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Repeat Anterior Cruciate Ligament Injury and Return to Sport in Australian Soccer Players After Anterior Cruciate Ligament Reconstruction With Hamstring Tendon Autograft

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Abstract: (326 words)

Background: Soccer is the most commonly played team sport in the world and a high-risk sport for Anterior Cruciate Ligament (ACL) injury and subsequent ACL reconstruction (ACLR).

Purpose: To assess the rate of further ACL injury in patients who have undergone ACLR with hamstring autograft following soccer injuries in Australia, and determine factors associated with repeat ACL injury and return to soccer (RTS)

Study Design: Case Series, Level of evidence III

Methods: From a prospectively collected database, a series of 1000 consecutive ACLRs using hamstring autografts, performed in soccer players were identified. Subjects were surveyed at a minimum of five years following reconstruction including details of further ACL injuries to either knee, return to soccer or other sports and psychological readiness with the ACL-RSI score

Results: Of the 862 participants reviewed ACL graft rupture occurred in 85 (10%) and contralateral ACL rupture occurred in 68 (8%) within five years following the reconstruction. The 5 year ACL graft survivorship was 94% for females and 88% for males. The survivorship of the contralateral ACL (CACL) was 92% for males and 90% for females. Compared to those aged 25 or more, the odds of ACL graft rupture was increased by 4-5 times in those aged 19-25, and 3-7 times in those 18 or less. Further ACL injury to the graft or contralateral knee occurred in 44% of males under 18 years. Risk factors for further ACL injury were: younger age at time of surgery, male gender and returning to soccer. Graft diameter did not influence ACL graft rupture rates and a total of 70% of patients returned to soccer after ACLR. The mean ACL-RSI score was 59, and patients who reported more fear of reinjury on this scale were less likely to have returned to soccer.

Conclusions

The prevalence of ACL graft rupture (10%) and CACL survivorship (8%) were near equivalent over 5 years in this large cohort of mostly recreational Australian soccer players. ACL reconstruction with hamstring autografts is a reliable procedure for allowing 70% of patients to return to soccer in this high-risk population. Risk factors for further ACL injury are progressively younger age at time of surgery, male gender and returning to soccer. Graft diameter was not a factor in ACL graft rupture indicating other factors, particularly age, are of primary importance.

Introduction:

Soccer is the team sport with the highest participation in the world, with athletes participating from grassroots through to elite level[23]. It is well documented that sports that involve pivoting, changing direction, contact or collision, such as soccer, are particularly high risk for Anterior Cruciate Ligament (ACL) injuries[11, 13, 18, 39]. The U.K. national ligament registry showed 48% of ACL injuries sustained in 2020 in the U.K. were soccer injuries[44] whilst the National Collegiate Athletic Association in North America reported soccer to be the third and fourth most common reason for an ACL rupture in Males and Females collegiate athletes, respectively, in North America[1]. Whilst the rate of ACL rupture playing soccer has been falling with the advent of injury prevention schemes, they remains high world-wide at around 2-3.5% in soccer players over a one to four season period [38, 39, 41].

Many patients who suffer an ACL injury opt for surgical ACL reconstruction (ACLR) to improve their knee stability, often with the expectation of returning to sport[8, 32, 53]. Despite this, ACL injury can be a career ending injury for many athletes and not all patients return to high-impact activities, such as soccer, even following reconstruction. The rate of ACLR is known to differ around the world, with Australia having the highest ACL injury rate and rate of reconstruction worldwide[25]. The rate of ACLR in Australia increased by 74% in those under 25 years between 2000 and 2015 [64]. After ACL reconstruction, second ACL injuries are reported to occur in 14-22% of subjects over the first 5 years [9, 27, 32, 40, 48, 57, 59, 63], and a recent study of female Swedish soccer players reported repeat ACL rates as high as 42% in those who returned to soccer a mean of 6.5 years[15].

Return to sport following ACLR has been well documented, with a meta-analysis [5] showing high rates of 81% returning to any sport, and 55% at competitive levels. The rates of return to soccer (RTS) specifically following ACL injury are less well documented, with studies mainly focusing on elite athletes or on subsequent re-injury rates [2, 5, 10, 28]. Less is known about reinjury and RTS in recreational soccer players, especially in populations outside the United States[10, 49]. Knowledge of sport specific risk is essential to facilitate accurate counselling, target injury prevention and allow informed decisions in athletes [17].

When carrying out ACLR, a hamstring autograft is one of the most commonly used grafts and is the graft of choice for many surgeons[44]. We investigated the outcome of this reconstructive technique in a large cohort who sustained ACL rupture playing soccer to observe the subsequent rates of further ACL injury, RTS and patient reported outcome measures (PROMs). This study was designed to (i) determine the rate of further ACL injury in this high-risk population from a large cohort of Australian soccer players as the primary outcome variable, (ii) determine the rate of RTS in soccer players and (iii) assess the predictors of repeat ACL injury and RTS.

Patients and Methods:

Patient Selection

We conducted a single centre study from a high-volume centre for ACLR, with procedures performed by two experienced sports knee surgeons. Subjects included in the study were identified from a prospectively collected database of knee surgery and had undergone primary ACLR with hamstring tendon autograft at least five years earlier. Ethical approval was granted by a local independent human ethics committee. The participant flow is detailed in Figure 1. Patient demographics were recorded in the prospective database, which included information on the sport of injury, side of surgery, age, sex, graft size, graft fixation and meniscal or articular cartilage injury. Inclusion criteria were 1000 consecutive subjects that underwent ACLR with a hamstring tendon autograft between 2007 and 2015, who had sustained their primary ACL injury while participating in soccer. Subjects were excluded if they revoked consent to participation in a research study, died during the study period or had a history of contralateral ACL injury prior to the index ACL reconstruction. All patients clinic medical records were reviewed initially, and any documented further ACL injuries were noted. Patients were invited to participate in a survey at a minimum of five years after surgery via email. Respondents completed the survey online using the RedCap platform[20], or via telephone interview. Those who did not respond to the email were contacted by a research physical therapist, research exercise physiologist or an honours medical student, none of whom were involved in the original surgery, and administered the telephone interview. Each subject was sent a minimum of three emails and contacted by telephone a minimum of three times before they were deemed lost to follow up.

Patient Survey

Patients were surveyed regarding any further injuries to either knee following the index ACL reconstruction, and in the case of further ACL injuries details substantiated by review of relevant medical records in the vast majority of cases. The survey completed by patients included, the short version of the Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) scale[58], including the question “Are you fearful of reinjuring your knee by playing your sport?” (where the maximum 100 indicates “no fear at all” and a score of 0 indicates “extremely fearful”), Cincinnati Sports Activity Scale (CSAS) [6], questions on subsequent injuries and/or surgery to either knee, whether a return to soccer was achieved (“Did you ever return to your preinjury sport and level of activity?”), and questions relating to the family history of ACL ruptures. The family history was considered positive if the patient reported that a first-degree relative had sustained an ACL rupture at any time.

All patients who reported further injuries to either knee that had not previously been documented were invited to attend for a further clinical review. A graft rupture or CACL injury was considered to have occurred if any one of the following was present: (i) the patient underwent further knee reconstructive surgery (graft rupture) or primary reconstruction (CACL) performed in our unit or by another orthopaedic surgeon, (ii) clinical examination and/or magnetic resonance imaging (MRI) findings were reviewed by our unit to confirm ACL deficiency, or (iii) reporting of another injury characteristic of an ACL tear such as a non-contact pivoting injury associated with instability and

effusion, to either the reconstructed or native knee, that had not been reviewed by our unit. For this last group, it was assumed for the purposes of the survival analysis that an ACL graft rupture or CACL injury was a worst-case scenario.

Operative Technique

All patients included in the study underwent an anatomic, single bundle, arthroscopic ACLR using an ipsilateral hamstring tendon autograft at a single centre by one of two sports knee surgeons. The procedures were performed under general anaesthetic using antibiotic prophylaxis, a high thigh tourniquet and esmarch bandage to exsanguinate the limb. Chronicity of ACL injury was classified as acute (within 3 weeks), subacute (1-3 months) and chronic (>3 months). A two-portal technique was used with a high anterolateral and low anteromedial portal with an oblique incision over the pes anserinus. The semitendinosis and gracilis tendons were harvested using a tendon stripper (Linvatec, Florida, USA) and looped over two ultrabraid sutures to create a multi-strand graft (usually four strands) of suitable diameter. The graft ends were whip-stitched with a vicryl (Ethicon) suture. The graft diameter was measured using a graft diameter measuring device (Smith and Nephew, Andover, USA) taking the smallest sized tube that the graft could pass through as the graft diameter and the graft was left to soak in a vancomycin wrap while the arthroscopic drilling took place.

The ACL stump was debrided using a shaver and the femoral footprint of the ACL on the lateral wall of the intercondylar notch identified and marked with an awl. With the knee in deep flexion, an inside-out drilling technique was used through the anteromedial portal to drill a 4.5mm pilot hole which was then over-drilled with a stepped-router to the appropriate graft diameter to create a femoral socket 30mm in depth.

An adjustable tibial aiming guide (Smith and Nephew, Andover, USA) was used for drilling the tibial tunnel. Through the anteromedial portal, the guide was positioned to direct the tibial tunnel to enter the joint through the native tibial ACL footprint with a retrograde drill. The tunnel was then expanded over beath pin using a 45mm stepped-router to match the graft diameter.

After retrograde passing of the graft through the tibial tunnel and into the femoral tunnel, fixation was secured on the femoral side using an interference screw over a guide wire through the anteromedial portal with the knee in maximal flexion. The knee was then cycled through a range of motion to tension the graft. A tibial interference screw was then inserted posterior to the graft over a guide wire and fixation secured with the knee in maximal extension or hyperextension. Interference screw fixation was used in the vast majority of cases, with other fixation methods used if felt appropriate by the treating surgeon. If the patient was an adolescent then a radiographic assessment of whether the growth plate was closed was documented.

Post-operatively patients underwent a rehabilitation programme under a physiotherapist's guidance and advised to refrain from full contact and pivoting sporting activity for a one-year period. Braces were not routinely used at any time during rehabilitation or on returning to sport.

Statistical analysis

Statistical analysis was performed using SPSS software version 27 (IBM). Statistical significance was set a priori at $P < 0.05$. Missing data was not imputed and complete case analysis was performed. Groups were compared with t-tests for linear variables (mean CSAS and ACL-RSI score) and chi-square tests for categorical data (sex, age, family history, chronicity of injury). Pearson correlation co-efficients were calculated for linear variables of age and ACL-RSI score.

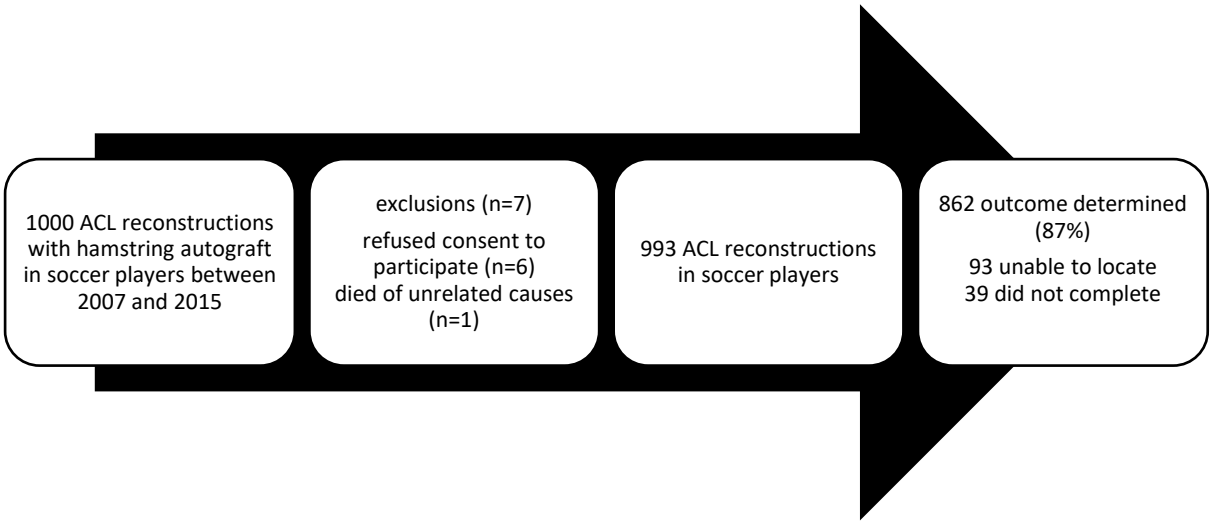
The ACL and CACL survival were assessed using the Kaplan-Meir method. To account for the variation in length of follow up across all subjects, right censoring was performed at 5 years. Survival tables at 1, 2, and 5 years were collated. Analyses was repeated for each sex independently. A comparison of survival curves was made with univariate Cox proportional hazards model. Each factor was assessed for proportionality of hazards graphically. Factors examined included age, family history of ACL injury (1^{st} degree relative), ACL graft diameter, BMI, chronicity of the ACL injury and return to soccer at any time. A forward method was used to build the multivariate model. Factors with $P <0.10$ on univariate analysis were entered into a multivariate Cox regression analysis.

For analysis of RTS a forward method was used to build the multivariate model. Factors with $P< 0.10$ on univariate analysis were entered into a multivariate Cox regression analysis. Factors examined included gender, age, family history of ACL injury, BMI and graft diameter.

Results

Of the 1000 subjects, six patients revoked consent to research, and one died of unrelated causes. Of the remaining 993 subjects, 92 (9%) were lost to follow up, 39 (4%) did not complete the survey and 862 (87%) were reviewed at a minimum of 5 years from surgery, See figure 1. The mean follow-up was 8.3 years (range 5-14 years).

Figure 1: Participant flow



There were 666 males (77%), 196 females (23%), and 441 (51%) left knees, with a mean age of 30 years (range 13-62). Timing of the surgery was acute (within 3 weeks) in 29 (3%), subacute (1-3 months) in 710 (72%), and chronic (>3 months) in 247 (25%). There was no significant difference in chronicity of the ACL injury between those with intact ACL graft compared to those with ACL graft rupture at 5 years (p=0.38). The ACL graft was fixed with an RCI screw in 854 (99%) on the femoral side and 840 (97%) on the tibial side.

At the time of ACL reconstruction a medial meniscal tear was noted in 286 (33%) and lateral meniscal tear in 429 (50%). When meniscal surgery was required, this was performed at the same time as the ACLR with either meniscal repair or meniscectomy performed after assessment by the treating surgeon. The lateral meniscus was either intact or the tear required no treatment in 590 (68.4%), a partial or full lateral meniscectomy was performed in 231 (26.8%) and lateral meniscal repair performed in 41 (4.8%). The medial meniscus was either intact or the tear required no treatment in 681 (79.0%), a partial or full meniscectomy was required in 150 (17.4%) and 31 (3.6%) had a medial meniscal repair.

A RTS at any time after their surgery was reported by 133 of 196 females (68%) and 469 of 666 males (70%) (p=0.510).

There was an ACL graft rupture in 85 participants (10%) and contralateral ACL rupture occurred in 68 (8%) within five years following the reconstruction. The prevalance of any further ACL injury to either knee is shown in Table 1. The

median time from ACL reconstruction to ACL graft rupture was 19 months, and CACL rupture was 35 months. Three patients (all male) sustained both a graft rupture and CACL injury within five years.

Table 1: Prevalence of any repeat ACL injury (ACL graft or contralateral ACL) in Males and Females over 5 years.

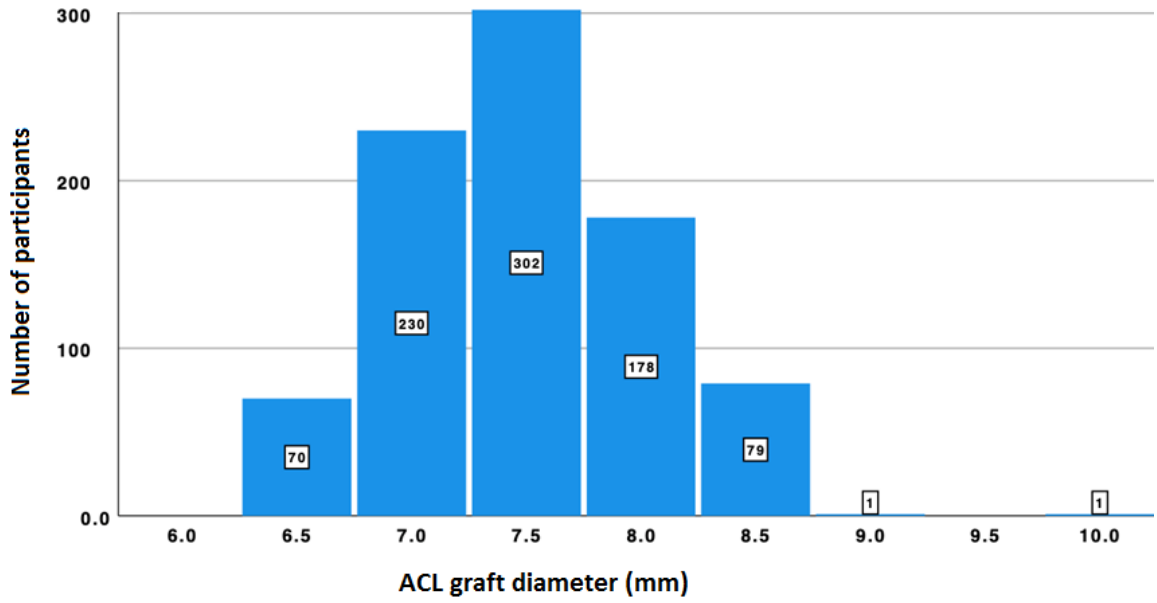
	All Ages n=862	**18 or less n=89**	**18 to 25 n=234**	**>25 years n=539**	**P****
ACL Graft Rupture					
Females n=196	11 of 196 (6%)	2 of 26 (8%)	6 of 54 (11%)	3 of 116 (3%)	0.071
Males n=666	74 of 666 (11%)	19 of 63 (30%)	32 of 180 (18%)	23 of 423 (5%)	0.001
*P-Value**	0.023	0.023	0.244	0.204	
Contralateral ACL Rupture					
Females n=196	19 of 196(10%)	5 of 26 (19%)	6 of 54(11%)	8 of 116 (7%)	0.145
Males n=666	49 of 666(7%)	12 of 63 (19%)	11 of 180 (6%)	26 of 423 (6%)	0.001
*P-Value**	0.286	0.984	0.214	0.786	
Any further ACL					
Females (n=196)	30 of 196 (15%)	7 of 26 (27%)	12 of 54 (22%)	11 of 116 (10%)	0.021
Males (n=666)	120 of 666 (18%)	28 of 63 (44%)	43 of 180 (24%)	49 of 423 (12%)	0.001
*P-Value**	0.379	0.124	0.800	0.524	

*P value comparing prevalence between genders

** P value comparing prevalence across age groups

Grafts were most commonly four-strand (range 3-6, mean 4.02) with a mean diameter of 7.49mm (range 6.5-10mm), see figure 2. Fixation on the femoral side was most commonly a round-headed interference screw; Titanium RCI (743, 74.4%), PEEK RCI (249, 24.8%), Endobutton (6, 0.6%), Post (1, 0.1%), Other (1, 0.1%). Similarly on the tibial side the majority of fixation was with an RCI screw; Titanium RCI (622, 62.4%), PEEK RCI (268, 26.7%), BIOHA RCI (88, 8.8%), Milagro (9, 0.9%), Staple (1, 0.1%), Post (2, 0.2%), Other (10, 1.0%).

Figure 2: Distribution of ACL graft diameter



At the time of surgery radiographs showed the physes were closed in 925 cases (98.7%) and closing in 12 (1.3%). The International Knee Documentation Committee grading was grade A (no changes) in 950 (97.6%) `and grade B (mild changes) in 23 (2.4%) of patients, with no patients having more advanced arthritic changes.

Survival Analysis

ACL Graft Survival

The ACL graft survival for females was 99%, 97% and 94% at 1, 2, and 5 years after surgery respectively. On univariate analysis of ACL graft rupture in females the only significant factor was age (p=0.032), non-significant factors were return to soccer (p=0.135), ACL graft diameter (p=0.795), family history of ACL injury (p=0.207), and BMI 25 or more (p=0.706).

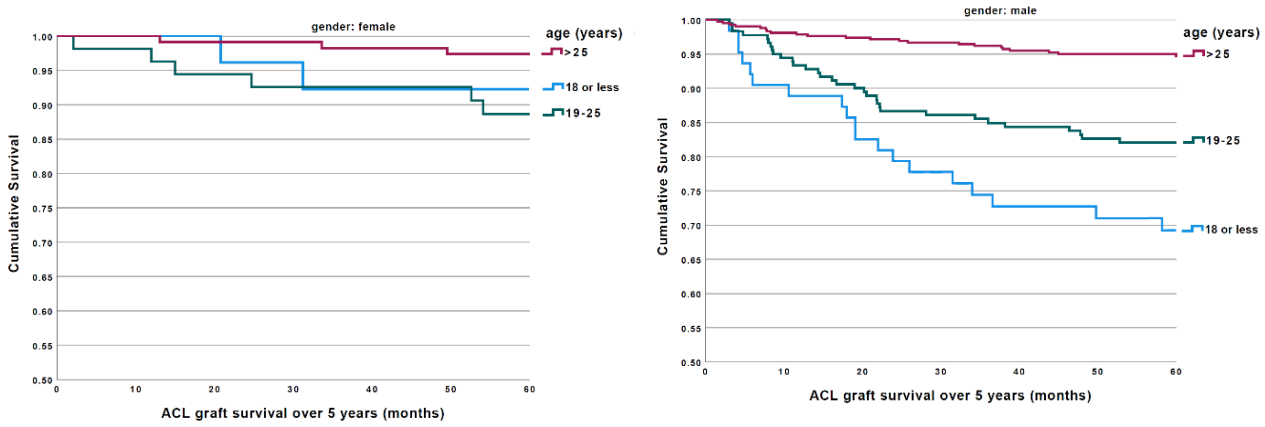
The ACL graft survival for males was 96%, 93% and 88% at 1, 2 and 5 years respectively. On univariate analysis of ACL graft rupture in males the significant factors were age (p=0.001), and a trend for BMI 25 or more (p=0.061), non-significant factors were return to soccer (p=0.332), ACL graft diameter (p=0.562), family history of ACL injury (p=0.900). Factors with p<0.10 on univariate analysis were entered in a forward fashion to a multivariate Cox Regression (Table 2). Age was the only persistent significant factor for males. Kaplan Meir survival curves are displayed for (the significant factor) age in Figure 3.

Table 2: 5-year Survival of ACL Graft with Significant Multivariate Hazard Ratios in Males and Females

	Males				Females			
	N	**ACL Survival**	**HR (95% CI)**	**p value**	**N**	**ACL Survival**	**HR (95% CI)**	**p value**
All	666	88%			196	94%		
Age (years)								
18 or less	63	69%	7.2 (3.5-14.9)	0.001*	26	92%	3.1 (0.5-18.3)	0.222
19-25	180	82%	3.9 (2.1-7.4)	0.001*	54	89%	4.6 (1.1-18.2)	0.032*
>25	423	94%	ref		116	97%	ref	
BMI								
<25	187	88%						
25 or more	441	92%	0.7 (0.4-1.2)	0.684				

*denotes significant factor

Figure 3: ACL Graft Survival according to age at surgery in females (left) and male (right)



Contralateral ACL Survival

The native ACL in the contralateral knee had a survival for females of 97%, 93% and 90% at 1, 2, and 5 years respectively. On univariate analysis of CACL injury in females age was significant (p=0.046), and a trend for RTS (0.074), non-significant factors were family history of ACL (p=0.644) and BMI 25 or more (p=0.233).

The contralateral ACL survival for males was 98%, 96% and 92% at 1, 2 and 5 years respectively. On univariate analysis of CACL rupture in males return to soccer (p=0.001), and age (p=0.001) were both significant, non-significant factors were family history of ACL injury (p=0.189) and BMI 25 or more (p=0.764). The Kaplan Meir survival curves by age group are shown in Figure 4. The Kaplan Meir survival curves by return to soccer are shown in Figure 5.

Figure 4: Contralateral ACL Survival according to age at surgery in females (left) and male (right)

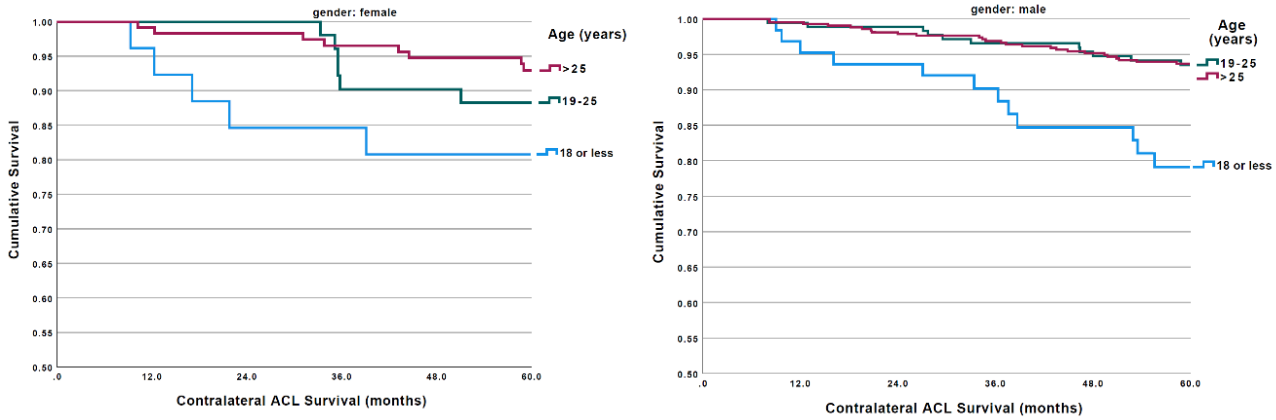
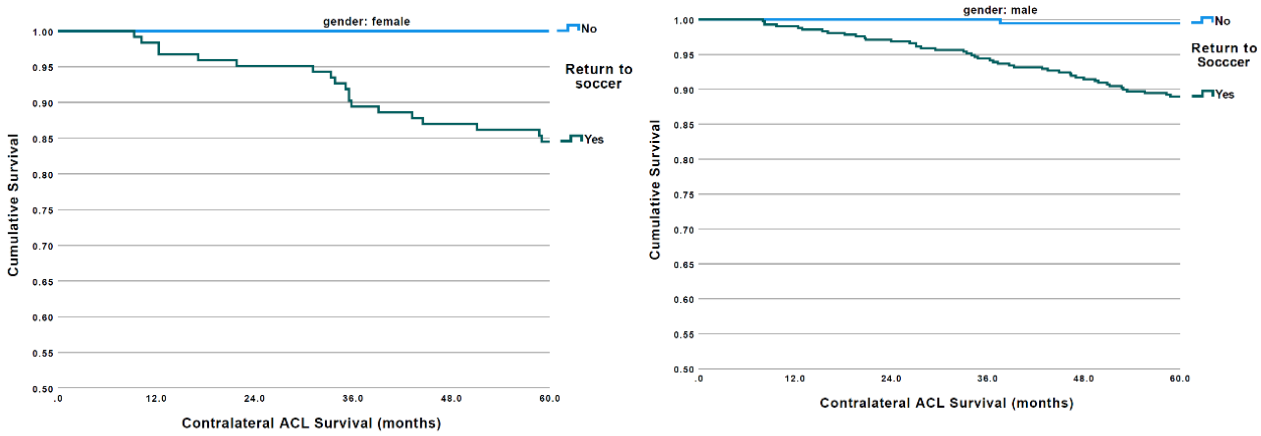


Figure 5: Contralateral ACL Survival according to RTS in females (left) and male (right)



A multivariate Cox model of predictors of CACL survival was not performed as there were insufficient numbers of positive events of contralateral ACL rupture occurring in those who did not RTS (n=0 in females and 2 in males), which is susceptible to bias with positive events of numbering less than five[54]. The significant factors on univariate analysis are shown in Table 3.

Table 3: 5-year Survival of Contralateral ACL with Significant Univariate Hazard Ratios in Males and Females

	Males				Females			
	N	**CACL Survival**	**HR (95% CI)**	**p value**	**N**	**CACL Survival**	**HR (95% CI)**	**p value**
All	666	92%			196	90%		
Age (years)								
18 or less	63	79%	3.6 (1.8-7.1)	0.001*	26	81%	3.1 (1.0-9.5)	0.046*
19-25	180	93%	1.0 (0.5-2.1)	0.953	54	88%	1.7 (0.6-4.9)	0.335
>25	423	94%			116	93%	ref	
Return to Soccer								
Yes	469	89%	10.5 (2.5-43)	0.001*	133	85%	38.3 (0.7-2086)	0.074
No	197	99%			63	100%		

CACL: Contralateral ACL
* denotes significant factors

Subjective Outcomes

There were 230 patients with intact ACL and contralateral ACL at follow up who were invited to complete subjective outcomes. Return to netball was reported by 134 of 230 (58%) patients with intact ACL and contralateral ACL at follow up. A return to any Level 1 CSAS sport was reported by 141 of 230 (61%).

210 of the 230 patients with intact ACL and contralateral ACL completed patient reported outcomes at a mean of 110 months (range 60-181).

Return to Soccer

A RTS was reported by 368 (67%) males and 104 (63%) females without further ACL injury (p=0.257). Of the 240 who did not return to soccer, 172 (72%) reported that it was because of their operated knee, the remaining patients cited other reasons.

On univariate regression of return to soccer, age (p=0.001), ACL RSI score of 60 or more (p=0.001), were significant predictors, non-significant factors were family history of ACL injury (p=0.082), gender (p=0.257), BMI 25 or more (p=0.466) and ACL graft diameter (p=0.248). Factors <0.10 entered into the multivariate regression model, younger age and ACL RSI score 60 or more were persisting significant predictors of return to soccer (Table 4).

Table 4: Significant Factors of Multivariate regression analysis of Return to Soccer

	N	Return to Soccer	HR (95% CI)	p value
Age (years)				
18 or less	54	82%	3.4 (1.5-7.8)	0.004**
19-25	179	78%	2.2 (1.4-3.5)	0.001**
>25	479	60%	ref	
ACL RSI				
60 or more	368	79%	4.3 (3.0-6.2)	0.001*
<60	258	48%		

Cincinnati Sports Activity Scale (CSAS)

The mean CSAS was 84 in females and 82 in males (p=0.105). A return to any jumping and pivoting sports was reported by 61% (101 of 166) of females, and 71% (387 of 546) of males (p=0.041) without further ACL injury. A high level of participation in any sports, at more than four days per week was reported by 23% (39 of 166) females and 16% (89 of 546) males (p=0.027).

ACL-RSI Scale

Of the 230 patients with an intact ACL graft and contralateral ACL at 7 years, 210 completed the ACL-RSI scale with the mean ACL-RSI score being 53. The ACL-RSI according to age, gender and return to soccer is shown in Table 5. Overall ACL–RSI score and fearlessness was highest in those who had returned to soccer (p=0.001), but was not affected by gender or age in those without further ACL injury.

Table 5: ACL RCI Score according to gender, age and return to soccer.

ACL RSI Score	ACL RSI Fear Score	P value	ACL RSI Score Mean	P value	ACL RSI 60 or more (%)	P value
Gender						
Females (n=152)	58	0.358	62	0.647	82 (54%)	0.164
Males (n=474)	59		64		286 (60%)	
Age						
18 or less (n=42)	49	0.151	57	0.211	20 (48%)	0.232
19-25 (n=146)	59		65		91 (62%)	
>25 (n=438)	59		64		257 (59%)	
Return to Soccer						
Yes (n=414)	62	0.001	68	0.001	290 (70%)	0.001
No (n=212)	47		51		78 (37%)	

Discussion

The primary aim of our study was to assess the rate of further ACL injury in a very large, inherently high risk, cohort of patients who sustained a primary ACL injury playing soccer in Australia. At five years following reconstruction, ACL graft survivorship was 90% and CACL survivorship was 92%. Being under 25 years at the time of surgery, male gender and returning to soccer were all significant risk factors for further ACL injury, whilst graft diameter had no effect on ACL graft rupture rates. A total of 70% of patients returned to soccer following their ACLR.

Further ACL Injury

Rupture of an ACL graft or the CACL is a devastating injury for a patient who has undergone surgery and rehabilitation. Age was by far the strongest predictor of re-injury in soccer players, with a graft rupture or CACL rupture occurring in an alarming 44% of adolescent males and 27% of adolescent females within the first five years following their primary ACL surgery. Adolescent males were seven times more likely to rupture the ACL graft compared to males 25 or older. Both adolescent males and females were three times more likely to rupture their contralateral ACL compared to those over 25 years. Conversely, for those patients over 25 years, (which represents 63% of our study population) second ACL injuries only occurred in 10%, with a similar distribution across the genders and a more comparable rate of both ACL graft (3-5%) and CACL injury (6-7%). The association between ACL reinjury and age is well documented[46, 47, 63]. Not surprisingly, younger age was also significant predictor of RTS by a factor of 2-3 times for those 25 or less, compared to those aged over 25 years. Others have also reported younger patients are more likely to return to sports and pivoting activities, which are known to increase the risk for further ACL injury[62, 63]. Additionally those that sustain injuries in their youth may have an underlying predisposition for ACL injury such as poor neuromuscular conditioning or anatomical factors such as increased tibial slope[22, 47, 56]. It has recently been demonstrated that athletic movement quality improves with advancing chronological age in youth[21]. The solution to the issue of preventing repeat ACL injuries in the young remains elusive, but counselling of the significant risk in young, and importance of injury prevention programs is warranted after ACL reconstruction.

In our study at 5 years, male soccer players were more likely to sustain an ACL graft rupture (11%) than females (6%) (p=0.023) despite equivalent rates of return to soccer. This is a recognised pattern in the literature, and one that is the converse for primary injury[9, 50, 55].

There is the question of when athletes should return to sport, with some advocating return should be delayed until two years to allow for graft maturation and further neuromuscular conditioning [42]. The mean time from surgery to graft rupture in our study was 22 months (2-60) similar to that in the published literature [46]. The prevalence of ACL graft (10%) and CACL rupture (8%) were similar in soccer players after ACL reconstruction with a hamstring tendon autograft, and this is supported by others [9, 46, 63], this is despite graft maturation being an ongoing process for three years [45]. The relative distribution of ACL graft and contralateral ACL injuries may be graft dependent. Rahardja recently reported patellar tendon graft was associated with an 1.9x increased risk of contralateral ACL reconstruction compared with the hamstring tendon graft in a series of 7155 ACL reconstructions from the New Zealand ACL

Registry [43], and similar results have been reported by others in a Scandinavian cohorts[33], and a recent systematic review[35]. Our results suggest in the first two years after ACLR with hamstring autograft in soccer players the ACL graft is at higher risk than the CACL, but thereafter show similar rates of injury in the following years at 1-2% per knee per year.

A return to sport was a significant predictor of CACL injury in our cohort (OR 11-38), but not ACL graft rupture. However, the effect of a return to sport on ACL graft rupture risk may have been diluted by the early ACL graft ruptures that occurred in the first year after surgery, (examples include secondary to falls, intra articular infection, accidents while intoxicated or early participation in informal sporting/ball activities against advice) before a return to competitive soccer was achieved. Sandon examined 1661 soccer players from the Swedish National Ligament registry and reported that of the players who returned to play soccer 28.7% (OR 2.3) had additional ACL injury, 9.7% (OR 2.9) had a graft failure and 20.6% (OR 2.1) had a contralateral ACL injury over 10 years[48]. Fältström et al. reviewed second ACL injuries in 119 female soccer players and found very high rates of further ACL injury at 42% (26% for the ACL graft and 18% for CACL) within 5-10 years of the index ACL rupture, compared to an ACL injury rate of 11% in knee-healthy female soccer players control group [15]. Wiggins et al. performed a systematic review and meta-analysis of second ACL injuries in those returning to sport after ACLR, from 19 articles and 23,740 participants from all sports, showing that in those under 25 years who return to sport, 23% will have a further ACL injury compared to 15% in their entire cohort [63]. All evidence suggests that a return to soccer after ACL reconstruction significantly increases the risk of repeat ACL injuries.

Return to Soccer

The rate of RTS among patients following surgery was 70% and of those who did not return to soccer, 68% of females and 73% of males reported that it was because of their operated knee. Despite this being a study of mainly recreational soccer players, a very high level of participation in any sport (four or more times a week) was achieved by nearly a quarter of females and 16% of males, indicating the knee is not a limiting factor for many patients. There is known to be an age-related decline in sporting activity[14] which may account for some patients giving up soccer, especially after a prolonged period of rehabilitation. Other studies have shown 63% of patients undergoing ACLR returned to their pre-injury sport, whilst 80% are able to return to other, lower demand sports that do not involve contact or pivoting[61]. Meta-analyses of athletes have reported the pooled rate of return to play to be 83% in elite athletes and about 81% in those under 18 years old, showing the importance of function and age when considering a return to sport[5, 31].

ACL-RSI were similar between females and males, with the fear levels reported by the patients being a significant factor in whether they made a return to soccer. Not returning to soccer is a protective factor for the ACL graft due to the association of reinjury whilst playing sport[4, 28 60]. Kostyun et al. found that in adolescent patients undergoing ACLR, males had significantly higher ACL-RSI scores at the pre-operative, three-month post-operative and return-to-sport stages than females[28]. It maybe that those with less fear of reinjury may have a higher level of confidence,

translating into a more aggressive and riskier play when returning to soccer, so increasing their risk of injury. In a study of female soccer players, injury rates were found to be higher in the higher-skilled athletes than those of lower skill levels, with their conclusions being the higher involvement in the game put those participants at more risk[51]. However, we also know that younger patients with lower psychological readiness scores are at a higher risk of a second ACL injury if they return to sport than those with higher scores[37].

Our studies RTS rate is similar to Brophy et al. [10] who reported a 72% rate of RTS in 100 soccer players, from a cohort in the USA. Sandon et al. reported a RTS rate of 51% in 684 soccer players at 10 years after ACLR from the Swedish ligament registry[48]. They showed a similar percentage of those who did not return to soccer cited their knee as the reason for not returning, at 65% compared to 72% in our series.

So, what factors contribute to a successful return to play? Some of these factors are unmodifiable, such as gender, age, levels of competitiveness and a longer experience in the professional arena[31, 60]. Aside from timing of surgery, the modifiable factors that can be influenced are mostly psychological; with fear[29], pain levels at one year[7], better subjective knee function[19], motivation[52], positive psychological response and psychological readiness[3, 5], all playing a role. Low psychological readiness to return to sport (ACL RSI <60) was reported by 40%, and fear of injury was also common even after 5 years, but did not differ between genders or age in our series. Both factors were improved in those who had returned to soccer. Fear of reinjury is frequently reported as the most common reason athletes don't return to sports and was a significant factor in our series as well as others [5, 16, 30].

Graft Size

Graft diameter was not a risk factor in our series for ACL graft rupture, nor was it a factor in whether the patient was able to RTS. Graft size also had no impact on patients PROM scores. This indicates that other factors are more important to consider as risk for re-rupture and RTS and is an important finding given the variation in hamstring diameter and length between patients of different gender and size[26, 36 47]. The relationship of graft type and size has been a controversial area for many years[12, 36] with Magnussen et al. concluding a graft size of 8mm or less was associated with an increased graft rupture rate (OR 2) in those under the age of 20 years[34]. However, in their series, age of 20 or less was associated with a far higher odds ratio of 19 for graft rupture, and in their whole cohort of 256 graft size was not an independent risk factor for graft rupture. In keeping with our findings, Inderhaug et al. performed the largest series assessing the relationship with graft size and revision risk. They reviewed over 4000 ACLR performed using hamstring autografts from the Norwegian ligament registry and found that graft diameter was not an independent risk factor for requiring a revision ACRL procedure, they also found no correlation with PROM data and graft size[24]. Morgan et al also concluded graft size was not predictive of ACL graft rupture in a study of 242 adolescents[40]. Our findings support the conclusion that autologous hamstring ACL graft size is not predictive of ACL graft rupture.

Limitations

Our study is not without its limitations, it was a single centre and two surgeon study. Additionally, patients are from a single population. Previous literature has shown Australia has the highest rate of ACLR in the world[25] and as such, other confounding factors may have influenced the risk of initial injury and RTS. We also assumed as a worst-case scenario that patients had sustained graft or CACL ruptures if they reported a typical injury, in some cases without clinical or radiographic evidence. This may have resulted in over reporting of ACL rupture in our survival analysis. We did not have PROM scores on the patients who had graft ruptures prior to their injury which may have skewed some of our data regarding confidence toward their knee and activity levels. Whilst patients routinely had post-operative physiotherapy this may not have been standardised between the treating physiotherapist over the large cohort of subjects, but regardless should be representative of contemporary rehabilitation practices.

Conclusions:

A successful return to soccer is common in this large cohort of mainly recreational Australian soccer players following ACL reconstruction with hamstring autografts. Further ACL injuries in this high-risk population are more common in those under 25 years of age at time of surgery, male gender and those returning to soccer. Graft diameter was not a factor in ACL graft rupture indicating other factors, particularly age, are of primary importance.

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