Age (years) *	31.2 ± 13.6	28.8 ± 13.0	0.083[a]
Male gender **	109 (52.9%)	101 (60.8%)	0.125[b]
Right side **	107 (51.9%)	89 (53.6%)	0.748[b]
Tegner level *	6.2 ± 1.0	6.7 ± 1.1	**<0.001**[a]
Time injury to clinic (months) ***	1.4 ± 1.0	1.3 ± 1.0	0.432[a]
Any meniscus tear **	69 (33.5%)	76 (45.8%)	**0.016**[b]
MM tear only **	31 (15.0%)	24 (14.5%)	0.873[b]
LM tear only **	26 (12.6%)	38 (22.9%)	**0.009**[b]
MM and LM tear **	12 (5.8%)	14 (8.4%)	0.327[b]

LM, lateral meniscus; MM, medial meniscus.
* Data displayed as mean ± standard deviation.
** Data displayed as n (%)
*** Data displayed as median (interquartile range)
[a] Independent *t*-test.
[b] Chi-squared test.

follow up. If patients had symptomatic instability (multiple giving way episodes despite NMT), or they could not return to their wished activity levels despite NMT progress, the option of ACL reconstruction was discussed and surgery was scheduled.

2.3. Surgical treatment

All patients underwent NMT and had full ROM prior to surgery. Standard anatomic ACL reconstruction was performed using autograft hamstring tendon, independent femoral tunnel drilling, proximal graft fixation with a cortical button and tibial graft fixation with an interference screw. Postoperative rehabilitation consisted of a similar protocol as conservative NMT treatment with the three phases of control of swelling and return of ROM, muscular strengthening and light sport-specific exercises, and more extensive sport-specific exercises as mentioned above [39].

2.4. Data collection

All patient files were retrospectively reviewed for patient demographic information and treatment. Demographic information consisted of age, gender, side, Tegner activity level, time from injury to presentation. Tegner activity level were both presented as the raw score, and as a binary outcome of participating in higher-level sports defined as a Tegner activity score of ≥ 7 [40,41]. Radiological information was reviewed for presence of meniscus injury and other ligamentous injuries.

It was reviewed when patients started conservative treatment and if they had successfully completed conservative treatment (discharged from follow up without surgery) or were scheduled for ACL reconstruction and thus failed conservative treatment. If patients were discharged from follow up and had not undergone surgery in our hospital, patients or their general practitioner were contacted to assess whether future ACL reconstruction was performed in other hospitals. Patients without ACL reconstruction after 2 years were defined as 'copers, and patients that were scheduled for or underwent ACL reconstruction were defined as 'non-copers'.

2.5. Imaging evaluation

All MRI scans were performed with 1.5-T magnets and had 3-mm slice thickness, and were conducted with the knee extended and the patient in supine position. Three independent raters (JPL, FJH and HAZ) performed tibial slope measurements on MRI, one rater with experience in measuring ACL tear location performed ACL tear location measurements (JPL) and one experienced musculoskeletal radiologist rated ALL injury (CvD). All patients were de-identified and randomized for blinded measurements.

Tear location of the ACL was measured using a previously validated method by our group (citation blinded), which has an interobserver and intra-observer reliability of 0.92–0.96 and 0.91–0.97, respectively. The sagittal image best showing the distal remnant and proximal remnant was selected. The distal remnant length was measured using a digital ruler from the point of the anterior tibial insertion to the mid-section of the torn proximal part of the distal remnant. The proximal remnant length was measured from the most superior point of the femoral insertion on the lateral femoral condyle to the mid-section of the torn distal part of the proximal remnant (Fig. 2(a)). Tear location was calculated as the length of the distal remnant divided by the sum of the proximal and distal remnant length and presented as percentage of the total remnant length.

Tibial slope of the medial and lateral plateau were measured on the sagittal images on MRI using a previously validated method [42], which has an interobserver and intra-observer reliability of 0.79 and 0.89, respectively, and variability of 1.08° and 1.18°, respectively [43]. The sagittal image where the posterior cruciate ligament attached to the tibia was identified and using two horizontal lines at a 5-cm distance the longitudinal tibial axis was determined [43]. On the axial images the center of the lateral plateau was then determined, and at this level on the sagittal images a line was drawn along the subchondral bone of the lateral tibial plateau. The lateral tibial slope was measured as the angle between this lateral tibial plateau line and longitudinal tibial axis line (Fig. 2(b)). This measurement was then repeated for the medial side with a similar method.

Presence of bone bruises was assessed using a previously reported method with an intra-observer reliability of 0.92 [38]. The sagittal proton-density fat-suppression (PD-FS) images were reviewed and bone bruises in the lateral femoral condyle (LFC), lateral tibial plateau (LTP), medial femoral condyle (MFC) and medial tibial plateau (MTP) were graded as none, minimal (only at subchondral bone), moderate (from articular surface to physeal scar) and severe (from articular surface beyond physeal scar) (Fig. 2(c)) [44,45].

ALL injury was assessed using a previously reported method with an interobserver and intra-observer reliability for ALL presence of 1 and 1, respectively, and for differentiation partial/complete injury of 0.64 and 0.60–0.75, respectively, and an accuracy for ALL presence of 88.5% and partial/complete injury of 61.5% [46]. Coronal images were reviewed and the ALL was defined as the low signal band originating from the lateral condylar femoral region that crosses the proximal surface of the lateral collateral ligament deep to the iliotibial band to its insertion between Gerdy's tubercle and the fibular head. The ALL were considered abnormal when there were irregular contours, a wavy aspect, or areas of discontinuity (Fig. 2(d)). If full-thickness tears were identified, it was scored as a complete injury and otherwise it was scored as partial injury.

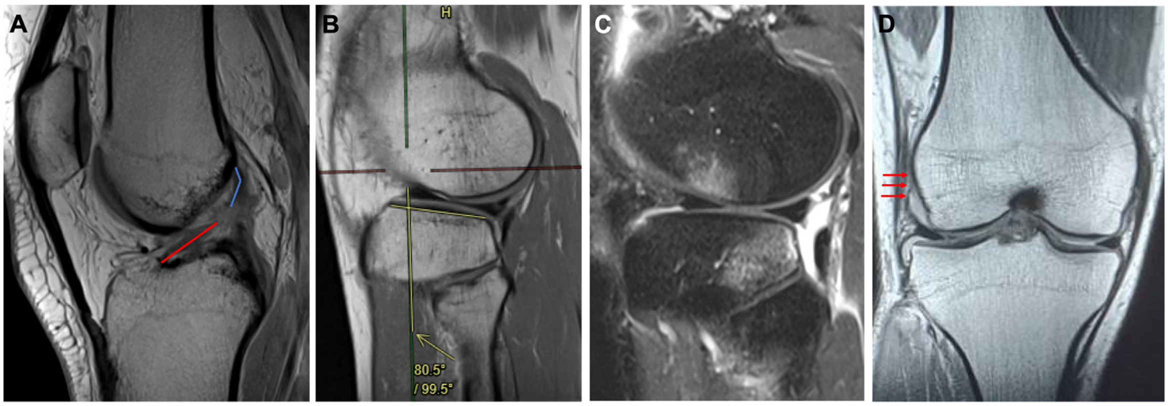

Fig. 2. (a) An example of measuring the tear location, which can be calculated by dividing the distal remnant (in red) by the sum of the distal (in red) and proximal remnant (in blue) and is expressed in percentage. (b) An example of measuring lateral tibial slope is shown. (c) An example of assessing lateral bone bruises is shown with a minimal lateral femoral condyle bone bruise and moderate lateral tibial plateau bone bruise. (d) An example of assessing anterolateral ligament (ALL) injury is shown on a coronal T1 image as indicated by the arrows with a partial femoral ALL injury. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.6. Statistical analysis

SPSS version 26.0 was used for the statistical analysis (IBM Software, Armonk, NY, USA). First, patient demographics were assessed for all included and excluded patients in order to assess potential selection bias. Baseline demographics, and radiologic measurements were then compared between copers and non-copers. Continuous data were presented in mean ± standard deviation and compared using independent *t*-tests and nominal data were presented in number (percentage; %) and compared using chi-squared tests, or Fisher's exact test if one of the expected cells was <5. Tibial slope was presented as continuous data and additionally also as the proportion of patients with a lateral tibial slope of $\geq 9°$ as this threshold has been identified as clinically relevant by previous studies [32,34]. The statistical analyses were performed for the entire cohort and for the subgroup of patients without meniscus injuries to better inform surgeons on different clinical scenarios. Correlation between age and tear location was performed using Pearson correlation analysis.

Multivariate logistic regression was then performed to assess independent predictors of coping with ACL injury and data was reported as odds ratio (OR) [95% CI]. Any meniscus tears rather than lateral meniscus tears were included in the multivariate analysis because of the low incidence of lateral meniscus tears (Table 2). All statistical tests were two-sided and a *P*-value of <0.05 was considered significant. Based on the literature [28,31,34], sample size calculation for tibial slope revealed that 35 patients would be needed in each group to be sufficiently powered for a 2° difference between two groups with an alpha of 0.05, a power of 80% and a standard deviation of 3°.

Table 2
Patient demographics and radiological characteristics in all patients and between copers and non-copers.

	All patients n = 206	Copers n = 65	Non-copers n = 141	Copers vs. non-copers
Patient demographics				
Age (years) *	31.2 ± 13.6	39.6 ± 13.6	27.4 ± 11.7	**<0.001**[a]
Male gender **	109 (52.9%)	28 (43.1%)	81 (57.4%)	0.055[b]
Tegner level *	6.2 ± 1.0	5.7 ± 1.1	6.5 ± 0.9	**<0.001**[a]
High Tegner level **	104 (50.5%)	14 (21.5%)	90 (63.8%)	**<0.001**[b]
Time injury to clinic (months)*	1.4 ± 1.0	1.3 ± 1.0	1.4 ± 1.0	0.534[a]
Any meniscus tear **	69 (33.5%)	18 (27.7%)	51 (36.2%)	0.231[b]
MM tear only **	31 (15.0%)	11 (16.9%)	20 (14.2%)	0.609[b]
LM tear only **	26 (12.6%)	3 (4.6%)	23 (16.3%)	**0.019**[c]
MM and LM tear **	12 (5.8%)	4 (6.2%)	8 (5.7%)	>0.999[c]
Tibial slope				
Medial slope *	4.4 ± 3.0°	4.1 ± 2.7°	4.6 ± 3.1°	0.351[a]
Lateral slope *	6.1 ± 3.4°	5.7 ± 3.5°	6.3 ± 3.3°	0.194[a]
Mean slope *	5.3 ± 2.8°	4.9 ± 2.7°	5.5 ± 2.9°	0.209[a]
Difference slope *	1.7 ± 2.8°	1.5 ± 3.1°	1.8 ± 2.7°	0.580[a]
Lateral slope ≥ 9° **	50 (24.3%)	12 (18.5%)	38 (27.0%)	0.187[b]
Presence of bone bruise				
Lateral femoral condyle **	116 (56.3%)	23 (35.4%)	93 (66.0%)	**<0.001**[b]
Lateral tibial plateau **	155 (75.2%)	48 (73.8%)	107 (75.9%)	0.753[b]
Medial femoral condyle **	22 (10.7%)	7 (10.8%)	15 (10.6%)	0.977[b]
Medial tibial plateau **	103 (50.0%)	31 (47.7%)	72 (51.1%)	0.653[b]
Anterolateral ligament				
Visualized **	199 (96.1%)	61 (92.3%)	138 (97.9%)	0.286[b]
Intact **	100 (50.3%)	25 (41.0%)	75 (54.3%)	0.204[b]
Partial injury**	79 (39.7%)	28 (45.9%)	51 (37.0%)	
Complete injury **	20 (10.1%)	8 (13.1%)	12 (8.7%)	
Tear location				
Distal remnant length *	27 ± 5 mm	27 ± 5 mm	27 ± 5 mm	0.490[a]
Proximal remnant length *	13 ± 4 mm	12 ± 3 mm	13 ± 4 mm	**0.048**[a]
Tear location *	67 ± 9%	69 ± 8%	67 ± 9%	0.092[a]
Tear proximal 25% **	39 (18.9%)	14 (21.5%)	25 (17.7%)	0.517[b]

LM, lateral meniscus; MM, medial meniscus.
*** Data displayed as mean ± standard deviation.
* Data displayed as median with interquartile.
** Data displayed as n (%).
[a] Independent *t*-test.
[b] Chi-squared test.
[c] Fisher's exact test.

3. Results

3.1. Baseline characteristics

Mean age of the 206 included patients was 31 years, 53% were male and 52% had an injury to the right knee. Tegner activity level was 6.2 ± 1.0 and 50% of patients participated in higher-level sports. Patients presented at mean 1.4 ± 1.0 months following injury at our department, and 33% of patients had a concomitant meniscus injury with their ACL injury. Mean follow up was 3.4 ± 1.1 years (range 1.9–5.7 years) following presentation at our department. This study cohort consisted of more female patients, patients with lower Tegner activity scale and fewer patients with meniscus injuries, specifically medial meniscus injuries, compared with the excluded patients (Table 1).

3.2. Copers versus non-copers: Univariate analysis

Sixty-five patients (32%) were copers with their ACL injury, whereas 142 patients (68%) failed conservative treatment and underwent ACL reconstruction. Copers were significantly older than non-copers (40 vs. 27 years, $P < 0.001$), and had lower preinjury activity level (Tegner 5.7 vs. 6.5, $P < 0.001$). Similarly, only 22% of copers were participating in higher level sports compared with 64% of non-copers ($P < 0.001$). Non-copers more often had lateral meniscus tears when compared with copers (16% vs. 5%, $P = 0.019$), but not medial meniscus tears (Table 2). No difference in follow up was noted between both groups ($P = 0.729$).

No difference was noted between copers and non-copers in distal remnant length (both 27 mm, $P = 0.490$) or tear location (69% vs. 67%, respectively, $P = 0.092$). Copers had a shorter proximal remnant length than non-copers (12 vs. 13 mm, respectively, $P = 0.048$). There was also no difference in the proportion of patients with a tear in the proximal quarter between copers and non-copers (23% vs. 18%, $P = 0.383$). Finally, there was a weak but significant positive correlation between older age and more proximal tears (correlation coefficient 0.169, $P = 0.015$).

No statistically significant or clinically relevant difference was noted between copers and non-copers in medial tibial slope (4.1 vs. 4.6°, respectively, $P = 0.351$) or lateral tibial slope (5.7 vs. 6.3°, respectively, $P = 0.194$). Also, no differences were noted in mean slope, difference between medial and lateral slope or proportion of patients with large lateral tibial slope (Table 2).

Regarding the presence of bone bruises, it was noted that copers had significantly less often bone bruises on the lateral femoral condyle when compared with non-copers (35% vs. 66%, respectively, $P < 0.001$). No differences in presence of bone bruises in the other compartments were noted between both groups.

No difference between copers and non-copers was noted in the presence of partial ALL injury (41% vs. 54%, respectively) or complete ALL injury (13% vs. 9%, respectively) (overall $P = 0.204$). Of all injuries, 51% were tibial injuries (8% bony avulsion (Segond fracture), 43% ligamentous injury), 43% were femoral injuries and 8% were both tibial and femoral ALL injuries.

Similar findings were noted for the subgroup of patients without meniscus injury (Table 3), in which 47 patients (34%) were copers and 90 patients (66%) were non-copers. Copers within this subgroup were also older than non-copers (39 vs. 26 years, $P < 0.001$), more often female (64% vs. 44%, $P = 0.031$), had lower preinjury activity level (Tegner 5.8 vs. 6.5, $P < 0.001$) and lower proportion of patients with high activity level (68% vs. 19%, $P < 0.001$). No differences in tear location, tibial slope or ALL injury were noted between copers and non-copers in this subgroup.

3.3. Copers versus non-copers: multivariate analysis

Multivariate binary logistic regression analysis showed that older age ($P < 0.001$), participating in Tegner level sports < 7 ($P = 0.003$) and absence of meniscus injuries ($P = 0.045$) were predictive of coping with ACL deficiency. ACL tear location, tibial slope, presence of lateral bone bruises, and ALL injury were not found to be significant predictors of coping with ACL deficiency when corrected for the other variables (Table 4).

4. Discussion

This study assessed the predictive role of patient demographics, tear location, tibial slope and ALL injury on the success of conservative treatment of ACL injury. Data in this study showed that older age, Tegner activity level and absence of meniscus injury were the only independent predictors of coping with ACL deficiency, whereas there was no role for tear location, tibial slope and ALL injury. These findings can be used by orthopaedic surgeons to assess the likelihood of patients coping with their ACL injury and either start conservative or directly operative treatment for ACL injuries depending on patient demographic or radiological factors.

ACL injuries can either be treated conservatively or operatively and mostly depend on patient factors. Initial conservative treatment can be attempted in patients with ACL injuries and has the advantage of giving patients a chance to become copers, which is estimated to occur in 40–50% of patients [4–6,8,9,47], and this consequently reduces the number of required ACL reconstructions along with surgical costs and potential complications [5]. However, attempting conservative treatment also has disadvantages, as in 50–60% of patients ACL reconstruction is ultimately required and delaying ACL reconstruction

Table 3
Patient demographics and radiological characteristics in patients without any meniscus injuries and between copers and non-copers in this subgroup.

	All patients without meniscus injury n = 137	Copers without meniscus injury n = 47	Non-copers without meniscus injury n = 90	Copers vs. non-copers
Patient demographics				
Age (years) *	30.3 ± 13.0	39.3 ± 13.4	25.6 ± 10.0	**<0.001**[a]
Male gender **	67 (48.9%)	17 (36.2%)	50 (55.6%)	**0.031**[b]
Tegner level *	6.3 ± 0.9	5.8 ± 0.9	6.5 ± 0.9	**<0.001**[a]
High Tegner level **	70 (51.1%)	9 (19.1%)	61 (67.8%)	**<0.001**[b]
Time injury to clinic (months)*	1.2 ± 1.0	1.1 ± 1.1	1.3 ± 1.0	0.491[a]
Tibial slope				
Medial slope *	4.5 ± 2.8	4.1 ± 2.6	4.7 ± 2.9	0.258[a]
Lateral slope *	6.3 ± 3.3	5.7 ± 3.5	6.6 ± 3.2	0.161[a]
Mean slope *	5.4 ± 2.7	4.9 ± 2.6	5.6 ± 2.8	0.151[a]
Difference slope *	1.8 ± 2.8	1.6 ± 3.2	1.9 ± 2.6	0.593[a]
Lateral slope ≥ 9° **	35 (25.5%)	9 (19.1%)	26 (28.9%)	0.215[b]
Anterolateral ligament				
Visualized **	130 (94.9%)	43 (91.5%)	87 (96.7%)	0.083[b]
Intact **	68 (52.3%)	18 (41.9%)	50 (57.5%)	0.242[b]
Partial injury**	49 (37.7%)	20 (46.5%)	29 (33.3%)	
Complete injury **	13 (10.0%)	5 (11.6%)	8 (9.2%)	
Presence of bone bruise				
Lateral femoral condyle **	75 (54.7%)	15 (31.9%)	60 (66.7%)	**<0.001**[b]
Lateral tibial plateau **	103 (75.2%)	34 (72.3%)	69 (76.7%)	0.578[b]
Medial femoral condyle **	10 (7.3%)	2 (4.3%)	8 (8.9%)	0.322[b]
Medial tibial plateau **	63 (46.0%)	18 (38.3%)	45 (50.0%)	0.192[b]
Tear location				
Distal remnant length *	26 ± 4	26 ± 4	26 ± 4	0.500[a]
Proximal remnant length *	13 ± 4	12 ± 3	13 ± 4	0.159[a]
Tear location *	67 ± 8%	68 ± 8%	66 ± 8%	0.104[a]
Tear proximal 25% **	20 (14.6%)	9 (19.1%)	11 (12.2%)	0.276[b]

LM, lateral meniscus; MM, medial meniscus.
*** Data displayed as mean ± standard deviation.
[c] Fisher's exact test.
* Data displayed as median with interquartile.
** Data displayed as n (%).
[a] Independent *t*-test.
[b] Chi-squared test.

Table 4
Multivariate binary logistic analysis of variables predicting successful conservative treatment with anterior cruciate ligament injury (coping).

Variables	Variables	All patients n = 206 OR (95% CI)	*P*
Age (years)	Continuous	**1.06 (1.03–1.09)**	**<0.001**
Tegner activity	≥7 vs. < 7	**0.28 (0.12–0.66)**	**0.004**
Any meniscus tear	No vs. yes	**0.45 (0.20–0.99)**	**0.047**
Tear location	Continuous	1.03 (0.98–1.08)	0.236
Gender	Female vs. Male	1.47 (0.66–3.27)	0.344
ALL injury*	No vs. yes	1.30 (0.63–2.66)	0.478
Lateral bone bruise	No vs. yes	1.19 (0.47–2.99)	0.720
Lateral tibial slope	Continuous	1.01 (0.90–1.13)	0.847

For all patients: R^2 = 0.322, P < 0.001. ALL, anterolateral ligament; CI, confidence interval; OR, odds ratio.
* Partial and complete injury to the ALL was considered as ALL injury.

increases the risk of additional meniscal and cartilage damage [10–12], it will delay the total time from injury to full recovery for patients who want to return to sports, and is associated with higher indirect costs when compared with early ACL reconstruction [13]. It is therefore important to assess what the predictors are for successful conservative treatment of ACL injuries, so that appropriate treatment can be started for each patient.

Age and activity level were found to be the strongest predictors of coping with ACL deficiency in this study. This is similar to the study by Eitzen et al. that noted that patients failing conservative treatment of ACL injury were younger than copers and that there was a higher proportion of patients with level I activity in the non-copers group [48]. These findings are not surprising as it is well known that younger patients are more often participating in higher knee-demanding sports and consequently also have a higher risk of ACL injury [49]. Older patients, conversely, are more likely to adjust their activity level in order to prevent surgery. Another factor that may play a role, might be the severity of the injury in younger and older groups. It is possible that older and less active patients had lower-energy knee injuries and less injury of their secondary stabilizers (or less overall damage), and as a result are better copers than young patients that more often have higher-energy knee injuries. An argument for this hypothesis is the lower incidence of LFC bone bruises in the coping group that has a higher age and lower activity levels.

In a previous study by our group, we noted that patients younger than 25 years and patients younger than 40 years with high activity levels had a high likelihood of failing conservative treatment [8]. In these patients, surgeons should consider early ACL reconstruction as there are certain advantages. Delaying surgery in these patients not only causes a longer time from injury to final return to sports due to the extra weeks to months of NMT despite the low likelihood of success in these groups, but also increases the risk of additional meniscal and cartilage damage that is noted with delayed ACL reconstruction [10–12]. Furthermore, in these younger patients there are lower indirect costs by short sick-day leave when early surgery is performed [13]. Based on historical studies, some may argue that early surgery increases the risk of arthrofibrosis, but several recent randomized controlled trials and prospective studies have shown that there is no increased risk of arthrofibrosis with early arthroscopic surgery [50,51], while some have even suggested that there is less quadriceps muscle atrophy, better functional testing and less pain after 6 months [52,53].

Although there had been no interest in the location of ACL tears for decades, recently several studies have examined the role of primary repair for proximal ACL tears [16–21] and therefore the interest in tear location has increased [54–57]. Proximal tears in these cohorts are treated with primary repair in an early setting, and the overall results are generally good [16–21]. Primary repair of proximal tears has been advocated for selective patients with these tear types, since proximal ACL regions have better vascularity than mid-substance regions [14] and therefore proximal tears have healing potential that is similar to medial collateral ligament tears [15]. Conversely, these same arguments can be used for treating proximal tears conservatively, as these tears might have better chance of healing or reattachment with the better vascularity. This is supported by case reports or small case series that have shown healing of predominantly proximal ACL tears [22–25], but this could not be confirmed in this study. Although there was a significant difference in proximal remnant length between copers and non-copers (albeit small with 1 mm) and a trend towards a more proximal tear location in the copers compared with the non-copers group, these differences were not present in the multivariate regression analysis. This can be explained by the confounding factor of age that was present as there was a significant correlation between older age and more proximal tear location in this cohort ($P = 0.015$). As copers are generally older patients than non-copers, the tear location might have seemed a significant factor in univariate analysis but multivariate analysis showed that age is the significant and relevant predictor of coping and not tear location. Other cohorts have also reported that there is a correlation between older age and more proximal tear location [55,58], although the reason for this remains unknown.

It was hypothesized in this study that tibial slope would play a predictive role in the success of conservative treatment but this was not found in this study. There are possible explanations for these findings. First of all, it was noted that age and Tegner activity were both independent predictors of the success of conservative treatment and it seems that those factors are more relevant than tibial slope. Furthermore, the number of patients with a lateral tibial slopes of $\geq 9^{\circ}$ were fairly small, and it is possible that larger cohorts with these extreme slopes would find a significant role on failing conservative treatment. Also, it is possible that a selection bias has occurred in this study as a large group of patients were excluded for undergoing direct operative treatment. It is possible that these patients potentially had a larger tibial slope, and consequently were more symptomatic with more giving way symptoms or a more severe ACL injury and were therefore scheduled for surgery without first undergoing conservative treatment. Future prospective studies in which all patients with ACL injuries are included and followed are needed to repeat this analysis.

ALL injury was also not found to be a significant predictor of success of conservative treatment of ACL injuries. First of all, the number of patients that had successful coping in this study was only 65, and that makes analysis of the role of ALL on successful coping difficult. Furthermore, it is possible that, similar to tibial slope, there has been a selection bias in this study with more exclusion of patients with ALL injury. Future studies assessing ALL injury, clinical preoperative pivot shift and final coping with ACL injury are necessary to further investigate this.

For gender, univariate analysis showed a trend towards more females in the coping group and suggested that females might be better copers, but multivariate analysis showed that there was no predictive role for gender. This can be explained by the confounding effect of age on gender and coping, as female patients in this study were significantly older (35 ± 15 years) compared with male patients (28 ± 11 years, $P < 0.001$), and multivariate analysis showed that an independent predictive role for gender could not be identified in this study. This is similar to the study by Eitzen et al. which found a higher proportion of female patients in the coping group in univariate analysis but not in multivariate analysis [48].

In this study, meniscus injury was found to be an independent predictor of failing conservative treatment and undergoing ACL reconstruction. In the univariate analysis, it was noted that non-copers had significantly more lateral meniscus tears when compared with copers while this was not the case for medial meniscus tears. This could be explained by the fact that lateral meniscus tears in the setting of ACL deficiency cause a higher degree of rotational instability as displayed in the pivot shift test whereas medial meniscus tears cause a higher degree of anterior tibial translation (ATT) as displayed in the Lachman test [59,60]. It is possible that medial meniscus tears and thus increased ATT can be stabilized with NMT or at least do not have symptomatic giving way, whereas patients with lateral meniscus tears have more rotational instability, and that this might be more difficult to stabilize with NMT, and they consequently have more symptoms of giving way and more dis-satisfaction with the function of their ACL-deficient knee [61,62]. Similar findings were noted with a higher proportion of patients with concomitant lateral meniscus injury in the excluded group, which were mainly excluded due to direct operative treatment (Table 1). These findings, however, need to be confirmed in larger-cohort studies, especially because the number of lateral meniscus tears was relatively low.

Finally, it should be noted that the goal of this study was not to assess the percentage of copers and non-copers following ACL injury, and the percentage of copers (32%) was relatively low in this study compared with other studies (40–50%) [4–6,8,9]. In this study, (older) patients without MRI were excluded and this may have resulted in a lower incidence of copers. A previous study by our group that had the goal of assessing the percentage of copers with ACL injury, found a percentage of 40% (citation blinded), which is comparable with the literature [4–6,8,9,47].

Limitations are present in this study. A potential selection bias might be present as not all patients with ACL injury might have presented to our clinic (copers might have presented to their general practitioner and a referral might have been felt to be unnecessary given their good coping). Nonetheless, we believe that this group is a representative group of patients that present with acute or subacute tears in the orthopaedic department of a hospital. Secondly, this is a retrospective study and potential confounders and other biases might also have been present. Also, small number of patients with lateral meniscus tears and large tibial slopes were present in this study, and future studies assessing the role of these secondary stabilizers is needed, especially as these factors are correlated with pivot shift mechanism and giving way symptoms in patients, and might be an important reason for failing conservative treatment.

5. Conclusions

This study assessed the predictive role of patient demographics and radiological parameters on the success of conservative treatment of ACL injuries, and noted that older age, lower activity level and absence of meniscus injuries were independent predictors of coping with ACL deficiency, while no predictive role for tear location, tibial slope, bone bruises, or ALL injury were found. These findings can be used for advising patients on the likelihood of success of conservative treatment of ACL injuries, and can help surgeons to indicate patients for conservative treatment or early ACL reconstruction based on these patient demographics and radiological parameters.

Funding

None.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Lyman S, Koulouvaris P, Sherman S, Do H, Mandl LA, Marx RG. Epidemiology of anterior cruciate ligament reconstruction: trends, readmissions, and subsequent knee surgery. J Bone Joint Surg Am 2009;91:2321–8.
[2] Sanders TL, Maradit Kremers H, Bryan AJ, Larson DR, Dahm DL, Levy BA, et al. Incidence of anterior cruciate ligament tears and reconstruction: A 21-year population-based study. Am J Sports Med 2016;44:1502–7.
[3] Gianotti SM, Marshall SW, Hume PA, Bunt L. Incidence of anterior cruciate ligament injury and other knee ligament injuries: a national population-based study. J Sci Med Sport 2009;12:622–7.
[4] Frobell RB, Roos EM, Roos HP, Ranstam J, Lohmander LS. A randomized trial of treatment for acute anterior cruciate ligament tears. N Engl J Med 2010;363:331–42.
[5] Frobell RB, Roos HP, Roos EM, Roemer FW, Ranstam J, Lohmander LS. Treatment for acute anterior cruciate ligament tear: five year outcome of randomised trial. BMJ 2013;346:f232.
[6] Eitzen I, Moksnes H, Snyder-Mackler L, Risberg MA. A progressive 5-week exercise therapy program leads to significant improvement in knee function early after anterior cruciate ligament injury. J Orthop Sports Phys Ther 2010;40:705–21.
[7] van Melick N, van Cingel RE, Brooijmans F, Neeter C, van Tienen T, Hullegie W, et al. Evidence-based clinical practice update: practice guidelines for anterior cruciate ligament rehabilitation based on a systematic review and multidisciplinary consensus. Br J Sports Med 2016;50:1506–15.
[8] van der List JP, Hagemans FJA, Hofstee DJ, Jonkers FJ. The role of patient characteristics on the success of nonoperative treatment of anterior cruciate ligament injuries. Am J Sports Med 2020;48:1657–64.
[9] Hurd WJ, Axe MJ, Snyder-Mackler L. Influence of age, gender, and injury mechanism on the development of dynamic knee stability after acute ACL rupture. J Orthop Sports Phys Ther 2008;38:36–41.
[10] Fithian DC, Paxton EW, Stone ML, Luetzow WF, Csintalan RP, Phelan D, et al. Prospective trial of a treatment algorithm for the management of the anterior cruciate ligament-injured knee. Am J Sports Med 2005;33:335–46.
[11] Karikis I, Ahlen M, Sernert N, Ejerhed L, Rostgard-Christensen L, Kartus J. The long-term outcome after early and late anterior cruciate ligament reconstruction. Arthroscopy 2018;34:1907–17.
[12] Sommerfeldt M, Goodine T, Raheem A, Whittaker J, Otto D. Relationship between time to ACL reconstruction and presence of adverse changes in the knee at the time of reconstruction. Orthop J Sports Med 2018;6. 232596711881391.
[13] von Essen C, McCallum S, Barenius B, Eriksson K. Acute reconstruction results in less sick-leave days and as such fewer indirect costs to the individual and society compared to delayed reconstruction for ACL injuries. Knee Surg Sports Traumatol Arthrosc 2019;28:2044–52.
[14] Toy BJ, Yeasting RA, Morse DE, McCann P. Arterial supply to the human anterior cruciate ligament. J Athl Train 1995;30:149–52.
[15] Nguyen DT, Ramwadhdoebe TH, van der Hart CP, Blankevoort L, Tak PP, van Dijk CN. Intrinsic healing response of the human anterior cruciate ligament: An histological study of reattached ACL remnants. J Orthop Res 2014;32:296–301.

[16] Achtnich A, Herbst E, Forkel P, Metzlaff S, Sprenker F, Imhoff AB, et al. Acute proximal anterior cruciate ligament tears: Outcomes after arthroscopic suture anchor repair versus anatomic single-bundle reconstruction. Arthroscopy 2016;32:2562–9.
[17] van der List JP, DiFelice GS. Primary repair of the anterior cruciate ligament: A paradigm shift. Surgeon 2017;15:161–8.
[18] Hoffmann C, Friederichs J, von Ruden C, Schaller C, Buhren V, Moessmer C. Primary single suture anchor re-fixation of anterior cruciate ligament proximal avulsion tears leads to good functional mid-term results: a preliminary study in 12 patients. J Orthop Surg Res 2017;12:171.
[19] Heusdens CHW, Hopper GP, Dossche L, Roelant E, Mackay GM. Anterior cruciate ligament repair with independent suture tape reinforcement: A case series with 2-year follow-up. Knee Surg Sports Traumatol Arthrosc 2019;27:60–7.
[20] Hoogeslag RAG, Brouwer RW, Boer BC, de Vries AJ, Huis in 't Veld R. Acute anterior cruciate ligament rupture: Repair or reconstruction? Two-year results of a randomized controlled clinical trial. Am J Sports Med 2019;47:567–77.
[21] Kosters C, Glasbrenner J, Spickermann L, Kittl C, Domnick C, Herbort M, et al. Repair with dynamic intraligamentary stabilization versus primary reconstruction of acute anterior cruciate ligament tears: 2-year results from a prospective randomized study. Am J Sports Med 2020;48:1108–16.
[22] Crain EH, Fithian DC, Paxton EW, Luetzow WF. Variation in anterior cruciate ligament scar pattern: does the scar pattern affect anterior laxity in anterior cruciate ligament-deficient knees?. Arthroscopy 2005;21:19–24.
[23] Fujimoto E, Sumen Y, Ochi M, Ikuta Y. Spontaneous healing of acute anterior cruciate ligament (ACL) injuries – conservative treatment using an extension block soft brace without anterior stabilization. Arch Orthop Trauma Surg 2002;122:212–6.
[24] Hetsroni I, Delos D, Fives G, Boyle BW, Lillemoe K, Marx RG. Nonoperative treatment for anterior cruciate ligament injury in recreational alpine skiers. Knee Surg Sports Traumatol Arthrosc 2013;21:1910–4.
[25] Costa-Paz M, Ayerza MA, Tanoira I, Astoul J, Muscolo DL. Spontaneous healing in complete ACL ruptures: a clinical and MRI study. Clin Orthop Relat Res 2012;470:979–85.
[26] Wordeman SC, Quatman CE, Kaeding CC, Hewett TE. In vivo evidence for tibial plateau slope as a risk factor for anterior cruciate ligament injury: a systematic review and meta-analysis. Am J Sports Med 2012;40:1673–81.
[27] Andrade R, Vasta S, Sevivas N, Pereira R, Leal A, Papalia R, et al. Notch morphology is a risk factor for ACL injury: a systematic review and meta-analysis. J ISAKOS 2016;1:70–81.
[28] DePhillipo NN, Zeigler CG, Dekker TJ, Grantham WJ, Aman ZS, Kennedy MI, et al. Lateral posterior tibial slope in male and female athletes sustaining contact versus noncontact anterior cruciate ligament tears: A prospective study. Am J Sports Med 2019;47:1825–30.
[29] Bayer S, Meredith SJ, Wilson K, de Sa D, Pauyo T, Byrne K, et al. Knee morphological risk factors for anterior cruciate ligament injury: a systematic review. J Bone Joint Surg Am 2020;102:703–18.
[30] Christensen JJ, Krych AJ, Engasser WM, Vanhees MK, Collins MS, Dahm DL. Lateral tibial posterior slope is increased in patients with early graft failure after anterior cruciate ligament reconstruction. Am J Sports Med 2015;43:2510–4.
[31] Jaecker V, Drouven S, Naendrup JH, Kanakamedala AC, Pfeiffer T, Shafizadeh S. Increased medial and lateral tibial posterior slopes are independent risk factors for graft failure following ACL reconstruction. Arch Orthop Trauma Surg 2018;138:1423–31.
[32] Napier RJ, Garcia E, Devitt BM, Feller JA, Webster KE. Increased radiographic posterior tibial slope is associated with subsequent injury following revision anterior cruciate ligament reconstruction. Orthop J Sports Med 2019;7. 2325967119879373.
[33] Sharifi M, Shirazi-Adl A, Marouane H. Computation of the role of kinetics, kinematics, posterior tibial slope and muscle cocontraction on the stability of ACL-deficient knee joint at heel strike – towards identification of copers from non-copers. J Biomech 2018;77:171–82.
[34] Rahnemai-Azar AA, Abebe ES, Johnson P, Labrum J, Fu FH, Irrgang JJ, et al. Increased lateral tibial slope predicts high-grade rotatory knee laxity pre-operatively in ACL reconstruction. Knee Surg Sports Traumatol Arthrosc 2016;25:1170–6.
[35] Getgood AMJ, Bryant DM, Litchfield R, Heard M, McCormack RG, Rezansoff A, et al. Lateral extra-articular tenodesis reduces failure of hamstring tendon autograft anterior cruciate ligament reconstruction: 2-year outcomes from the STABILITY Study Randomized Clinical Trial. Am J Sports Med 2020;48:285–97.
[36] Sonnery-Cottet B, Saithna A, Cavalier M, Kajetanek C, Temponi EF, Daggett M, et al. Anterolateral ligament reconstruction is associated with significantly reduced acl graft rupture rates at a minimum follow-up of 2 years. Am J Sports Med 2017;45:1547–57.
[37] Porter M, Shadbolt B. Modified iliotibial band tenodesis is indicated to correct intraoperative residual pivot shift after anterior cruciate ligament reconstruction using an autologous hamstring tendon graft: A prospective randomized controlled trial. Am J Sports Med 2020;48:1069–77.
[38] Viskontas DG, Giuffre BM, Duggal N, Graham D, Parker D, Coolican M. Bone bruises associated with ACL rupture. Am J Sports Med 2017;36:927–33.
[39] van Grinsven S, van Cingel REH, Holla CJM, van Loon CJM. Evidence-based rehabilitation following anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2010;18:1128–44.
[40] Eshuis R, Lentjes GW, Tegner Y, Wolterbeek N, Veen MR. Dutch Translation and cross-cultural adaptation of the Lysholm Score and Tegner Activity Scale for patients with anterior cruciate ligament injuries. J Orthop Sports Phys Ther 2016;46:976–83.
[41] Hendrix ST, Barrett AM, Chrea B, Replogle WH, Hydrick JM, Barrett GR. Relationship between posterior-inferior tibial slope and bilateral noncontact ACL injury. Orthopedics 2017;40:e136–40.
[42] Hashemi J, Chandrashekar N, Gill B, Beynnon BD, Slauterbeck JR, Schutt RC, et al. The geometry of the tibial plateau and its influence on the biomechanics of the tibiofemoral joint. J Bone Joint Surg Am 2008;90:2724–34.
[43] Lipps DB, Wilson AM, Ashton-Miller JA, Wojtys EM. Evaluation of different methods for measuring lateral tibial slope using magnetic resonance imaging. Am J Sports Med 2012;40:2731–6.
[44] Brittberg M, Winalski CS. Evaluation of cartilage injuries and repair. J Bone Joint Surg Am 2003;85:58–69.
[45] Marot V, Corin B, Reina N, Murgier J, Berard E, Cavaignac E. Femoral and tibial bone bruise volume is not correlated with ALL injury or rotational instability in patients with ACL-deficient knee. Knee Surg Sports Traumatol Arthrosc 2020.
[46] Monaco E, Helito CP, Redler A, Argento G, De Carli A, Saithna A, et al. Correlation between magnetic resonance imaging and surgical exploration of the anterolateral structures of the acute anterior cruciate ligament-injured knee. Am J Sports Med 2019;47:1186–93.
[47] Kvist J, Filbay S, Andersson C, Ardern CL, Gauffin H. Radiographic and symptomatic knee osteoarthritis 32 to 37 years after acute anterior cruciate ligament rupture. Am J Sports Med 2020;48:2387–94.
[48] Eitzen I, Moksnes H, Snyder-Mackler L, Engebretsen L, Risberg MA. Functional tests should be accentuated more in the decision for ACL reconstruction. Knee Surg Sports Traumatol Arthrosc 2010;18:1517–25.
[49] Nicholls M, Aspelund T, Ingvarsson T, Briem K. Nationwide study highlights a second peak in ACL tears for women in their early forties. Knee Surg Sports Traumatol Arthrosc 2018;26:648–54.
[50] Deabate L, Previtali D, Grassi A, Filardo G, Candrian C, Delcogliano M. Anterior Cruciate ligament reconstruction within 3 weeks does not increase stiffness and complications compared with delayed reconstruction: a meta-analysis of randomized controlled trials. Am J Sports Med 2019;48:1263–72.
[51] Kwok CS, Harrison T, Servant C. The optimal timing for anterior cruciate ligament reconstruction with respect to the risk of postoperative stiffness. Arthroscopy 2013;29:556–65.
[52] Eriksson K, von Essen C, Jonhagen S, Barenius B. No risk of arthrofibrosis after acute anterior cruciate ligament reconstruction. Knee Surg Sports Traumatol Arthrosc 2018;26:2875–82.
[53] von Essen C, Eriksson K, Barenius B. Acute ACL reconstruction shows superior clinical results and can be performed safely without an increased risk of developing arthrofibrosis. Knee Surg Sports Traumatol Arthrosc 2019;28:2036–43.
[54] van der List JP, DiFelice GS. Role of tear location on outcomes of open primary repair of the anterior cruciate ligament: a systematic review of historical studies. Knee 2017;24:898–908.
[55] van der List JP, Mintz DN, DiFelice GS. The location of anterior cruciate ligament tears: a prevalence study using magnetic resonance imaging. Orthop J Sports Med 2017;5. 2325967117709966.

[56] Henle P, Roder C, Perler G, Heitkemper S, Eggli S. Dynamic Intraligamentary Stabilization (DIS) for treatment of acute anterior cruciate ligament ruptures: case series experience of the first three years. BMC Musculoskelet Disord 2015;16:27.
[57] Krismer AM, Gousopoulos L, Kohl S, Ateschrang A, Kohlhof H, Ahmad SS. Factors influencing the success of anterior cruciate ligament repair with dynamic intraligamentary stabilisation. Knee Surg Sports Traumatol Arthrosc 2017;25:3923–8.
[58] van der List JP, Jonkergouw A, van Noort A, Kerkhoffs G, DiFelice GS. Identifying candidates for arthroscopic primary repair of the anterior cruciate ligament: A case-control study. Knee 2019;26:619–27.
[59] Musahl V, Citak M, O'Loughlin PF, Choi D, Bedi A, Pearle AD. The effect of medial versus lateral meniscectomy on the stability of the anterior cruciate ligament-deficient knee. Am J Sports Med 2010;38:1591–7.
[60] Hoshino Y, Miyaji N, Nishida K, Nishizawa Y, Araki D, Kanzaki N, et al. The concomitant lateral meniscus injury increased the pivot shift in the anterior cruciate ligament-injured knee. Knee Surg Sports Traumatol Arthrosc 2019;27:646–51.
[61] Monaco E, Maestri B, Conteduca F, Mazza D, Iorio C, Ferretti A. Extra-articular ACL reconstruction and pivot shift. Am J Sports Med 2014;42:1669–74.
[62] Kocher MS, Steadman JR, Briggs K, Zurakowski D, Sterett WI, Hawkins RJ. Determinants of patient satisfaction with outcome after anterior cruciate ligament reconstruction. J Bone Joint Surg Am 2002;84:1560–72.