

Combined Anterior Cruciate and Anterolateral Ligament Reconstruction in the Professional Athlete: Clinical Outcomes From the SANTI Group in a Series of 70 Patients With a Minimum Follow-Up of 2 Years

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Purpose: To evaluate clinical outcomes in professional athletes after combined anterior cruciate ligament (ACL) and anterolateral ligament (ALL) reconstruction at a minimum follow-up of 2 years. **Methods:** A retrospective analysis of prospectively collected data from the SANTI Study Group database was performed. All professional athletes who underwent primary combined ACL and ALL reconstruction between January 2011 and March 2016 were included. Patient assessment included physical examination, pre- and postoperative subjective and objective International Knee Documentation Committee (IKDC), Tegner activity scale, and Lysholm scores. **Results:** Seventy-two professional athletes underwent primary ACL and ALL reconstruction; 70 (97%) were available, with a mean follow-up of 3.9 years (range, 2-7). The preoperative side-to-side anteroposterior laxity difference was 7.1 ± 1.4 mm, and this decreased significantly after surgery to 0.4 ± 0.9 mm ($P < .0001$). Pivot-shift grade evolved from 16 grade I (22.8%) and 54 grade II or III (77.2%) preoperatively, to 66 absent pivot shift (94.3%) and 4 grade I (5.7%; $P < .001$). By 1-year postoperatively, 60 athletes (85.7%) returned to professional sport, with a mean time interval of 7.9 months (range, 5-12). Preoperatively, the mean subjective IKDC was 56.1 ± 12.3 , the Lysholm score was 48.4 ± 12.5 , and the Tegner score was 9.3 ± 1 . At final follow-up, the mean subjective IKDC was 90.5 ± 7.6 ($P < .0001$), the Lysholm score was 94.4 ± 7.5 ($P < .0001$), and the Tegner score was 8.8 ± 1.5 ($P < .004$). The objective IKDC evolved from 39 grade C (55.7%) and 31 grade D (44.3%) preoperatively to 65 grade A (92.9%) and 5 grade B (7.1%) ($P < .0001$). Eleven Patients (15.7%) underwent a subsequent ipsilateral reoperation including 4 (5.7%) revision ACL reconstructions. The risk of graft rupture was significantly higher in female patients (13.6% vs 2.1% in male patients; $P = .048$). **Conclusions:** Combined ACL and ALL reconstruction is associated with excellent outcomes in professional athletes with respect to graft rupture rates, return to sport, knee stability, and reoperation rates after injury. **Level of Evidence:** Level IV, case series.

Despite a major focus on injury prevention, the rates of anterior cruciate ligament (ACL) rupture have remained relatively unchanged over the last 25 years.¹⁻³ ACL rupture continues to represent a devastating injury with potentially career-ending consequences for the professional athlete. Even for those individuals who return to elite sport, there is evidence that they may not be used by their team in competition

as frequently, that their earning potential is significantly reduced, and that their overall careers may be shorter than age-matched controls.^{4,5} However, in contrast to the general population, the rate of return to sport in professional athletes is very high,⁶ but this also means that they are at significantly greater risk of ACL graft rupture when compared with those with a sedentary lifestyle.^{7,8}

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Walden et al.⁹ highlighted that the rates of ACL graft rupture were unacceptably high in professional soccer athletes, and these concerns are mirrored in numerous reports of graft rupture rates between 18% and 20% in high-risk populations.¹⁰⁻¹³ Specifically, Walden et al. also reported that a large proportion of these injuries occurs in the first year after ACL reconstruction (ACLR), with 4% having a graft rupture before returning to match play and a further 3% having reinjury within 3 months after their first match appearance. The investigators concluded that changes in primary and secondary preventive measures are urgently needed in professional football.⁹

Recently, Sonnery-Cottet et al.¹⁴ demonstrated that combined ACL and anterolateral ligament (ALL) reconstruction was associated with significantly reduced ACL graft rupture rates when compared with isolated ACLR. Furthermore, several systematic reviews have demonstrated that a lateral extra-articular procedure performed at the time of ACLR results in improved knee stability.¹⁵⁻¹⁷ This is consistent with the work of Guzzini et al.,¹⁸ who reported no graft ruptures and excellent knee stability at medium term follow-up after combined ACLR and lateral extra-articular tenodesis in a high-risk population of 16 elite female soccer players. Although these results are promising, further study is required because of the small study population and the lack of applicability to professional athletes participating in other sports.

The aim of this study was to evaluate clinical outcomes in professional athletes after combined ACL and ALL reconstruction at a minimum follow-up of 2 years. The study hypothesis was that combined ACL and ALL reconstruction in professional athletes would be associated with good clinical outcomes.

Methods

The study was approved by the hospital research and ethics committee and was performed in accordance with the Declaration of Helsinki ethical standards. Informed consent was obtained from all participants prior to enrollment in the study.

A retrospective analysis of prospectively collected data from the SANTI database was performed. All professional athletes who had sustained a primary ACL rupture and had undergone ligament reconstruction by an experienced orthopaedic surgeon (B.S.-C.) during the study period (January 2011 to March 2016) were considered for study eligibility. Patients were defined as professional athletes by participation in competition at national and/or international levels at the time of injury. Patients were only excluded from the study if they met one of the following criteria: <2 years of postoperative follow-up available, age <15 years at the time of surgery, injury to the collateral ligaments of severity > grade 2, and any other ligament injury.

Meniscal injuries were not considered to be an exclusion criterion.

In all cases, the indication for surgery was symptomatic instability owing to ACL rupture confirmed by clinical and magnetic resonance imaging evaluation. Since November 2010, it has been our standard practice to perform concomitant ALL reconstruction in all professional athletes undergoing ACLR, and therefore all patients in the study underwent a combined procedure.

Surgical Procedure

Combined ACL and ALL reconstruction was performed as described elsewhere.^{19,20} Concomitant intra-articular meniscal and chondral pathology was addressed in the standard manner. The procedure is briefly summarized here and illustrated in [Figure 1](#): Hamstring tendon autograft was harvested. The gracilis tendon was detached and sutured to a tripled semitendinosus with its tibial attachment preserved. The ACL graft was then created using a tripled semitendinosus tendon and an additional strand of the gracilis tendon, the excess length of gracilis tendon forming the ALL graft. An outside-in femoral guide



Fig 1. Anterior cruciate ligament reconstruction combined with anterolateral ligament (quadruple hamstring graft + anterolateral ligament).

Table 1. Patient Demographics

	Patients (n = 70)
Gender (%)	48 male (68.6), 22 female (31.4)
Age, yr (range)	23.2 (15-37)
Body mass index (range)	23.7 (19-36)
Follow-up, years (range)	3.9 (2-7)
Time from injury to surgery, mo (range)	1.1 (0.1-7)
Meniscal tears, n (%):	
Medial	22 (31.9)
Lateral	31 (45)
Meniscal surgery, n (%):	
Medial:	
Repair	19 (86.4)
Meniscectomy	3 (13.6)
Lateral:	
Repair	29 (93.5)
Meniscectomy	2 (6.5)

was placed proximal and posterior to the lateral epicondyle and at the femoral origin of the ACL and used to drill a tunnel of the same size as the graft diameter. For ALL reconstruction, a 4.5-mm drill was used to create a tibial tunnel. The combined graft was then routed proximally through the knee. The ACL portion of the graft was fixed with interference screws on tibial and femoral sides with the knee in 30° of flexion. The ALL graft was then routed deep to the iliotibial band from the femur, through the tibial tunnel, and back under the iliotibial band to the anatomic origin of the ALL. The knee was placed in full extension and neutral rotation, and the graft was secured to itself at this location with a previously placed nonabsorbable suture.

Rehabilitation

Patients were asked to mobilize brace free, weight bearing with crutches immediately after surgery, unless they underwent a meniscal repair, in which case they were instructed to remain partial weight bearing and limit their flexion to 90° for 6 weeks. Cycling was recommended at 1 month, jogging at 3 months, and return to competition at 6 to 9 months.

Outcome Assessment

Patients were reviewed at 3 and 6 weeks and at 3, 6, 12, and 24 months postoperatively and at their final follow-up appointment. Patient assessment included preinjury, pre- and postoperative subjective and objective International Knee Documentation Committee (IKDC), Tegner activity scale, and Lysholm score. Physical examinations were performed by a sports medicine physician, a surgeon, or an author other than the primary surgeon. This examination included complete ligament examination following the instruction for the 2000 IKDC knee examination form. Instrumented knee testing was performed before

surgery and at final follow-up with the Rolimeter Arthrometer (Aircast Europe). Any complications or ongoing symptoms were assessed by clinical examination and with further imaging if necessary. A record of whether the athlete underwent any subsequent knee injury or surgery was made, including revision ACLR or a contralateral ACL rupture. Furthermore, the level of competition before and after surgery and the time taken to return to a competitive level after surgery were analyzed.

Statistical Analysis

All calculations were made with SAS for Windows (version 9.4; SAS Institute) unless otherwise stated. The level of statistical significance was set at $P < .05$. Descriptive data (mean, median, range, proportion) are reported for the entire series, and demographic variables (sex, age, body mass index, and follow-up) were examined. The paired Student's *t*-test was used to compare the pre- and postoperative IKDC subjective evaluation and Lysholm scores. The Mantel-Haenszel test was used to compare variables for which the Gaussian distribution was not verified. This included the pre- and postoperative pivot-shift test results, knee laxity, and the IKDC objective evaluation. The signed rank test was used to compare the preinjury and postoperative Tegner evaluation and the side-to-side laxity differential. The Kaplan-Meier method was used to estimate the cumulative survivorship with respect to both ipsilateral graft failure and contralateral ACL rupture. The

Table 2. Clinical Outcomes

	Preoperative	Postoperative	<i>P</i> Value
IKDC subjective score	56.1 ± 13.3	90.5 ± 7.6	<.0001
IKDC objective score:			<.0001
A		65 (92.9)	
B		5 (7.1)	
C	39 (55.7)		
D	31 (44.3)		
Tegner	9.3 ± 1*	8.8 ± 1.5	.0004
Lysholm	48.4 ± 12.5	94.4 ± 7.5	<.0001
Pivot shift (IKDC grade):			<.0001
0 (equal)		66 (94.3)	
1 (glide)	16 (22.8)	4 (5.7)	
2 (clunk)	23 (32.9)		
3 (gross)	31 (44.3)		
Mean instrumented anteroposterior laxity side-to-side, mm (range)	7.1 ± 1.4 (4-12)	0.4 ± 0.9 (-2 to 3)	<.0001
Laxity (IKDC grade), mm:			<.0001
<3		69 (98.6)	
3-5	2 (2.9)	1 (1.4)	
6-10	63 (90)		
>10	5 (7.1)		

Values are reported as mean ± standard deviation or n (%).

IKDC, International Knee Documentation Committee.

*Preinjury Tegner.

Table 3. Indications for Reoperation After the Index Procedure

Reoperations	n (%)	Mean Time in Months From Index Surgery to Reoperation
Total no. of reoperations	11 (15.7)	15.3
Revision anterior cruciate ligament reconstruction	4 (5.7)	23.9
Medial partial meniscectomy	3 (4.3)	14
Lateral partial meniscectomy	1 (1.4)	18
Cyclops removal	1 (1.4)	11.7
Hemarthrosis	1 (1.4)	0.1
Deep infection	1 (1.4)	0.3

stratified log-rank statistic was used to select predictors in univariate analysis of postoperative graft failure or contralateral ACL rupture. A univariate Cox model was used to estimate hazard ratios and 95% confidence limits.

Results

Seventy-two professional athletes underwent primary ACLR using the combined ACL+ALL reconstruction technique. Two patients were lost to follow-up despite efforts to contact them. The remaining 70 (97%) patients were available, with a mean follow-up of 3.9 years (range, 2-7). Patient demographics and details of meniscal pathology and treatment are summarized in Table 1.

Postoperative Outcomes

The clinical outcomes including subjective scoring and objective results are reported in Table 2. Eleven patients (15.7%) underwent a subsequent reoperation, and specific details are reported in Table 3. It should be noted that none of the patients experienced any restriction in range of flexion postoperatively.

ACL graft rupture rates are also reported in Table 3. In total only 4 patients sustained a graft rupture and 3 of these occurred in professional soccer players. The

Table 4. Characteristics of Patients Sustaining an ACL Graft Rupture

	ACL Graft Rupture Group
Age at index surgery, yr (range)	19.7 (16-21.8)
Gender	1 male; 3 female
Patients with meniscal lesion at index surgery (%)	25
Follow-up, yr (range)	4 (3.4-4.7)
IKDC subjective score at final follow-up (range)	76.4 (57.9-98.9)
Tegner at final follow-up (range)	7.25 (5-10)
Lysholm at final follow-up (range)	77.5 (60-86)
IKDC objective score at final follow-up	1A, 3B

ACL, anterior cruciate ligament; IKDC, International Knee Documentation Committee.

Table 5. The Spectrum of Occurrence of Contralateral ACL Rupture Within the Study Population

	n (%)
Total no. of contralateral ACL ruptures	19 (27.1)
Before index procedure	9 (12.8)
After index procedure	10 (14.3)

ACL, anterior cruciate ligament.

characteristics of patients sustaining a graft rupture are reported in Table 4.

Contralateral ACL rupture rates are reported in Table 5 and stratified by gender in Table 6. Although 19 patients had a contralateral ACL rupture prior to the end of the study period it is important to highlight that approximately half of these occurred before the index procedure.

Figure 2 shows the data from Kaplan-Meier analysis of ACL graft failure, stratified by gender. This analysis shows a significantly greater risk of graft failure for female athletes ($P = .048$).

Univariate analysis was performed to evaluate potentially important factors for an association with the risk of graft rupture or a postoperative contralateral ACL rupture. None of the investigated variables showed a significant association (Tables 7 and 8).

Table 9 stratifies the occurrence of contralateral ACL rupture and ipsilateral graft rupture by each specific sport.

Return to Sport and Retirement

By 1 year of follow-up, 60 athletes (85.7%) had returned to the same level of professional competition that they participated in prior to injury, with a mean delay of 7.9 months (range, 5-12). Table 10 reports return to sport metrics. At final follow-up, 16 athletes had retired from professional sports, with only 1 citing knee problems (Table 11).

Discussion

The main findings of this study are that combined ACL and ALL reconstruction are associated with good clinical results in the professional athlete. In all, 85.7% of patients were able to return to the same level of competitive sports that they had participated in prior to the

Table 6. Rates of Contralateral and Revision ACLR After Index Procedure Stratified by Gender Distribution With the Kaplan-Meier Method

	Female (n = 22)	Male (n = 48)	P Value Log-Rank
Contralateral ACL (%)	5 (22.7)	5 (10.4)	.170
Revision ACLR (%)	3 (13.6)	1 (2.1)	.048

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction.

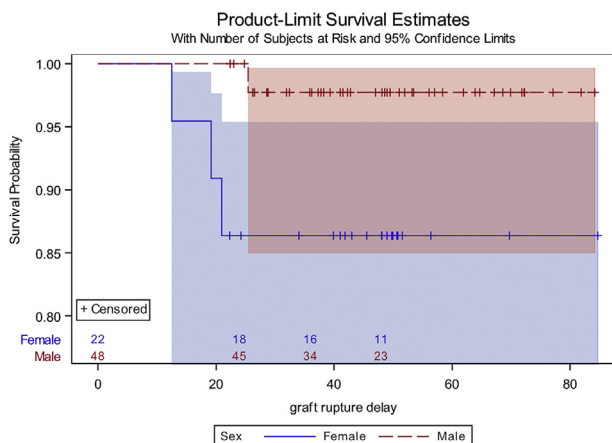


Fig 2. Survivorship data from Kaplan-Meier analysis of anterior cruciate ligament graft failure stratified by gender.

injury. The time taken to return to this level varied between 5 and 12 months from the date of surgery; 93% of patients ($n = 65$) improved their subjective IKDC score beyond the minimal clinically important difference value (16.7), and 97% ($n = 68$) of patients have a final IKDC score superior to the patient acceptable symptom state value.²¹ All patients improved their Lysholm score over the MDC value (8.9). The Tegner score was lower than the preoperative one without statistical significance, and 61 patients (87%) have a difference lower or equal to the Tegner minimum detectable change. The overall graft rupture rate was 5.7% at a mean follow-up of 3.9 years. These figures are broadly comparable to the findings of Lai et al.,⁶ who in a recent systematic review reported that a mean of 83% of elite athletes were able to return to the preinjury level of sport; they took a mean time of 6 to 13 months to do so, and the pooled graft rupture rate was 5.2%. However, it is important to note that both the return to sport rates (42%-100%)²²⁻²⁴ and the graft rupture rates (0%-19.3%)^{23,25-27} reported in the studies

Table 7. Univariate Analysis of Predictive Factors of Graft Failure

Variable	Unadjusted Hazard Ratio	Unadjusted Hazard Ratio 95% Confidence Limits	P Value
Age, ≥ 20 yr vs < 20 yr	1.470	[0.188; 29.707]	.739
Sex, female vs male	7.084	[0.907; 143.225]	.090
Type of sport, contact vs noncontact	1.669	[0.178; 221.325]	.758
Laxity preop, mm:	—		.310
6-10 vs 3-5	0.234	[0.023; 31.466]	—
>10 vs 3-5	1.200	[0.064; 175.119]	—
Meniscal lesion	—		.705
LM vs. no lesion	0.260	[0.002; 2.68]	—
MM vs. no lesion	1.843	[0.178; 11.21]	—
MM LM vs. no lesion	0.318	[0.002; 3.277]	—

LM, lateral meniscus; MM, medial meniscus.

Table 8. Univariate Analysis of Predictive Factors of Contralateral Anterior Cruciate Ligament Rupture

Variable	Unadjusted Hazard Ratio	Unadjusted Hazard Ratio 95% Confidence Limits	P Value
Age, ≥ 20 yr vs < 20 yr	0.424	[0.105; 1.603]	.201
Sex, female vs male	2.342	[0.646, 8.51]	.182
Type of sport, contact vs noncontact	1.348	[0.301; 12.721]	.750
Laxity preop, mm:	—		.745
6-10 vs 3-5	0.624	[0.079; 80.46]	—
>10 vs 3-5	0.205	[0.001; 39.226]	—
Meniscal lesion	—		.848
LM vs no lesion	1.083	[0.149; 5.589]	—
MM vs no lesion	2.109	[0.29; 10.936]	—
MM LM vs no lesion	1.073	[0.145; 5.655]	—

LM, lateral meniscus; MM, medial meniscus.

included by Lai et al.⁶ varied broadly. This highlights the fact that the risk of graft rupture is higher in certain sports or even certain positions within the same sport. For example, in the National Football League, receivers and backs have a significantly greater injury risk than players in other positions.²⁸ To the authors' knowledge, the highest rates of graft rupture in professional athletes are reported in female patients participating in handball (19.3%)²⁸ and alpine skiing (27% revision rate).²⁹ In the current study, there were no graft ruptures in the skiers or handball athletes, but the overall numbers of patients in these categories were too small to gain a reliable estimate of the graft rupture rate. However, in keeping with previous reports,³⁰⁻³² female patients had a significantly higher risk of graft rupture (13.6%) than male patients (2.1%), and this 6-fold increased risk was statistically significant ($P = .048$). Similarly, the contralateral ACL injury rate was also higher in female patients (22.7% vs 10.4%), but this trend was not statistically significant.

We found a reoperation rate of 15.7% for our cohort of professional athletes, which is within the range of published reoperation rates for nonprofessional athletes

Table 9. The Incidence of Contralateral ACL Rupture and Graft Rupture Occurring After the Index Procedure, Stratified by Sport

Sport	n (%)	Contralateral ACL, n (%)	Graft Rupture, n (%)
Total	70	10 (14.3)	4 (5.7)
Soccer	32 (45.7)	4 (40)	3 (12.5)
Rugby	11 (15.7)	2 (20)	
Basketball	10 (14.3)	3 (30)	
Ski	9 (12.9)	1 (10)	
Handball	4 (5.7)	0	
Hockey	2 (2.9)	0	1 (50)
Motocross	2 (2.9)	0	

ACL, anterior cruciate ligament.

Table 10. RTP Metrics

Sport (n)	Delay RTP, mo (range)	RTP at the same level (%)
All (70)	7.9 (5-12)	60 (85.7)
Football (32)	7.6 (6-12)	25 (78.1)
Rugby (11)	7.5 (6-10)	10 (99)
Basket (10)	8.7 (7-12)	9 (90)
Handball (4)	8.75 (6-12)	4 (100)
Skiing (9)	7.8 (6-10)	8 (88.9)
Hockey (2)	10.5 (10-11)	2 (100)
Motocross (2)	7.5 (5-10)	2 (100)

RTP, return to sport.

(13.5%-27.6%).^{33,34} Data for professional athletes are scarce and seem to indicate an even higher reoperation rate of up to 51.4% in professional collegiate athletes (football, lacrosse).¹¹

The largest category in the current study was professional soccer players. In this group, 3 patients sustained a graft rupture at 13, 22, and 25 months after the index procedure. Although not directly comparable, these outcomes seem favorable when compared with those reported by Walden et al.,⁹ who identified a 7% early (within 1 year or 3 months of the first match played after ACLR) graft failure rate in a series of professional soccer players.

Graft choice in professional athletes undergoing ACLR has been evaluated by Erickson et al.³⁵ in a survey of team orthopaedic surgeons responsible for National Hockey League, Major League Soccer, and the U.S. Olympic Ski/Snowboard teams. It was identified that 70% of surgeons would use bone-patella tendon-bone (BTB) for their athletes.³⁵ Although the authors of this study agree that BTB has been considered the gold standard,³⁶⁻³⁸ it should be highlighted that in a large comparative series of young patients involved in pivoting sports, the rate of ACL graft rupture was 3-fold less in patients who underwent combined ACL+ALL reconstruction when compared with a BTB graft choice.¹⁴ Similar advantages of BTB have not been demonstrated in the meta-analyses or systematic reviews comparing the outcomes of BTB and hamstring tendon autografts.^{39,40} The potential advantage of a combined ACL+ALL graft has been attributed to load sharing of the ALL⁴¹ with the reconstructed ACL. Furthermore, it has also been reported that at lateral exploration of apparently isolated acute ACL injured

Table 11. Reasons for Retirement From Professional Career

	n (%)
Retirement from professional sports	16 (22.5)
Age	5 (31.25)
Without a club	4 (25)
Studies	5 (31.25)
Knee	1 (6.25)
Other injuries	1 (6.25)

knees, injury to the anterolateral structure is identified in approximately 90% of cases.⁴² Furthermore biomechanical study has demonstrated that when a combined ACL and anterolateral injury exists, an isolated ACLR fails to restore normal knee stability.⁴³

Although 85.7% of patients in this series returned to the preinjury level of competition after combined ACL and ALL reconstruction, by the mean final follow-up of 3.9 years, 22.5% of the original population had retired, leaving 77.5% still involved in professional sports. This compares favorably with data from Mai et al.,⁴⁴ who reported that overall, 3 seasons after ACLR, only 67% of professional athletes remain on the active roster. However, when the specific sports included are evaluated individually, it can be seen that there are significant differences between them, with National Football League players being the least likely to still be on the active roster (60%) and National Hockey League players being the most likely (98%). The investigators concluded that ACLR leads to excellent outcomes for professional athletes but that the intricacies of each sport place significantly different physical demands on the reconstructed ligament and lead to differences in outcomes.⁴⁴ In the current series, only 1 patient stated that he had retired because of ongoing knee-related issues. This type of data has not been reported in other series, so no comparison can be drawn.

Limitations

The main limitation of this study was the small population of professional athletes in each sports category and no comparative group. This limited the ability to provide a reliable estimate of graft rupture in many of the categories and also prevented comparison with other published data.

Nine athletes included in the study had sustained a contralateral ACR prior to the index surgery. We were not able to demonstrate any significant differences between this specific group and the other patients, but this could be owing to the limited number of patients (n = 9) in this specific group.

Further limitations include the lack of a sample size analysis when conducting a comparison with previously reported rates of graft rupture in professional soccer players and a minimum follow-up of only 2 years.

Conclusions

Combined ACL and ALL reconstruction is associated with excellent outcomes in professional athletes with respect to graft rupture rates, return to sport, and reoperation rates after injury.

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