Factors Associated With a Successful Return to Performance After Anterior Cruciate Ligament Reconstruction

A Multiparametric Evaluation in Soccer Players

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Background: Anterior cruciate ligament reconstruction (ACLR) is highly recommended in patients with ACL deficiency who must perform at a high physical level. A combination of functional and psychological outcome measures is necessary to provide a comprehensive evaluation of functional status after successful return to sport after ACLR.

Purpose: To identify factors associated with higher functional outcomes among soccer players who had returned to full sports participation after ACLR.

Study Design: Cohort study; Level of evidence, 3.

Methods: A total of 168 out of 231 patients who underwent primary unilateral arthroscopic anatomic single-bundle ACLR were available at follow-up. Postoperatively, knee function, generic health outcomes, and psychological impact were assessed using the International Knee Documentation Committee (IKDC), the Knee injury and Osteoarthritis Outcome Score (KOOS), the Lysholm Knee Scoring Scale, the 12-item Short Form Health Survey (SF-12), and the ACL–Return to Sport after Injury scale.

Results: After a mean follow-up of 35.5 ± 22.6 months, 85% of soccer players returned to performance. Midfielder position was associated with a better SF-12 Physical Component Summary (PCS) score ($P = .013$), IKDC ($P = .003$), total KOOS ($P < .001$), KOOS Symptoms ($P = .004$), KOOS Pain ($P = .029$), KOOS Activities of Daily Living (ADL) ($P = .044$), KOOS Sport and Recreation (Sport/Rec) ($P = .001$), KOOS Quality of Life (QoL) ($P < .001$), and Lysholm score ($P = .008$). Playing only on natural grass was associated with lower SF-12 PCS scores ($P = .003$), total KOOS ($P = .001$), and KOOS Sport/Rec ($P = .011$). Playing only on artificial turf was associated with lower Lysholm score ($P = .018$) and total KOOS ($P = .014$). The contact mechanism was associated with higher IKDC ($P = .044$) and KOOS QoL ($P = .048$), and injury affecting the dominant limb was associated with lower SF-12 Mental Component Summary scores ($P = .012$). Playing at a nonprofessional level was associated with lower total KOOS ($P = .028$), KOOS Symptoms ($P = .002$), KOOS ADL ($P = .033$), and KOOS Sport/Rec ($P = .016$).

Conclusion: Professional soccer players and the midfielder position are associated with better functional scores upon returning to the sport. A history of noncontact ACL injury and playing on a single type of surface are associated with lower functional outcomes upon returning to the sport. Lower mental health scores can be expected after injury of the dominant limb.

Keywords: knee ligaments; ACL; ACL reconstruction; football (soccer); psychological aspects of sport; playing surface; midfielder; dominant limb

Pivoting sports such as soccer are considered high-risk activities for anterior cruciate ligament (ACL) injuries[21,25] because of the high axial and torsional loads applied to the knee joint during sport-specific tasks[19] and contact with an opponent. Soccer is the most played sport in the world[11]

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and the ACL injury rate is 0.4 to 0.6 per soccer team every season.[16] The burden of ACL injury is particularly relevant since players lose ≥6 months of play on average. Currently, ACL reconstruction (ACLR) is highly recommended in patients who must perform at a high physical level.[32]

One important goal for ACLR is to quickly return to sports (RTS), and it is considered a continuum: return to participation, RTS, and return to performance.[30] The RTS continuum was developed to support the sports medicine team in RTS decision making. During return to participation, the athlete may participate in some training, but he or she is not ready to RTS. RTS happens when the athlete has returned to competition, though one has not reached one's desired level of performance. In the last phase, return to performance, the athletes' performance capabilities have returned to or exceeded the preinjury level.

Even if most players can return to soccer after ACLR, time-loss injuries that result in long periods without training or competing are considered major adverse events for the career of a soccer player.[20,41] Kiliç et al[27] found that athletes who sustain severe musculoskeletal time-loss injuries are likely to develop subsequent symptoms of mental disorder, such as distress, anxiety, and depression, emphasizing the need for an interdisciplinary medical approach. Therefore, a combination of functional and psychological outcome measures is likely necessary to provide a comprehensive evaluation of functional status after RTS after ACLR.[15] Previous studies[4,40] have found that the key factors that increase the possibility of RTS with return to performance after ACLR include younger age, male sex, playing an elite sport, and a positive psychological response. However, little knowledge of successful RTS after ACLR exists with regard to factors such as playing position, surface, and mechanism of injury in soccer.

The aim of this study was to investigate sport level, playing position and surface, mechanism of injury, and type of graft to identify factors associated with greater functional outcomes among soccer players who had returned to full sports participation after anatomic single-bundle ACLR. The return-to-performance rate was also investigated.

METHODS

The study protocol was approved by the local ethics committee (institutional review board approval was obtained from University of Molise), and the research was conducted in compliance with the Declaration of Helsinki.

A retrospective multicenter study with prospective data collection was undertaken on 231 patients who underwent primary unilateral arthroscopic anatomic single-bundle ACLR between October 2017 and September 2022 at the following institutions: Mater Domini University Hospital of Catanzaro, Villa del Sole Clinic of Catanzaro, and Casa di Cura Villa Betania of Rome in Italy.

Patient Involvement Statement

Eligibility criteria were as follows: (1) >16 years old at the time of surgery, (2) ACLR using semitendinosus and gracilis tendon (ST-G) autograft, bone–patellar tendon–bone (BPTB) autograft, or synthetic graft, (3) played soccer at least once a week in training or in a match before the ACL injury, (4) return to full participation in soccer after ACLR, and (5) the capability to communicate with health care professionals and give valid informed consent. Soccer players who underwent bilateral ACLR, revision surgery, multiligament injuries, concomitant meniscal repair procedures, and fractures of the knee at any time as well as patients showing severe knee osteoarthritis (Kellgren-Lawrence grades 3 and 4) were excluded. The diagnosis was based on clinical and radiological evaluation of the knee (plain radiographs and magnetic resonance imaging). A total of 176 patients met the study criteria. Signed informed consent was provided by each patient who was made aware of all aspects of the study.[37] Demographic data, including age, sex, mechanism of injury (contact or noncontact), graft type (doubled ST-G, BPTB, or synthetic), dominant limb (defined as the preferred kicking limb), level of play (professional or nonprofessional), playing position (goalkeeper, defender, midfielder, forward), and playing surface (natural grass and artificial turf), were collected from medical records and then recollected at follow-up.

Surgical Technique

All ACLRs were performed by 3 surgeons (O.G., R.S, S.C.) with high levels of experience in knee arthroscopy. For the tibial tunnel, the aimer was adjusted to the 45° to 55° position to ensure adequate tibial tunnel length. Femoral tunnel drilling was performed via the anteromedial portal technique with the knee flexed to 120°. The ST-G were harvested for a 4-strand graft aiming for a minimum size of 8

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mm. For BPTB autografts, a standard harvest was performed using the middle third of the tendon for a 10 mm–wide graft.

In all ACLR procedures, a cortical suspension device was used for femoral fixation. A bioabsorbable interference screw was used for tibial fixation while the graft was tensioned at 30° of knee flexion.

Postoperative Rehabilitation

Postoperatively, all patients underwent a common rehabilitation protocol regardless of the type of graft used. Patients walked with elbow crutches bearing weight as tolerated, and the range of motion was limited to 90° for 1 week. After 1 week, patients began range of motion therapy. After nearly full range of motion was achieved, patients started strength training, with an emphasis on closed kinetic chain exercises. The preservation of quadriceps function in the early postoperative stage of rehabilitation after ACLR was emphasized with an early initiation of isometric quadriceps setting exercises. Activities that prepared the individual for progression to full weightbearing and ambulation, improved balance and postural control, and achieved normal gait were allowed after 4 weeks. Weightbearing strengthening activities were initiated and progressed after 6 weeks. Strengthening exercises through the full range of motion and activities to enhance neuromuscular control were also continued to ensure full recovery and maintenance of strength and dynamic stability. Rehabilitation progressed from functional activities to sports-specific training. With the knee stable at Lachman and pivot-shift tests; when the quadriceps index was $\geq$85%; and strength, proprioception, and endurance for functional progression were satisfied, the patients began full-effort sprinting, cutting, and plyometric activities. RTS was permitted no earlier than 6 months after surgery.

Patient-Reported Outcome Measures

At follow-up, each patient was functionally and psychologically evaluated in person by a trained researcher (K.C.). Measures of knee function were assessed using the International Knee Documentation Committee subjective knee form (IKDC), the Knee injury and Osteoarthritis Outcome Score (KOOS), and the Lysholm Knee Scoring Scale.

The IKDC[24] is an 18-item instrument. Possible scores range from 0 to 100, where 100 means no limitation with daily or sporting activities and the absence of symptoms.

The KOOS[34] contains 42 questions organized into 5 subscales: (1) *Pain* frequency and severity during functional activities; (2) *Symptoms* such as the severity of knee stiffness and the presence of swelling, grinding or clicking, catching, and range of motion restriction; (3) *Activities of Daily Living* (ADL) functions experienced with difficulty; (4) *Sport and Recreation* (Sport/Rec) activities carried out with difficulty; and (5) *Quality of Life* (QoL) as it relates to the knee. Possible scores range from 0 to 100, where 100 means no knee problems.

The Lysholm scale[39] is an 8-item questionnaire. The total score ranges from 0 to 100, where 100 means no symptoms or disability.

The 12-item Short Form Health Survey (SF-12)[44] is a 12-item questionnaire used to assess generic health outcomes from the patient's perspective. Two summary scales (the Physical Component Summary [PCS] and the Mental Component Summary [MCS]) can be computed with scores ranging from 0% to 100%, with higher scores indicating better QoL.

The psychological impact was assessed using the ACL–Return to Sport after Injury scale developed and validated by Webster and Feller[43] and Webster et al[45] in relation to 3 elements that have been correlated with the RTS in the literature: emotions, confidence in one's performance, and the evaluation of risk. The total score was calculated by adding the values of the 12 responses and then dividing by 100 to obtain a percentage. High scores corresponded to a positive psychological response.

Statistical Analysis

The mean, standard deviation, and range were noted for the continuous variables, and counts were noted for the categorical variables. All data were collected, measured, and reported with 1 decimal accuracy. The distribution of the numeric samples was assessed with the Kolmogorov-Smirnov normality test. Based on this preliminary analysis, parametric tests were adopted. Correlations between outcome scales with pairwise correlation coefficients were evaluated; the correlation was considered to be strong ($r > 0.5$), medium ($0.5 > r > 0.3$), or small ($0.3 > r > 0.1$).[9] In the current study, the return-to-performance rate was calculated as the percentage of players with ACLR who returned to soccer training and match at their previous level of play.[42] An analysis of variance model was used in the univariate analysis to test if outcomes significantly changed among the categories of the variables. The variables that were noted to be significant after univariate analysis were included in the multivariate linear regression analysis model to test possible outcome predictors. The following variables were considered predictors: body mass index (continuous), playing position (categorical), dominant limb (categorical), playing surface (categorical), level of sport (categorical), graft type (categorical), and mechanism of injury (categorical). All the models were adjusted for age (continuous), sex (categorical), and follow-up (continuous). The regression equation for multiple regression analysis is as follows:

$$Y = ®_0 + ®_1X_1 + ®_2X_2 \ldots\ldots ®_pX_p + ©$$

Y = *dependent variable*
® = *constant/intercept*
X = *independent variable*
© = *random error term*

Stata statistical software (Release 16; StataCorp) and GraphPad Prism (Version 7.0; GraphPad Software Inc) were used for the database construction and statistical

TABLE 1
Baseline Characteristics of Included Patients[a]

Patients (N = 168)	Mean ± SD (range) or No. (%)
Sex	
Male	132 (78.6)
Female	36 (21.4)
Age at surgery, y	26.3 ± 8.2 (16-52)
Dominant limb	132 (78.6)
Level of play	
Professional	52 (31.0)
Nonprofessional	116 (69.0)
BMI, kg/m^2	24.1 ± 2.6 (18.6-34.2)
Playing position	
Goalkeeper	18 (10.7)
Defender	63 (37.5)
Midfielder	49 (29.2)
Forward	38 (22.6)
Playing surface	
Natural grass	44 (26.2)
Artificial turf	64 (38.1)
Natural grass and artificial turf	60 (35.7)
Mechanism of ACL injury	
Contact	87 (51.8)
Noncontact	81 (48.2)
Graft type	
ST-G	133 (79.2)
BPTB	27 (16.1)
Synthetic	8 (4.8)
Follow-up, mo	35.5 ± 22.6 (6-84)

[a]ACL, anterior cruciate ligament; BMI, body mass index; BPTB, bone–patellar tendon–bone; ST-G, semitendinosus and gracilis.

analysis. Confidence intervals were set at 95%, and $P < .05$ was considered significant.[31]

RESULTS

Of the 176 patients who met inclusion criteria, 8 were lost at follow-up, leaving 168 patients available for the final evaluation. The characteristics of the study population are summarized in Table 1.

There were 132 (78.6%) men, and the mean age at surgery was 26.3 ± 8.2 years (range, 16-52 years). Professional soccer players numbered 52 (31.0% of the cohort), and the dominant limb was involved in 78.6% of cases. The types of grafts used for ACLR were ST-G, BPTB, and synthetic in 79.2%, 16.1%, and 4.8% of cases, respectively. Overall, 85% of patients returned to their previous level of play. No differences in terms of playing position and playing surface emerged between data collected from medical records and those recollected at follow-up.

Clinical Outcomes

Clinical outcomes after a mean follow-up period of 35.5 ± 22.6 months are shown in Table 2.

At the correlation analysis, the correlation was positive and strong between Lysholm and KOOS ($r = 0.826$; $P < .001$), KOOS and IKDC ($r = 0.802$; $P < .001$), Lysholm and IKDC ($r = 0.691$; $P < .001$), SF-12 PCS and IKDC ($r = 0.615$; $P < .001$) and KOOS and SF-12 PCS ($r = 0.610$; $P < .001$). The correlation was medium and positive between Lysholm scores and SF-12 PCS scores ($r = 0.462$; $P < .001$) and small and positive between IKDC scores and SF-12 MSC scores ($r = 0.295$; $P < .001$) and between KOOS scores and SF-12 MSC scores ($r = 0.238$; $P = .002$) (Supplemental Table S1, available separately).

Tables 3 and 4 show the univariate analysis among outcome measures and the categories of the variables.

Midfielders reported a greater SF-12 PCS score (54.4 ± 3.1) compared with other positions ($P = .049$). A greater postoperative KOOS was detected in professional compared with nonprofessional soccer players (85.4 ± 11.1 vs 80.4 ± 14.9, respectively; $P = .031$) and in players with a history of contact ACL injury compared with those with noncontact injury (83.8 ± 11.2 vs 78.8 ± 16.7, respectively; $P = .024$). Athletes playing soccer on both natural grass and artificial turf showed higher KOOS (87.1 ± 10.4 vs 81.3 ± 14.5 vs 79.2 ± 15.7, respectively; $P = .023$) and SF-12 PCS scores (54 ± 4.4 vs 53 ± 4.6 vs 50.7 ± 8.2, respectively; $P = .04$) when compared with athletes playing on artificial turf or natural grass alone or both. Players who underwent ACLR on the dominant limb reported lower SF-12 MCS scores than players in whom the nondominant limb was involved (45.6 ± 11.1 vs 50.8 ± 8.7, respectively; $P = .017$).

Regression Analysis

The multivariate regression analysis demonstrated that midfielder position was associated with better SF-12 PCS score (β = 4.9; 95% CI, 1.05-8.72; $P = .013$), IKDC (β = 13.2; 95% CI, 4.57-21.84; $P = .003$), total KOOS (β = 16.35; 95% CI, 7.59-25.12; $P < .001$), KOOS Symptoms (β = 14.4; CI 4.7-24.04; $P = .004$), KOOS Pain (β = 8.52; 95% CI, 0.91-16.13; $P = .029$), KOOS ADL (β = 9.6; 95% CI, 0.27-18.94; $P = .044$), KOOS Sport/Rec (β = 25.43; 95% CI, 10.59-40.27; $P = .001$), KOOS QoL (β = 27.62; 95% CI, 13.84-41.41; $P < .001$), and Lysholm score (β = 9.4; 95% CI, 2.52-16.36; $P = .008$).

Nonprofessional players were associated with lower total KOOS (β = −5.7; 95% CI, –10.76 to 0.62; $P = .028$), KOOS Symptoms (β = −7.8; 95% CI, –12.73 to 2.82; $P = .002$), KOOS ADL (β = −5.2; 95% CI, –9.92 to 0.41; $P = .033$), and KOOS Sport/Rec (β = −9.9; 95% CI, –17.9 to 1.83; $P = .016$).

The habit of playing only on natural grass was associated with lower SF-12 PCS scores (β = −4.5; 95% CI, –7.36 to 1.55; $P = .003$), total KOOS (β = −11.3; 95% CI, –18.03 to 4.57; $P = .001$), and KOOS Sport/Rec (β = −14.3; 95% CI, –25.19 to 3.3; $P = .011$). Playing only on artificial turf was associated with lower Lysholm scores (β = −5.6; 95% CI, –10.23 to 0.97; $P = .018$) and total KOOS (β = −7.1; 95% CI, –12.72 to 1.46; $P = .014$).

TABLE 2
Clinical Outcomes of Study Population[a]

	Mean	SD	Min	Max
SF-12 PCS	52.4	5.9	27.8	61.4
SF-12 MCS	49.6	9.1	17.3	65.0
IKDC	75.6	14.9	20.7	100.0
KOOS Symptoms	80.9	14.4	21.0	100.0
KOOS Pain	87.4	12.1	33.0	100.0
KOOS ADL	92.4	12.7	25.0	100.0
KOOS Sport/Rec	75.4	22.7	0.0	100.0
KOOS QoL	69.7	21.5	0.0	100.0
KOOS total	81.9	14.0	20.0	100.0
Lysholm	88.8	11.0	16.0	100.0
ACL-RSI	68.5	11.4	16.0	100.0

[a]ACL-RSI, Anterior Cruciate Ligament–Return to Sport after Injury; ADL, Activities of Daily Living; IKDC, International Knee Documentation Committee subjective knee form; KOOS, Knee injury and Osteoarthritis Outcome Score; Max, maximum; MCS, Mental Component Score; Min, minimum; PCS, Physical Component Score; QoL, Quality of Life; Sport/Rec, Sport and Recreation; SF-12, 12-item Short Form Health Survey.

TABLE 3
Univariate Analysis[a]

	SF-12 PCS		SF-12 MCS		IKDC	
	Mean (SD)	*P*	Mean (SD)	*P*	Mean (SD)	*P*
Playing position						
Forward	54.3 (4.15)	**.049**	50.5 (9.93)	.217	68.9 (10.81)	.072
Midfielder	54.4 (3.08)		50 (7.80)		70.9 (10.04)	
Defender	50.3 (8.45)		51.7 (7.57)		62.8 (16.11)	
Goalkeeper	53.1 (2.97)		48.6 (6.28)		64.7 (13.59)	
Level of play						
Professional	53.5 (3.77)	.122	49.5 (9.21)	.956	68.3 (11.42)	.085
Nonprofessional	52 (6.56)		49.6 (9.13)		64.5 (13.53)	
Mechanism of injury						
Contact	52.7 (5.05)	.251	50.6 (8.27)	.196	67 (10.59)	.124
Noncontact	51.7 (6.84)		48.8 (9.19)		63.8 (15.72)	
Playing surface						
Natural grass	50.7 (8.23)	**.040**	50.3 (8.79)	.881	64.7 (15.25)	.243
Artificial turf	53 (4.60)		49.6 (8.95)		64.6 (12.70)	
Natural grass and artificial turf	54 (4.40)		49.2 (9.56)		68.7 (11.60)	
Graft type						
ST-G	52.1 (6.22)	.478	49.5 (9.42)	.959	65.8 (12.66)	.833
BPTB	53.6 (4.59)		49 (9.52)		64.5 (16.10)	
Synthetic	51.5 (6.66)		49.1 (6.26)		63.6 (13.11)	
Dominant limb involved						
Yes	53.2 (5.05)	.114	45.6 (11.09)	**.017**	64.5 (10.87)	.525
No	51.1 (6.73)		50.8 (8.72)		62.7 (14.56)	

[a]BPTB, bone–patellar tendon–bone; IKDC, International Knee Documentation Committee subjective knee form; MCS, Mental Component Score; PCS, Physical Component Score; SF-12, 12-item Short Form Health Survey; ST-G, semitendinosus and gracilis. *P* value in bold are statistically significant.

ACL injury due to contact mechanism was associated with higher IKDC (β = 4.4; 95% CI, 0.12 to 8.73; *P* = .044) and KOOS QoL (β = 7.4; 95% CI, 0.07 to 14.73; *P* = .048), and ACL injury affecting the dominant limb predicted lower SF-12 MCS (β = −6.1; 95% CI, –10.9 to 1.38; *P* = .012).

DISCUSSION

In the current study, high patient functional and psychological scores were reported a mean of 3 years after anatomic single-bundle ACLR. Overall, 85% of patients returned to performance at their previous level of play.

TABLE 4
Univariate Analysis[a]

	KOOS Total		Lysholm		ACL-RSI	
	Mean (SD)	*P*	Mean (SD)	*P*	Mean (SD)	*P*
Playing position						
Forward	84.7 (13.09)	.069	89.1 (11.91)	.231	68.5 (13.43)	.393
Midfielder	87.4 (9.16)		92.8 (7.39)		66.9 (12.77)	
Defender	80.2 (17.11)		88.7 (10.84)		65.1 (8.61)	
Goalkeeper	85.3 (11.21)		89.8 (10.00)		72.6 (9.57)	
Level of play						
Professional	85.4 (11.10)	**.031**	90.4 (9.64)	.216	69.9 (10.68)	.286
Nonprofessional	80.4 (14.88)		88.1 (11.49)		67.9 (11.73)	
Mechanism of injury						
Contact	83.8 (11.23)	**.024**	89.7 (8.85)	.179	68.4 (10.23)	.821
Noncontact	78.7 (16.68)		87.3 (13.48)		68 (10.63)	
Playing surface						
Natural grass	79.2 (15.65)	**.023**	89.4 (10.95)	.300	68.3 (12.65)	.995
Artificial turf	81.3 (14.48)		87.5 (14.33)		68.1 (12.11)	
Natural grass and artificial turf	87.1 (10.39)		91.2 (8.35)		68.1 (10.55)	
Graft type						
ST-G	81.8 (13.84)	.852	89 (9.55)	.747	68.2 (11.71)	.976
BPTB	81.5 (16.03)		87.2 (16.88)		68.7 (10.37)	
Synthetic	78.9 (12.84)		88.4 (9.50)		68.8 (9.44)	
Dominant limb involved						
Yes	80.9 (13.55)	.752	88.7 (8.79)	.877	68.6 (14.10)	.573
No	79.9 (15.47)		88.4 (10.04)		70.2 (11.87)	

[a] ACL-RSI, Anterior Cruciate Ligament–Return to Sport after Injury; BPTB, bone–patellar tendon–bone; KOOS, Knee injury and Osteoarthritis Outcome Score; ST-G, semitendinosus and gracilis. *P* value in bold are statistically significant.

Professional soccer players and the midfielder position reported better functional scores upon returning to the sport. The habit of playing soccer on both natural grass and artificial turf was associated with higher functional scores than those of athletes playing on just one of the surfaces. ACL injury due to a noncontact mechanism was associated with lower functionality and QoL. Injuries affecting the dominant limb were associated with lower SF-12 MCS.

Returning to sports after ACLR is a difficult and complex process that depends on both medical and nonmedical factors.[10] RTS is both a measure of the success of the surgical procedure and a measure of patient satisfaction.[30] In the current study, 85% of soccer players returned to performance at their preinjury level of play, and this finding is consistent with previously published rates.[22] Waldén et al[41] investigated ACL injuries in male professional soccer players and found that 88% of patients were still playing soccer 3 years after the RTS, but 65% played at the same level and 23% played at a lower level. Moreover, it should be considered that nearly 1 out of every 5 athletes who undergo ACLR do not return to playing the sport, which remains below the expectations of patients undergoing ACLR and their clinicians.[7,17]

In the current cohort, anatomic single-bundle ACLR using an autograft was performed in 95% of cases, mean values around 80% of the maximum achievable value were obtained for all functional outcomes evaluated, and mean values from 50% to 70% were obtained for the outcomes relating to mental health and psychological well-being. Interestingly, Sepulveda et al[35] reported that among the most influential factors associated with ACLR outcomes and RTS are graft choice and anatomic position; the authors found that an anatomic tunnel position, along with appropriate autograft tensioning, ensures optimal graft isometry and function.

Level of Play

We found that playing soccer on a professional level was associated with better functional scores upon returning to the sport. A combination of factors, including superior athletic skill,[1] levels of physical fitness[29] and knee proprioception,[28] ready access to high-quality health care,[26] and greater financial incentives to play, might help to explain why professional soccer players reported higher functional scores than nonprofessional athletes.

Playing Position

The risk of developing an ACL injury and the capability to RTS itself seem to vary with playing position as well. Previous literature suggested that pressing is one of the most common injury mechanisms.[8,21] In a pressing situation, the player typically makes a sidestep cut to reach the ball or to tackle an opponent. Other authors[12] reported that pressing tactics and a high-speed style of play have

important correlations with ACL injury mechanisms. An analysis of performance suggested that different play positional roles require unique technical, physiological, and tactical demands from the players. For instance, defenders are more frequently engaged in pressing and aerial duels than midfielders, and forward players cover significantly greater distances while sprinting than midfielders. These unique technical and physiological demands predispose players to a greater risk of concussion among defenders and strain among forward players due to the eccentric overload of the musculotendinous junction that has been found to emerge when sprinting[11]; however, no agreement regarding the correlation between position and injury risk exists in the literature. Overall, these aspects of the style of play and injury mechanisms could explain why, in the present study, the midfielder position was associated with better functional scores when returning to the sport.

Playing Surface

It was observed that the habit of playing soccer on both natural grass and artificial turf was associated with higher functional scores than those of athletes playing on just 1 surface. Biomechanical studies have generally supported increased frictional forces on artificial turf, but clinical studies have demonstrated inconclusive results.[14] Eisenstein et al[14] investigated the RTS rate after ACLR in the National Football League and reported no significant association with playing surface. Dragoo et al[13] supported the use of modern third-generation artificial turf as a safe and appropriate alternative to natural grass playing surfaces. Conversely, Andersson et al[3] reported a negative overall impression, poorer ball control, and greater physical effort among athletes playing on artificial turf than natural grass. However, natural grass surfaces are inherently variable due to several factors, such as soil type and grass root density. In addition, natural grass might not be as well maintained in training fields compared with match fields, where more attention is likely to be paid to keeping the fields in good condition for the competing athletes.[23] The response to physical wear and environmental exposures were also identified in the current literature as variables influencing the performance of playing surfaces.[46] In the current study, practicing on both artificial turf and natural grass could have had positive implications on neuromuscular aspects in soccer players, including proprioception, muscle activation, and interarticular coordination, with greater dynamic knee stability.[38]

Mechanism of Injury

In addition, it was found that ACL injury due to a noncontact mechanism was associated with lower functionality and QoL among athletes who returned to full sports participation. Noncontact ACL tears were considered injuries after nonphysical contact with other players; the most common mechanism includes a deceleration task with high knee internal extension torque combined with dynamic valgus rotation with the body weight shifted over the injured leg and the plantar surface of the foot fixed flat on the playing surface. Noncontact ACL injuries in soccer players have a multifactorial etiology,[5] and risk factors include knee joint laxity, narrow intercondylar notch width, and decreased proprioception. It should be considered that the prevention of noncontact ACL injuries through modification of anatomic risk factors seems to have limited potential for intervention.[2] These risk factors are often not managed during ACLR surgery and therefore persist postoperatively, conditioning the optimal RTS.

Limb Dominance

In the current study, ACL injury affecting the dominant limb was associated with lower SF-12 MCS among athletes who have returned to full sports participation. The difference in SF-12 MCS values (5.2) between the players with ACL injury affecting the dominant limb and those with injury of the nondominant limb was greater than the minimal clinically important difference after ACLR.[33] The MCS component is a determinant of disability, and the demonstration of the value of treatment at a global level is also becoming more of a requirement from many policy makers.[36] When data from the current study were compared with the general population, >88% of our cohort scored in the mean or above mean range for both the PCS and the MCS scores of the SF-12. The effect of limb dominance on ACL injuries and biomechanics is controversial, and there is limited literature on this topic. Boo et al[6] reported that 92.9% of patients with a nondominant limb injury and 87.2% with a dominant limb injury had returned to their preinjury sport 1 year after ACLR. The authors also found that limb dominance does not have a significant impact on patient-reported functional outcome scores, which is consistent with our results.

Limitations and Strengths

There are several limitations to our study. Given the retrospective nature of the design of this study, potential bias cannot be excluded. Since we only evaluated athletes who returned to sports, we cannot comment on whether the differences we noted would be predictive of successful return to sport. Also, while we observed some differences in scores based on position, level of participation, and playing surface, we cannot determine causation. Also, the use of different types of grafts may represent a weakness of the study. We were unable to control for confounding factors, such as shoe type, field conditions, type of artificial turf field, and training and match exposures. Further studies should explore this topic and assess any possible confounding factors that may not be captured. The study design adhered to the consensus statement on injury definitions and data collection procedures in studies on soccer injuries.[18] This multicentric study consisted of patients who underwent ACLR by different surgeons; therefore, the risk of selection bias should also be considered in our cohort. The comprehensive evaluation of patients by validated tools recommended by the consensus criteria for defining successful outcomes

after ACLR[30] and the rigorous collection of ACL injury data, as well as the sample size and follow-up time, which was comparable with the largest and longest series available on multiparametric evaluation of RTS in soccer represent considerable strengths of the present study.

CONCLUSION

After anatomic single-bundle ACLR, 85% of soccer players can expect to return to performance at their preinjury level. Professional soccer players and the midfielder position are associated with better functional scores upon returning to the sport. A history of noncontact ACL injury and playing on a single type of surface are associated with lower functional outcomes when returning to the sport. Postoperatively, lower mental health scores can be expected after injury to the dominant limb. This information may assist in guiding the expectations of soccer players and clinicians as well as in improving outcomes in these subgroups.

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REFERENCES

1. Aglioti SM, Cesari P, Romani M, Urgesi C. Action anticipation and motor resonance in elite basketball players. *Nat Neurosci*. 2008;11(9):1109-1116.
2. Alentorn-Geli E, Myer GD, Silvers HJ, et al. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 1: Mechanisms of injury and underlying risk factors. *Knee Surg Sports Traumatol Arthrosc*. 2009;17(7):705-729.
3. Andersson H, Ekblom B, Krustrup P. Elite football on artificial turf versus natural grass: movement patterns, technical standards, and player impressions. *J Sports Sci*. 2008;26(2):113-122.
4. Ardern CL, Taylor NF, Feller JA, Webster KE. Fifty-five per cent return to competitive sport following anterior cruciate ligament reconstruction surgery: an updated systematic review and meta-analysis including aspects of physical functioning and contextual factors. *Br J Sports Med*. 2014;48(21):1543-1552.
5. Boden BP, Dean GS, Feagin JA, Garrett WE. Mechanisms of anterior cruciate ligament injury. *Orthopedics*. 2000;23(6):573-578.
6. Boo H, Howe T, Koh JS. Effect of leg dominance on early functional outcomes and return to sports after anterior cruciate ligament reconstruction. *J Orthop Surg*. 2020;28(1):230949901989623.
7. Bradley JP, Klimkiewicz JJ, Rytel MJ, Powell JW. Anterior cruciate ligament injuries in the National Football League: epidemiology and current treatment trends among team physicians. *Arthroscopy*. 2002;18(5):502-509.
8. Brophy RH, Schmitz L, Wright RW, et al. Return to play and future ACL injury risk after ACL reconstruction in soccer athletes from the Multicenter Orthopaedic Outcomes Network (MOON) group. *Am J Sports Med*. 2012;40(11):2517-2522.
9. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Routledge; 1988.
10. Creighton DW, Shrier I, Shultz R, Meeuwisse WH, Matheson GO. Return-to-play in sport: a decision-based model. *Clin J Sport Med*. 2010;20(5):379-385.
11. Delfico AJ, Garrett WE. Mechanisms of injury of the anterior cruciate ligament in soccer players. *Clin Sports Med*. 1998;17(4):779-785, vii.
12. Della Villa F, Mandelbaum BR, Lemak LJ. The effect of playing position on injury risk in male soccer players: systematic review of the literature and risk considerations for each playing position. *Am J Orthop (Belle Mead NJ)*. 2018;47(10):doi: 10.12788/ajo.2018.0092
13. Dragoo JL, Braun HJ, Harris AHS. The effect of playing surface on the incidence of ACL injuries in National Collegiate Athletic Association American Football. *Knee*. 2013;20(3):191-195.
14. Eisenstein ED, Rawicki NL, Rensing NJ, Kusnezov NA, Lanzi JT. Variables affecting return to play after anterior cruciate ligament injury in the National Football League. *Orthop J Sports Med*. 2016;4(10):232596711667011.
15. 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(11):1517-1525.
16. Ekstrand J, Hägglund M, Waldén M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med*. 2011;45(7):553-558.
17. Feucht MJ, Cotic M, Saier T, et al. Patient expectations of primary and revision anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2016;24(1):201-207.
18. Fuller CW. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Br J Sports Med*. 2006;40(3):193-201.
19. Gornitzky AL, Lott A, Yellin JL, Fabricant PD, Lawrence JT, Ganley TJ. Sport-specific yearly risk and incidence of anterior cruciate ligament tears in high school athletes: a systematic review and meta-analysis. *Am J Sports Med*. 2016;44(10):2716-2723.
20. Gouttebarge V, Aoki H, Ekstrand J, Verhagen EALM, Kerkhoffs GMMJ. Are severe musculoskeletal injuries associated with symptoms of common mental disorders among male European professional footballers? *Knee Surg Sports Traumatol Arthrosc*. 2016;24(12):3934-3942.
21. Grassi A, Macchiarola L, Filippini M, Lucidi GA, Della Villa F, Zaffagnini S. Epidemiology of anterior cruciate ligament injury in Italian first division soccer players. *Sports Health*. 2020;12(3):279-288.
22. Harris JD, Abrams GD, Bach BR, et al. Return to sport after ACL reconstruction. *Orthopedics*. 2014;37(2):103-108.
23. Howard M, Solaru S, Kang HP, et al. Epidemiology of anterior cruciate ligament injury on natural grass versus artificial turf in soccer: 10-year data from the National Collegiate Athletic Association Injury Surveillance System. *Orthop J Sports Med*. 2020;8(7):2325967120934434.
24. Irrgang JJ, Anderson AF, Boland AL, et al. Development and validation of the International Knee Documentation Committee Subjective Knee Form. *Am J Sports Med*. 2001;29(5):600-613.
25. Kaeding CC, Léger-St-Jean B, Magnussen RA. Epidemiology and diagnosis of anterior cruciate ligament injuries. *Clin Sports Med*. 2017;36(1):1-8.
26. Koning RH, Amelink R. Medium-term mortality of Dutch professional soccer players. *Econ Labour Relations Rev*. 2012;23(2):55-68.
27. Kiliç Ö, Aoki H, Goedhart E, et al. Severe musculoskeletal time-loss injuries and symptoms of common mental disorders in professional soccer: a longitudinal analysis of 12-month follow-up data. *Knee Surg Sports Traumatol Arthrosc*. 2018;26(3):946-954.
28. Lin CH, Lien YH, Wang SF, Tsauo JY. Hip and knee proprioception in elite, amateur, and novice tennis players. *Am J Phys Med Rehabil*. 2006;85(3):216-221.
29. Lorenz DS, Reiman MP, Lehecka BJ, Naylor A. What performance characteristics determine elite versus nonelite athletes in the same sport? *Sports Health*. 2013;5(6):542-547.
30. Lynch AD, Logerstedt DS, Grindem H, et al. Consensus criteria for defining ''successful outcome'' after ACL injury and reconstruction:

a Delaware-Oslo ACL cohort investigation. *Br J Sports Med*. 2015;49(5):335-342.
31. Mansournia MA, Collins GS, Nielsen RO, et al. A CHecklist for statistical Assessment of Medical Papers (the CHAMP statement): explanation and elaboration. *Br J Sports Med*. 2021;55(18):1009-1017.
32. Mascarenhas R, MacDonald PB. Anterior cruciate ligament reconstruction: a look at prosthetics—past, present and possible future. *McGill J Med*. 2008;11(1):29-37.
33. Nwachukwu BU, Chang B, Voleti PB, et al. Preoperative short form health survey score is predictive of return to play and minimal clinically important difference at a minimum 2-year follow-up after anterior cruciate ligament reconstruction. *Am J Sports Med*. 2017;45(12): 2784-2790.
34. Roos EM, Roos HP, Lohmander LS, Ekdahl C, Beynnon BD. Knee Injury and Osteoarthritis Outcome Score (KOOS)—development of a self-administered outcome measure. *J Orthop Sports Phys Ther*. 1998;28(2):88-96.
35. Sepulveda F, Sanchez L, Amy E, Micheo W. Anterior cruciate ligament injury: return to play, function and long-term considerations. *Curr Sports Med Rep*. 2017;16(3):172-178.
36. Shapiro ET, Richmond JC, Rockett SE, McGrath MM, Donaldson WR. The use of a generic, patient-based health assessment (SF-36) for evaluation of patients with anterior cruciate ligament injuries. *Am J Sports Med*. 1996;24(2):196-200.
37. Staniszewska S, Brett J, Simera I, et al. GRIPP2 reporting checklists: tools to improve reporting of patient and public involvement in research. *BMJ*. 2017;358:J3453.
38. Sugimoto D, Alentorn-Geli E, Mendiguchía J, Samuelsson K, Karlsson J, Myer GD. Biomechanical and neuromuscular characteristics of male athletes: implications for the development of anterior cruciate ligament injury prevention programs. *Sports Med*. 2015;45(6):809-822.
39. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res*. 1985;198:43-49.
40. Toale JP, Hurley ET, Hughes AJ, et al. The majority of athletes fail to return to play following anterior cruciate ligament reconstruction due to reasons other than the operated knee. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(11):3877-3882.
41. Waldén M, Hägglund M, Magnusson H, Ekstrand J. ACL injuries in men's professional football: a 15-year prospective study on time trends and return-to-play rates reveals only 65% of players still play at the top level 3 years after ACL rupture. *Br J Sports Med*. 2016;50(12):744-750.
42. Waldén M, Hägglund M, Magnusson H, Ekstrand J. Anterior cruciate ligament injury in elite football: a prospective three-cohort study. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(1):11-19.
43. Webster KE, Feller JA. Development and validation of a short version of the Anterior Cruciate Ligament Return to Sport After Injury (ACL-RSI) scale. *Orthop J Sports Med*. 2018;6(4):2325967118763763.
44. Webster KE, Feller JA. Use of the short form health surveys as an outcome measure for anterior cruciate ligament reconstruction. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(5):1142-1148.
45. Webster KE, Feller JA, Lambros C. Development and preliminary validation of a scale to measure the psychological impact of returning to sport following anterior cruciate ligament reconstruction surgery. *Phys Ther Sport*. 2008;9(1):9-15.
46. Williams S, Hume PA, Kara S. A review of football injuries on third and fourth generation artificial turfs compared with natural turf. *Sports Med*. 2011;41(11):903-923.