Original Research

Failure Rates After Anterior Cruciate Ligament Repair With Suture Tape Augmentation in an Active-Duty Military Population

Christian A. Cruz,*† MD, Brian J. Mannino,† MD, Connor B. Venrick,† MD, Rebecca N. Miles,‡ BS David R. Peterson,† MD, Liang Zhou,† MD, Kyong S. Min,† MD, and Craig R. Bottoni,† MD

Investigation performed at Tripler Army Medical Center, Honolulu, Hawaii, USA

Background: Anterior cruciate ligament (ACL) repair had previously been considered the standard of care for a ruptured ACL; however, ACL reconstruction has became the standard of care because of poor midterm outcomes after ACL repair. Recently, studies have suggested that the treatment paradigm should shift back to ACL repair.

Purpose/Hypothesis: The purpose of this study was to evaluate the outcomes of ACL repair augmented with suture tape in a high-demand military population. We hypothesized that for proximal ACL avulsions, ACL repair with suture tape augmentation would lead to acceptable failure rates, satisfactory knee stability, excellent functional outcomes, and high rates of return to preinjury activity levels.

Study Design: Case series; Level of evidence, 2.

Methods: Patients who were treated with ACL repair by a single surgeon between March 2017 and June 2019 and who had a minimum of 2 years of follow-up were included. Intraoperatively, all patients first underwent an arthroscopic examination. If an ACL avulsion of the proximal insertion with adequate remaining tissue was visualized, then ACL repair was performed. The primary outcome assessed was ACL repair failure, defined as reruptures or clinical instability requiring revision to ACL reconstruction. Analysis of the risk factors for ACL repair failure was conducted, with age at surgery, sex, body mass index, level of competition, and tobacco use evaluated.

Results: Included were 46 patients (32 male and 14 female; mean age, 28.3 ± 8.4 years) who underwent ACL repair with suture tape augmentation. There were 12 cases of failure (26.1%; 8 male and 4 female). The mean time from injury to surgery in the failure group was 164.1 ± 59.4 days compared to 107.3 ± 98.0 days in the nonfailure group ($P = .02$). According to multivariate regression analysis, patients aged ≤17 and ≥35 years, elite/competitive/operational patients, and current smokers had a higher chance of ACL repair failure. The mean time to pass a military physical fitness test was 5.0 months. There were no complications other than ACL repair failure.

Conclusion: Primary arthroscopic ACL repair with suture tape augmentation resulted in unacceptably high failure rates at a minimum of 2 years of follow-up in a highly active military population. Age ≤17 and ≥35 years, elite level of competition, time from injury to surgery, and active tobacco use were independent risk factors for ACL repair failure.

Keywords: anterior cruciate ligament; repair; failure rates; risk factors; military

Historically, primary repair of the anterior cruciate ligament (ACL) has been found to have poor clinical outcomes.[1,9,33] The results of a seminal study of ACL repair on West Point cadets by Feagin and Curl[10] found an unacceptably high rate of reruptures and subjective instability. Of note, however, these repair procedures were all performed before the advent of arthroscopic surgery and without the advantage of magnetic resonance imaging. Subsequently, the standard of care for the surgical treatment of an ACL rupture has become ACL reconstruction (ACLR) using either autograft or allograft tissue.[25,29,34] Recently, the concept of ACL repair in very limited cases has been revisited. Proponents of ACL repair have suggested that, in select cases, repair of a proximally ruptured ACL may be more preferable than reconstruction.[2] Several studies have shown that, in proximal ACL tears, repair may be considered because of the adequate healing potential of the native ligament.[30] Proposed advantages of ACL repair include the preservation of native proprioception and vascularity through innervation and blood supply of the native ligament. Additional potential benefits

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of repair are smaller incisions, the obviation of graft site morbidity, and a quicker return to function.[5,7,8,22,24]

Recently, several studies have investigated the clinical outcomes of ACL repair.[15,20,35] One factor that has been specifically addressed in several studies is the use of strong nonabsorbable suture tape to protect the ACL repair site during the early phase of healing. Jonkergouw et al[22] reported a 10.7% failure rate of ACL repair at an minimum 2-year follow-up. In a similar study, Heusdens et al[17] reported a 4.8% failure rate in 48 patients who underwent ACL repair with suture tape augmentation. Lastly, van der List et al,[36] in a meta-analysis, reported on arthroscopic ACL repair techniques, with failure rates of 7% to 11%, no complications, and functional outcome scores of >85% of the maximum.

The purpose of this study was to evaluate the outcomes of ACL repair augmented with suture tape in a high-demand military population. We hypothesized that for proximal ACL avulsions, ACL repair with suture tape augmentation would lead to acceptable failure rates, satisfactory knee stability, excellent functional outcomes, and high rates of return to preinjury activity levels.

METHODS

Between March 2017 and June 2019, a total of 196 ACL ruptures were managed operatively by the senior author (C.R.B.). Of these cases, 144 ACLR and 52 ACL repair procedures were performed. All patients with an ACL rupture who were indicated for operative management consented to undergo both ACL repair and ACLR. Indications for ACL repair included a proximal lateral femoral condyle avulsion with adequate remaining native ACL tissue. We excluded patients who chose ACLR as well as those with multiligamentous knee injuries and those who had not completed 2-year follow-up at the time of data collection.

Initially included in this study were 52 consecutive patients treated with ACL repair between March 2017 and June 2019. Overall, 6 patients were lost to follow-up, leaving 46 patients available for analysis at a minimum 2-year follow-up. This study was considered exempt from institutional review board approval by our institution. All study patients provided informed consent.

Surgical Procedure

All ACL repair procedures and arthroscopic evaluations were performed at a single institution by the senior author (C.R.B.), who is board certified and fellowship trained in sports medicine. All patients first underwent an examination under anesthesia to confirm pathological laxity of the ACL and a subsequent arthroscopic examination to confirm the ligament injury. Most importantly, to ascertain the feasibility of ACL repair, the location of the rupture and the quality of remaining tissue were carefully examined (Figure 1).

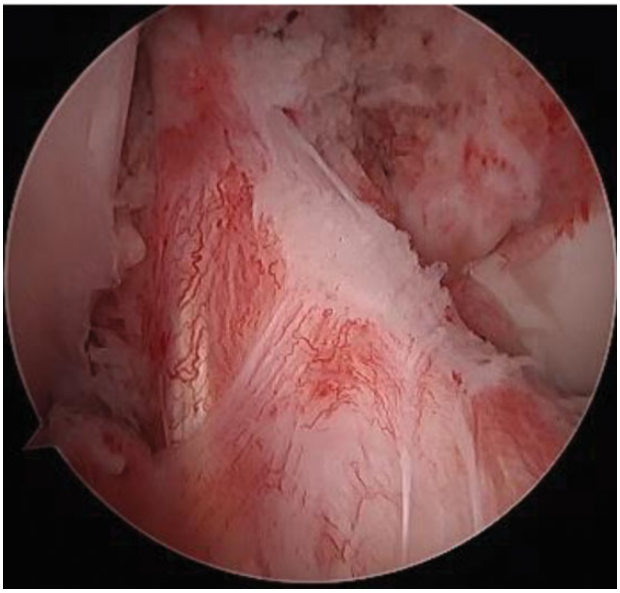

Figure 1. Proximal anterior cruciate ligament avulsion with adequate good-quality remaining tissue.

If a proximal ACL avulsion from the medial wall of the lateral femoral condyle was identified during initial arthroscopic surgery, the remaining ACL tissue was thoroughly inspected. If it was determined that the quality of the native ACL was adequate, then ACL repair was performed. To help mitigate suture entanglement and facilitate instrument passage, a large flexible cannula was inserted into the anteromedial portal (10-mm PassPort Cannula; Arthrex). The ligament was sutured using a self-retrieving suture-passing instrument (Scorpion; Arthrex) loaded with a high-strength nonabsorbable suture (No. 2 FiberWire; Arthrex) in an interlocking-loop fashion starting from the distal aspect (tibial insertion) and working proximally (Figure 2).

The femoral footprint on the medial wall of the lateral femoral condyle was abraded with an arthroscopic shaver to stimulate a healing response and to clearly identify the femoral footprint for repair (Figure 3A). A suture anchor (4.75-mm BioComposite SwiveLock; Arthrex) was preloaded with high-strength suture tape (FiberTape; Arthrex) as well as the free ends of the suture that was

*Address correspondence to Christian A. Cruz, MD, Department of Orthopaedic Surgery, Tripler Army Medical Center, 1 Jarret White Road, Honolulu, HI 96859, USA (email: chcruz93@gmail.com).

†Department of Orthopaedic Surgery, Tripler Army Medical Center, Honolulu, Hawaii, USA.

‡School of Medicine, Uniformed Services University of the Health Sciences, Bethesda, Maryland, USA.

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passed through the native ACL (Figure 3B). A standard ACL tibial drill guide was utilized to pass a drill-tip pin to the base of the ACL tibial footprint, taking care not to damage the previously placed sutures. Over this guide pin, a 4.5-mm cannulated reamer was used to create a tunnel, after which the reamer was left in place and the guide pin removed. Through the cannulated reamer, a nitinol wire with a looped end was passed into the joint and retrieved out the anteromedial portal. The free ends of the suture tape were then shuttled into the joint and down the tibial drill hole with the nitinol wire. The ligament was then reapproximated to the anatomic femoral footprint using the suture anchor. Next, the ends of the suture tape were tensioned and secured to the tibia using an additional suture anchor (4.75-mm BioComposite SwiveLock, Arthrex) while the knee was placed in full extension (Figure 3C).

Postoperative Management

Patients without concomitant meniscal repair were immediately permitted to be weightbearing as tolerated with a hinged knee brace locked in extension for the first 2 weeks. While in a nonweightbearing status, these patients were permitted knee range of motion as tolerated. For the following 4 weeks, patients continued to wear their hinged knee brace; however, they were allowed to have full range of motion with the use of a crutch for ambulation. If meniscal repair was performed, the postoperative regimen was altered accordingly: the patients were nonweightbearing, and range of motion was restricted to 90° of flexion for 4 weeks postoperatively. All patients followed a standardized ACLR rehabilitation protocol supervised by a physical therapist.[21] Full active motion was encouraged in all cases. The hinged knee brace was typically discontinued at 4 weeks postoperatively. Patients were allowed to return to sport or military activity when cleared by their physical therapist at a minimum of 4 months postoperatively.

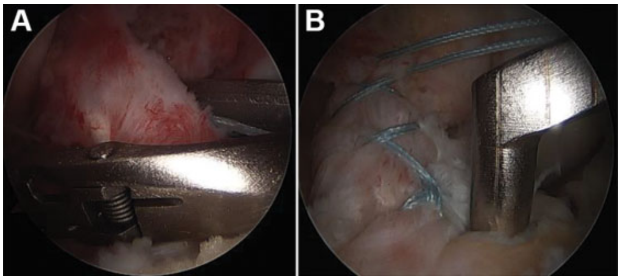

Figure 2. (A) A Scorpion suture passer (Arthrex) was used to pass the suture through the anterior cruciate ligament (ACL). (B) The ACL was sutured with an interlocking-loop technique.

Evaluation at Latest Follow-up

Study patients were contacted by telephone to complete a survey to ascertain if they had sustained any injury that necessitated revision ACL surgery or if they had any subjective knee instability. Patients were queried as to whether they were able to remain on active-duty status after ACL repair. Additionally, if they remained on active duty, they were asked when they were able to pass a military physical fitness test after their ACL surgery. Online questionnaires were administered via email to assess functional outcomes. Patients completed the Knee injury and Osteoarthritis Outcome Score (KOOS) and International Knee Documentation Committee (IKDC) questionnaires as well as the Single Assessment Numeric Evaluation (SANE). Patient-reported outcomes from those who sustained ACL repair failure were excluded. Knee stability was assessed by asking patients if they had subjective stability with sports or daily activities. Postoperative complications were assessed via a chart review and telephone questionnaire.

Statistical Analysis

Descriptive statistical analysis were performed using Excel (Microsoft) for ACL repair failure requiring revision surgery; KOOS, IKDC, and SANE scores; postoperative subjective instability; return to full active-duty status; and time to pass a military physical fitness test. The primary outcome was ACL repair failure requiring revision surgery.

Analysis of the risk factors for ACL repair failure was conducted based on age at surgery (3 comparison groups), sex, body mass index, level of competition (2 comparison groups), and tobacco use (never vs former vs current; current [yes vs no]). Age comparisons were as follows:

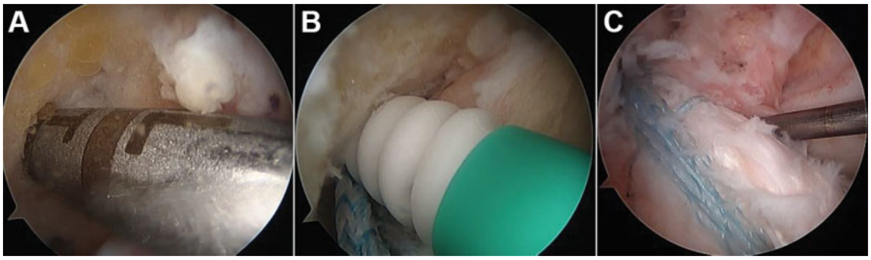

Figure 3. (A) A SwiveLock punch (Arthrex) was used in the native anterior cruciate ligament (ACL) insertion on the lateral femoral condyle after the femoral condyle was abraded with an arthroscopic shaver. (B) A SwiveLock anchor (Arthrex) containing the sutures placed in the ACL preloaded with high-strength suture tape (FiberTape; Arthrex) was inserted for internal brace augmentation. (C) Final ACL repair construct with suture tape augmentation.

TABLE 1
Patient Demographics (n = 46)[a]

Variable	Value	Variable	Value[b]
Age		Competition level	
12-17 y	6 (13.0)	Recreational	27 (64.3)
18-27 y	16 (34.8)	Competitive/operational	5 (11.9)
28-34 y	14 (30.4)	Elite	10 (23.8)
35-50 y	10 (21.7)	Tobacco use	
Mean ± SD, y	28.3 ± 8.4	Never	37 (80.4)
Median (IQR), y	28.5 (23-34)	Former	2 (4.3)
Sex		Yes (cigarettes)	4 (8.7)
Female	14 (30.4)	Yes (e-cigarettes)	2 (4.3)
Male	32 (69.6)	Yes (chewing tobacco)	1 (2.2)
Body mass index		Current tobacco use	
<25 kg/m^2	6 (13.3)[b]	No	39 (84.8)
25-29 kg/m^2	25 (55.6)	Yes	7 (15.2)
≥30 kg/m^2	14 (31.1)		

[a]Data are reported as n (%) unless otherwise indicated. IQR, interquartile range.
[b]46 is the total number of patients included in follow-up for the study. Not all patients met the competition level.

(1) 12-17 versus 18-27 versus 28-34 versus 35-50 years, (2) 18-27 versus ≤17 or ≥28 years, and (3) 18-34 versus ≤17 or ≥35 years. Comparisons of level of competition were as follows: (1) recreational versus competitive/operational versus elite and (2) recreational versus competitive/elite/operational. "Operational" is a military special forces activity designation. The analysis of risk factors was performed using the Fisher exact test if there were 2 levels and the chi-square test if there were >2 levels. In addition, multivariate logistic regression analysis was performed for risk factors associated with ACL repair failure, with variables of interest being age at surgery, body mass index, sex, level of competition, tobacco use, and time from injury to surgery. Significance was assumed for P values <.05. Statistical analysis was conducted using SPSS version 18.0 statistical software (IBM).

A post hoc power analysis was performed with the variable of interest being the failure rate. Based on an effect size of 0.5 and an alpha value of 0.8, a minimum of 91 patients per study group was required to achieve a power of 0.8.

RESULTS

All 46 study patients (32 male and 14 female) were active-duty service members at the time of their index procedure. The mean time from injury to surgery was 96.8 ± 77.4 days. Patient characteristics are shown in Table 1. Concomitant intra-articular abnormalities including medial meniscal tears, lateral meniscal tears, tears requiring repair, medial femoral condyle chondromalacia, lateral femoral condyle chondromalacia, and patellofemoral chondromalacia for all patients are shown in Table 2.

At a mean follow-up of 3.1 ± 1.1 years, there were 12 cases of failure (26.1%) defined as reruptures or clinical instability requiring conversion to ACLR. Of the patients with failures, 8 were male (66.7%), and 4 were female

TABLE 2
Concomitant Intra-articular Abnormalities[a]

	Failure (n = 12)	Nonfailure (n = 34)
Medial meniscal tear	0 (0.0)	6 (13.0)
Lateral meniscal tear	3 (37.5)	20 (43.5)
Tears requiring repair	0 (0.0)	5 (10.9)
Patellofemoral chondromalacia	1 (12.5)	4 (8.7)
Medial femoral condyle chondromalacia	0 (0.0)	3 (6.5)
Lateral femoral condyle chondromalacia	2 (25.0)	4 (8.7)

[a]Data are reported as n (%).

(33.3%) ($P > .99$). Of these, 3 failures (25.0%) were a result of chronic residual instability without a traumatic reinjury. The mean time from injury to surgery in the failure group was 164.1 ± 59.4 days compared to 107.3 ± 98.0 days in the nonfailure group ($P = .02$). Patients aged ≥35 years had a failure rate of 50.0% compared to 12.5% in patients aged 18-27 years and 21.4% in patients aged 28-34 years. Additionally, there was a 33.3% failure rate in patients aged 12-17 years (Table 3).

There was a significantly higher failure rate in patients identified as elite athletes compared to competitive and/or recreational athletes ($P = .020$) (Table 3). Multivariate logistic regression analysis indicated a significantly higher failure rate in patients aged ≤17 years or ≥35 years ($P = .049$). Tobacco use was identified as a risk factor for failure, with a higher failure rate in smokers compared to nonsmokers ($P = .035$) (Table 4).

At a minimum 2-year follow-up, of the nonfailure group (n = 34), 83.7% of patients reported subjective stability with cutting and pivoting activities. Additionally, of the nonfailure group, the mean IKDC score was 81.2 ± 8.8, the mean KOOS score was 83.7 ± 8.4, and the mean SANE score was 82.9 ± 9.3. There were 6 patients (13.0%) who were not able to return to full active-duty status without restrictions. The mean time from surgery to clearance by a physical therapist and the ability to pass a military physical fitness test was 5.0 months. There were no other complications other than ACL repair failure.

DISCUSSION

The results of this study demonstrated poor short-term failure rates after ACL repair with suture tape augmentation in an active-duty military population. The overall failure rate in this active-duty military population was 26.1%. Additionally, of the nonfailure group, only 83.7% reported subjective stability with cutting and pivoting activities.

In contrast to our study results, recent literature has demonstrated improved clinical outcomes as well as lower rerupture rates with modern ACL repair techniques.[§] In a prospective randomized controlled trial comparing ACL repair to ACLR, Hoogeslag et al[19] found that augmented ACL

[§]References 6, 12, 16, 17, 19, 22, 26–29, 31, 36–40

TABLE 3
Failure Rates (n = 12)[a]

	Total No. of Patients	n (%)	*P* Value
Age (grouping 1)			.186
12-17 y	6	2 (33.3)	
18-27 y	16	2 (12.5)	
28-34 y	14	3 (21.4)	
35-50 y	10	5 (50.0)	
Age (grouping 2)			.170
18-27 y	16	2 (12.5)	
≤17 or ≥28 y	30	10 (33.3)	
Age (grouping 3)			.077
18-34 y	30	5 (16.7)	
≤17 or ≥35 y	16	7 (43.8)	
Sex			>.999
Female	14	4 (28.6)	
Male	32	8 (25.0)	
Body mass index[b]			.881
<25 kg/m²	6	2 (33.3)	
25-29 kg/m²	25	6 (24.0)	
≥30 kg/m²	14	4 (28.6)	
Competition level (grouping 1)[b]			**.032**
Recreational	27	3 (11.1)	
Competitive/operational	5	2 (40.0)	
Elite	10	5 (50.0)	
Competition level (grouping 2)[b]			**.020**
Recreational	27	3 (11.1)	
Competitive/elite/operational	15	7 (46.7)	
Tobacco use			—[c]
Never	37	8 (21.6)	
Former	2	0 (0.0)	
Yes (cigarettes)	4	2 (50.0)	
Yes (e-cigarettes)	2	1 (50.0)	
Yes (chewing tobacco)	1	1 (100.0)	
Current tobacco use			.064
No	39	8 (20.5)	
Yes	7	4 (57.1)	

[a]Boldface *P* values indicate a statistically significant difference between groups ($P < .05$).
[b]46 is the total number of patients included in follow-up for the study. Not all patients met the competition level.
[c]The model was not run for this variable.

TABLE 4
Multivariate Logistic Regression Analysis of ACL Repair Failure[a]

	Odds Ratio (95% CI)	*P* Value
Age (grouping 1)		
18-27 y	1.00 (reference)	—
12-17 y	8.67 (0.58-130.00)	.118
28-34 y	3.55 (0.32-39.10)	.302
35-50 y	10.40 (0.92-117.00)	.058
Age (grouping 2)		
18-27 y	1.00 (reference)	—
≤17 or ≥28 y	6.16 (0.69-54.60)	.103
Age (grouping 3)		
18-34 y	1.00 (reference)	—
≤17 or ≥35 y	4.50 (1.01-20.10)	**.049**
Competition level		
Recreational	1.00 (reference)	—
Elite/competitive/operational	7.00 (1.45-33.69)	**.015**
Current tobacco use		
No	1.00 (reference)	—
Yes	6.44 (1.14-36.60)	**.035**

[a]Boldface *P* values indicate a statistically significant difference. ACL, anterior cruciate ligament.

suture repair was not inferior to ACLR in terms of subjective patient-reported outcomes and rerupture rates at 2-year follow-up. Furthermore, Jonkergouw et al[22] reported that 88.9% of patients who underwent ACL repair had stable knees. They also reported a rerupture rate of 10.7% with excellent subjective outcomes in 89.3% of patients at 3.2-year follow-up. Lastly, Heusdens et al[18] reported excellent outcomes after ACL repair with suture tape augmentation with a 4.8% failure rate in 42 patients at 2-year follow-up.

Gagliardi et al[13] reported a 48.8% failure rate after ACL repair in 22 adolescents at 3-year follow-up. These results were more similar to the findings of our study. Additionally, we found poor results in subjective stability during cutting and pivoting activities, with only 83.7% reporting subjective stability. Our results may be explained by the demands of active-duty service members. Similar to high-level athletes, military personnel are under time constraints to return to duty. An important finding from this study was the ability of patients who underwent ACL repair to be cleared by a physical therapist and be able to pass a military physical fitness test at a mean of 5.0 months. Clearance by a physical therapist was determined by a standardized protocol.[21] Traditionally, ACLR has been associated with quadriceps weakness and knee stiffness.[3] Additionally, graft harvest is associated with significant morbidity including kneeling pain for those with bone–patellar tendon–bone autografts and hamstring weakness for those with hamstring tendon autografts.[6] A benefit of ACL repair includes the potential preservation of proprioception of the native ligament.[11,24,27] However, given the lack of morbidity associated with graft harvest and the maintenance of native proprioception, patients may feel ready to return to sport before the repair site has completely healed. In this study, the mean time to return to duty of 5.0 months may be too soon to allow adequate healing of ACL repair. Further investigation is required to determine the appropriate time to return to sport after ACL repair.

However, in the nonfailure group, patients demonstrated good to excellent functional outcome scores. Similarly, Gagliardi et al[13] reported good functional outcome scores in patients who did not sustain a failure. Our study patients were able to return to duty at a mean of 5.0 months. This finding corroborates the proposed benefits of ACL repair: lack of donor site morbidity and improved proprioception. We do believe that this demonstrates a select set of patients who may benefit from ACL repair; however, careful patient selection and appropriate rehabilitation are necessary.[14,32]

In this study, we identified several risk factors associated with a higher chance of ACL repair failure: age $\leq$17 and $\geq$35 years, elite level of competition, and active tobacco use. Additionally, patients with ACL repair failure had a significantly longer interval from their initial injury to surgery. Similar to our findings, Kaeding et al[23] found that younger age and higher activity level significantly increased the risk of ACLR failure. Furthermore, Cancienne et al[4] found that tobacco use led to a higher rate of revision ACLR after an index procedure. The findings of our study are in line with recent literature and may allow for better patient selection. Based on our findings, ACL repair is not recommended for high-level athletes, patients with active tobacco use, and those aged $\leq$17 and $\geq$35 years. Additionally, we believe time from injury to ACL repair to be critical in patient selection.

Limitations

This was a retrospective study in nature and therefore subject to bias. There is inherent selection bias, as patients selected for ACL repair had an arthroscopic evaluation to determine which treatment modality to undergo. Furthermore, this study represents a single surgeon's technique and indications. An additional limitation of the study is that postoperative stability was assessed subjectively via patient telephone calls. Ideally, postoperative stability would be assessed using an instrumented measure such as a KT-2000 arthrometer. Lastly, our study was limited to a minimum 2-year follow-up. As previously mentioned, a longer term follow-up is necessary.

CONCLUSION

Primary arthroscopic ACL repair with suture tape augmentation resulted in unacceptably high failure rates at 2-year follow-up in a highly active military population. However, we identified that age $\leq$17 and $\geq$35 years, elite level of competition, time from injury to surgery, and active tobacco use were independent risk factors for ACL repair failure. We believe that consideration of these risk factors may allow for better patient selection to improve ACL repair failure rates.

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