A commentary by Frank A. Cordasco, MD, MS, is linked to the online version of this article at jbjs.org.

Return to Function, Complication, and Reoperation Rates Following Primary Pectoralis Major Tendon Repair in Military Service Members

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Background: Pectoralis major tendon ruptures have become increasingly common injuries among young, active individuals over the past 30 years; however, there is presently a paucity of reported outcome data. We investigated the ability to return to full preoperative level of function, complications, reoperation rates, and risk factors for failure following surgical repair of the pectoralis major tendon in a cohort of young, highly active individuals.

Methods: All U.S. active-duty military patients undergoing pectoralis major tendon repair between 2008 and 2013 were identified from the Military Health System using the Management Analysis and Reporting Tool (M2). Demographic characteristics, injury characteristics, and trends in preoperative and postoperative self-reported pain scale (0 to 10) and strength were extracted. The ability to return to the full preoperative level of function and rates of rerupture and reoperation were the primary outcome measures. Univariate analysis followed by multivariate analysis identified significant variables.

Results: A total of 257 patients with pectoralis major tendon repair were identified with a mean follow-up (and standard deviation) of 47.8 ± 17 months (range, 24 to 90 months). At the time of the latest follow-up, 242 patients (94%) were able to return to the full preoperative level of military function. Fifteen patients (5.8%) were unable to return to duty because of persistent upper-extremity disability. A total of 15 reruptures occurred in 14 patients (5.4%). Increasing body mass index and active psychiatric conditions were significant predictors of inability to return to function (odds ratio, 1.56 [p = 0.0001] for increasing body mass index; and odds ratio, 6.59 [p = 0.00165] for active psychiatric conditions) and total failure (odds ratio, 1.26 [p = 0.0012] for increasing body mass index; and odds ratio, 2.73 [p = 0.0486] for active psychiatric conditions).

Conclusions: We demonstrate that 94% of patients were able to return to the full preoperative level of function within active military duty following surgical repair of pectoralis major tendon rupture and 5.4% of patients experienced rerupture after primary repair. Increasing body mass index and active psychiatric diagnoses are significant risk factors for an inability to return to function and postoperative failures.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Pectoralis major tendon ruptures are uncommon injuries that, until the mid-twentieth century, were primarily vocational injuries[1-3]. In 1822, Patissier first described a pectoralis major tendon rupture[4] in a butcher's assistant, incurred while attempting to lift a heavy load from a hook. By 1972, only 45 cases of rupture had been reported[5].

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TABLE I Demographic and Injury Characteristics of Patients with Pectoralis Major Tendon Injuries*

Characteristic	No. of Patients (%)
Age	
<30 years	116 (45%)
≥30 years	141 (55%)
Male sex	257 (100%)
Laterality	
Right	139 (54%)
Left	118 (46%)
Dominance	
Dominant side involved	80 (31%)
Nondominant side involved	81 (32%)
Ambidextrous or unknown	96 (37%)
BMI	
<30 kg/m^2	168 (65%)
≥30 kg/m^2	58 (23%)
Unknown	31 (12%)
Service	
Army	143 (56%)
Navy	34 (13%)
Marines	36 (14%)
Air Force	40 (16%)
Coast Guard	4 (2%)
Rank	
Junior enlisted	56 (22%)
Senior enlisted, officer	201 (78%)
Military occupation	
CA/CS	55 (21%)
CSS	87 (34%)
Unknown	115 (45%)
Tobacco use	67 (26%)
Alcohol use	157 (61%)
Psychiatric condition	70 (27%)
Performance-enhancing drug use (anabolic steroids, creatine)	4 (1.6%)
Injury setting	
Deployment	89 (35%)
Training	43 (17%)
Other	125 (49%)
Injury mechanism	
Bench press	158 (61%)
Other weight lifting	15 (6%)
Falls	7 (3%)
Military training	32 (13%)
Other training	15 (6%)
Sports	10 (4%)
Other, not otherwise specified	20 (8%)
Degree of tear	
Complete (both heads)	120 (47%)
Partial	114 (44%)
Sternal head	83 (32%)
Clavicular head	3 (1.2%)
Unspecified	28 (11%)
Unknown	23 (8.9%)
Tear location	
Insertion	72 (28%)
Tendon	26 (10%)
Myotendinous junction	109 (42%)
Intramuscular	12 (4.7%)
Sternal origin	1 (0.4%)
Unknown	37 (14%)
Technique	
Anchor	54 (21%)
Tunnel	20 (7.8%)
Cortical button	9 (3.5%)
Suture repair	11 (4.3%)
Unknown or combined	163 (63%)

*The mean value (and standard deviation) was 47.8 ± 17.1 months for follow-up, 31.5 ± 7.2 years for patient age, and 28.2 ± 3.3 kg/m^2 for BMI.

Contemporary literature over the past 3 decades is replete with smaller clinical series of predominantly sport and fitness-related injuries[6-13]. Indirect trauma sustained during athletic activities, particularly eccentric overload during the bench press, has emerged as the most common mechanism of injury[1,2,7-9,11,14-18], and the incidence has continued to rise among active cohorts with current trends in physical fitness and emphasis on healthy lifestyles[1,8,11,12,15]. Furthermore, anabolic steroid and/or other performance-enhancing drug use among athletes may adversely affect tendon loading behavior, leading to heightened risk of rupture[19].

Most authors recommend surgical repair of pectoralis major tendon ruptures in the young athlete, given the reported superior functional outcomes and strength preservation when compared with those treated nonoperatively[1,7-13,16,20]. Despite this consensus, existing studies have limited statistical power ($n < 20$)[7,8,10-13,16,20] and fail to evaluate the ability to return to preoperative levels of activity[9,11-13], to discern between non-athletic populations with undefined activity levels[1,9-11,13], to report comprehensive perioperative complication profiles[1,7-13,16,20], and to assess for variables influencing postoperative function after surgical repair[8-11,13,16,20].

This study aimed to determine the ability to return to the full preoperative level of function, complications, reoperation rates, and risk factors for failure following surgical repair of the pectoralis major tendon in a cohort of young, highly active individuals.

TABLE II Clinical and Functional Outcomes After Primary Pectoralis Major Repair

	No. of Patients Reporting* (N = 257)	Values†‡
Self-reported pain scale (0 to 10)		
Preop. pain	219 (85%)	3.6 ± 2.5 points
Postop. pain		
At 6 wks	231 (90%)	1.0 ± 1.4 points
At 3 mos	204 (79%)	0.5 ± 0.9 points
At 6 mos	131 (51%)	0.5 ± 1.2 points
At 12 mos	26 (10%)	0.7 ± 1.2 points
At latest follow-up	245 (95%)	0.5 ± 1.1 points
Strength§		
Forward flexion		
Preop. strength	50 (19%)	3.6 ± 2.5 points
Postop. strength		
At 6 wks	38 (15%)	4.4 ± 0.8 points
At 3 mos	120 (47%)	4.1 ± 0.6 points
At 6 mos	113 (44%)	4.5 ± 0.5 points
At 12 mos	18 (7.0%)	4.8 ± 0.4 points
At latest follow-up	163 (63%)	4.8 ± 0.4 points
Adduction		
Preop. strength	51 (20%)	4.3 ± 0.7 points
Postop. strength		
At 6 wks	11 (4.3%)	4.1 ± 0.6 points
At 3 mos	53 (21%)	4.7 ± 0.4 points
At 6 mos	83 (32%)	4.8 ± 0.3 points
At 12 mos	14 (5.4%)	4.8 ± 0.4 points
At latest follow-up	135 (53%)	4.9 ± 0.3 points
Internal rotation		
Preop. strength	72 (28%)	4.4 ± 0.6 points
Postop. strength		
At 6 wks	33 (13%)	4.0 ± 0.6 points
At 3 mos	121 (47%)	4.6 ± 0.5 points
At 6 mos	112 (44%)	4.8 ± 0.3 points
At 12 mos	18 (7%)	4.8 ± 0.4 points
At latest follow-up	156 (61%)	4.8 ± 0.4 points
Clinical outcomes		
Return to full duty	242 (94%)	NA
Time to return to duty	132 (51%)	7.1 ± 4.4 months
Clinical failures (no return to duty)	15 (5.8%)	NA
Surgical failures	15 (5.8%)	NA
Postop. combat deployment	88 (34%)	NA
Return to duty after revision repair (n = 8)	7 (88%)	NA
Bak criteria outcome scores		
Excellent	223 (86.8%)	NA
Good	8 (3.1%)	NA
Fair	11 (4.3%)	NA
Poor	15 (5.8%)	NA

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the mean and the standard deviation. ‡NA = not applicable. §Strength was determined by the Medical Research Council Muscle Strength Grading Scale.

Materials and Methods

Following institutional review board approval, a retrospective review was conducted to identify all U.S. active-duty military service members who underwent primary repair of pectoralis major tendon ruptures (Current Procedural Terminology [CPT] code 24341) between 2008 and 2013 in the Military Health System through use of the Management Analysis and Reporting Tool (M2). The M2 is an established health-care management database that can be utilized to perform clinical outcomes research related to a variety of upper-extremity conditions[21-25].

Demographic data were initially extracted from the database, and a thorough review of the military electronic medical record (Armed Forces Health Longitudinal Technology Application [AHLTA]) yielded additional patient-based variables (laterality, hand dominance, body mass index [BMI], military occupation, tobacco use, medical comorbidities), injury-related variables (location and extent of rupture, time to the surgical procedure, mechanism of injury, injury setting), and surgical variables (fixation construct). All patients considered to have a psychiatric comorbidity had an active diagnosis that was being treated by a behavioral or mental health specialist at the time of pectoralis major tendon rupture. The preoperative and postoperative self-reported pain scale (SRPS; a scale of 0 to 10) and strength of forward flexion, adduction, and internal rotation using the Medical Research Council Muscle Strength Grading Scale (range, 0 to 5)[26] were recorded as measured by both the physical therapist and the surgeon at the time of follow-up.

Patients who underwent primary surgical repair, had active-duty military status, and had clinical follow-up of at least 2 years were included in this study. Exclusion criteria were pectoralis reconstruction with or without augmentation, other major tendon repairs of the upper extremity, non-military status at the time of the surgical procedure, clinical follow-up of less than 2 years, and/or incomplete documentation.

The primary outcomes of interest were inability to return to full preoperative occupational function, resulting in shoulder-related medical discharge from the military; surgical failure, constituting rerupture or the requirement for revision reoperation; overall failure, or the sum of shoulder-related medical discharges and surgical failures; presence of perioperative complications; and risk factors associated with inability to return to function, surgical failure, and overall failure following repair.

We classified each patient's outcome according to the Bak criteria[1]. Outcomes were considered excellent for patients who had full strength, no pain or cosmetic symptoms, and return to the previous activity level without

TABLE III Complications of Surgically Treated Pectoralis Major Tendon Rupture

Complications	No. of Patients with Each Complication* (N = 257)	No. of Surgeries Performed for Complication
Minor complications (n = 42)		0
Persistent intermittent pain	20 (7.8%)	0
Subjective episodic weakness	12 (4.7%)	0
Cosmetic deformity (keloid, asymmetry)	7 (2.7%)	0
Wound complication not requiring surgery†	1 (0.4%)	0
Adhesive capsulitis	2 (0.8%)	0
Major complications (n = 41)		0
Rerupture‡	14 (5.4%)	8
Partial rerupture	3 (1.2%)	0
Wound complications requiring surgery	13 (5.1%)	21
Wound infection or dehiscence	8 (3.1%)	15
Organism isolated		
None	3 (1.2%)	0
Propionibacterium acnes	2 (0.8%)	0
Beta-hemolytic streptococci	1 (0.4%)	0
Coagulase-negative staphylococci	1 (0.4%)	0
Propionibacterium granulosum	1 (0.4%)	0
Proximal humeral osteomyelitis	1 (0.4%)	1
Postoperative hematoma	1 (0.4%)	2
Scar revision	2 (0.8%)	2
Suture-related cyst	1 (0.4%)	1
Pain or weakness resulting in military separation	8 (3.1%)	0
Other, not otherwise specified§	2 (0.8%)	0

*The values are given as the number of patients with the given complication, with the percentage in parentheses. †This category included wound breakdown and drainage. ‡Fourteen patients experienced a rerupture; however, one patient had a rerupture twice, resulting in a total of 15 reruptures. §This category included complex regional pain syndrome and heterotopic ossification.

restriction, whereas outcomes were considered good for patients who had only mild restriction in movement or strength, no cosmetic symptoms, and return to the previous activity level without restriction. Outcomes for patients who were medically separated from military service because of pain and/or subjective weakness or who reported cosmetic concerns were classified as fair, whereas outcomes for patients who had reruptures and/or reoperation for wound complications were automatically classified as poor.

Return to full military function entails maintenance of rigorous weight standards and successful completion of a semiannual, service-specific physical fitness test that may include timed push-ups and sit-ups and an aerobic event. Service members may also be required to maintain a level of physical training exceeding these baseline standards, depending on their branch of service and military occupational specialty. The three overarching categories for organizing military occupational specialty in this study were combat arms (CA), combat service (CS), and combat service support (CSS). CA/CS is the category of service members who actively engage in direct tactical combat; this category may include infantry, armor, artillery, air defense, aviation, and combat medics, among others, and these are greater occupational demands. CSS units may provide supplies, transportation, health, and other services required by the soldiers of combat units to continue their military missions, and these are lower occupational demands.

Statistical Analysis

Multivariate logistic regression analysis was performed for risk factors with p values of <0.2 after initial univariate testing to assess the effect of the predictive variables. Risk was calculated with odds ratios (ORs) and 95% confidence intervals (95% CI). We determined that a p value of <0.05 and a 95% CI excluding 1.0 after multivariate analysis would be necessary to ascertain a significant, independent risk factor. All statistical calculations were performed using SAS version 9.3 (SAS Institute).

Results

Demographic and Injury Characteristics

A total of 299 patients with 302 pectoralis major tendon tears underwent pectoralis major tendon repair from 2008 to 2013, and 257 patients with pectoralis major tendon tears met inclusion criteria. The mean follow-up (and standard deviation) after repair was 47.8 ± 17.1 months (range, 24.1 to 89.5 months). The surgical procedures were performed by 152 different surgeons at 57 medical treatment facilities. The mean age was 31.5 ± 7.2 years (range, 19 to 55 years), all patients were male, and 54% had right-sided injuries. The mean BMI was 28.2 ± 3.3 kg/m^2, and the majority of patients (65%) had a BMI of <30 kg/m^2. Only 4 patients (1.6%) admitted to performance-enhancing drug use. Tobacco use was reported in 26% of patients and psychiatric comorbidities existed in one-third of the current cohort (Table I).

A total of 89 patients (35%) were injured during combat deployments, and bench press was the predominant mechanism

TABLE IV Univariate Analysis of Risk Factors for Surgical and Cumulative Failure After Pectoralis Major Tendon Repair

	Clinical Failure*	P Value	Surgical Failure*	P Value	All Failures*	P Value
Age (continuous)	1.00 (0.93 to 1.07)	0.9838	1.02 (0.95 to 1.10)	0.5390	1.00 (0.95 to 1.06)	0.9791
Age <30 yr vs. ≥30 yr	1.23 (0.45 to 3.39)	0.6868	1.07 (0.38 to 3.04)	0.9023	1.25 (0.58 to 2.67)	0.5695
Laterality						
Right vs. left	1.94 (0.66 to 5.76)	0.2313	1.29 (0.45 to 3.74)	0.6365	1.31 (0.61 to 2.85)	0.4901
Dominant vs. nondominant	0.83 (0.24 to 2.85)	0.7712	2.14 (0.62 to 7.40)	0.2307	1.55 (0.62 to 3.86)	0.3458
BMI	1.37 (1.16 to 1.62)	0.0002	0.92 (0.76 to 1.11)	0.3614	1.17 (1.04 to 1.31)	0.0097
≥30 kg/m^2 vs. <30 kg/m^2	5.99 (1.92 to 18.70)	0.0021	0.86 (0.23 to 3.25)	0.8261	2.87 (1.24 to 6.64)	0.0137
Service						
Army/Marines vs. Navy, Air Force, and Coast Guard	3.22 (0.72 to 14.54)	0.1277	1.21 (0.37 to 3.93)	0.7495	2.37 (0.87 to 6.44)	0.0907
Rank						
Junior enlisted vs. senior enlisted or officer	0.50 (0.11 to 2.28)	0.3710	1.35 (0.41 to 4.41)	0.6215	0.90 (0.35 to 2.32)	0.8241
Military occupation						
CA/CS vs. CSS	0.25 (0.03 to 2.14)	0.2052	1.64 (0.45 to 5.95)	0.4518	1.01 (0.37 to 2.78)	0.9884
Tobacco use						
Yes vs. no	1.31 (0.44 to 3.91)	0.6339	1.44 (0.48 to 4.39)	0.5175	1.76 (0.79 to 3.92)	0.1680
Alcohol						
Yes vs. no	0.80 (0.29 to 2.22)	0.6671	0.71 (0.25 to 2.01)	0.5139	0.94 (0.43 to 2.04)	0.8737
Psychiatric condition						
Yes vs. no	4.52 (1.31 to 15.56)	0.0169	1.69 (0.44 to 6.48)	0.4478	3.10 (1.24 to 7.77)	0.0155
Time from injury to surgery						
Continuous	1.00 (0.99 to 1.01)	0.8637	0.99 (0.98 to 1.02)	0.8516	1.00 (0.99 to 1.01)	0.7981
≥1.5 months vs. <1.5 months	4.06 (1.27 to 12.94)	0.0180	1.94 (0.67 to 5.63)	0.2211	2.81 (1.26 to 6.28)	0.0118
≥3 months vs. <3 months	2.81 (1.01 to 7.80)	0.0474	1.81 (0.62 to 5.27)	0.2800	2.59 (1.19 to 5.65)	0.0163
Degree of tear						
Complete vs. partial	0.46 (0.13 to 1.56)	0.2115	0.82 (0.29 to 2.34)	0.7120	0.67 (0.29 to 1.52)	0.3339
Location of tear						
Insertional vs. other	0.61 (0.18 to 2.08)	0.4257	0.93 (0.31 to 2.77)	0.8955	0.63 (0.27 to 1.47)	0.2811
Myotendinous vs. other	2.12 (0.62 to 7.25)	0.2318	0.55 (0.18 to 1.68)	0.2909	1.22 (0.54 to 2.76)	0.6408
Technique						
Anchor-based vs. other	0.73 (0.14 to 3.80)	0.7039	2.29 (0.23 to 22.9)	0.4794	0.92 (0.23 to 3.66)	0.9040

*The values are given as the odds ratio, with the 95% CI in parentheses.

of injury (61%). The mean time from the injury to the surgical procedure was 4.2 ± 9.3 months (range, 0.03 to 89.9 months), and 72% of patients underwent the surgical procedure within 3 months. Complete ruptures of both the sternocostal and clavicular components occurred in 120 patients (47%). There were 114 patients (44%) with partial ruptures: 83 patients (32%) had sternal head tears, 3 (1.2%) had clavicular head tears, and 28 (11%) had unspecified tears with respect to location. Most patients (n = 109 [42%]) had injuries that occurred at the myotendinous junction, with other patients having injuries occurring at the insertion (n = 72 [28%]) or within the substance of the tendon (n = 26 [10%]). The most common repair technique was suture anchor repair (21%), followed by a bone tunnel technique (7.8%) (Table I). In the setting of myotendinous injuries, high-tensile, nonabsorbable sutures were passed through any remaining tendon substance and clavipectoral fascia in an interlocking Krackow fashion to achieve stable repair.

Clinical and Functional Outcomes

The mean SRPS improved from 3.6 ± 2.5 points preoperatively to 0.5 ± 1.1 points at the time of the latest follow-up. The mean strength of forward flexion improved from 3.6 ± 2.5 points preoperatively to 4.8 ± 0.4 points at the time of the latest follow-up,

TABLE V Multivariate Analysis of Pectoralis Major Tendon Repair Surgical Failure Risk Factors

Risk Factor	Clinical Failure*	P Value	All Failures*	P Value
BMI ≥ 30 kg/m^2	1.56 (1.24 to 1.96)	0.0001	1.26 (1.10 to 1.45)	0.0012
Psychiatric condition	6.59 (1.41 to 30.77)	0.0165	2.73 (1.01 to 7.42)	0.0486
Time from injury to surgery				
≥1.5 months vs. <1.5 months	2.41 (0.54 to 10.81)	0.2495	2.02 (0.72 to 5.65)	0.1804
≥3 months vs. <3 months	1.62 (0.48 to 5.49)	0.4361	2.05 (0.86 to 4.87)	0.1034

*The values are given as the odds ratio, with the 95% CI in parentheses.

the mean adduction strength improved from 4.3 ± 0.7 points preoperatively to 4.9 ± 0.3 points at the time of the latest follow-up, and the mean internal rotation strength improved from 4.4 ± 0.6 points preoperatively to 4.8 ± 0.4 points at the time of the latest follow-up. A total of 242 patients (94%) were able to return to full occupational function, with a mean time for return to full, unrestricted duty of 7.1 ± 4.4 months. Additionally, 34% of patients participated in combat deployments after surgical repair. Of the 8 patients who underwent revision repair following rerupture, 7 (88%) were able to return to full military duty. Only 15 patients (5.8%) demonstrated substantial upper-extremity functional limitations and were unable to return to military duty (Table II). Nine patients (3.5%) underwent injury-related medical discharge, 5 patients (1.9%) elected for early retirement from the military because of persistent pain and/or weakness, and 1 patient (0.4%) chose to remain in the military, but required a permanent profile restricting his work activities because of persistent weakness. Utilizing the Bak criteria, we report 90% good to excellent outcomes, 4.3% fair outcomes, and 5.8% poor outcomes (Table II).

Complications

There were 42 minor complications in 36 patients (14%), most commonly persistent anterior shoulder pain (7.8%) and residual weakness (4.7%). A total of 41 major complications occurred in 31 patients (12%), with the most common being rerupture following repair (5.4%) and wound complications requiring return to the operating room (5.1%). Furthermore, 59 patients (23%) experienced either a major or a minor complication after pectoralis major repair.

Fifteen reruptures occurred in 14 patients (5.4%), including 1 patient who reruptured following revision repair. Ultimately, 8 patients (3.1%) underwent pectoralis major tendon revision for rerupture. With regard to reoperation for causes other than revision, 13 patients (5.1%) underwent 21 surgical procedures, with 8 patients (3.1%) undergoing 15 irrigation and debridements for wound infections, 2 of which were identified as *Propionibacterium acnes* (Table III).

Risk Factors

Univariate analysis identified several risk factors for inability to return to function, surgical failure, and overall failure following repair (Table IV). Multivariate regression analysis determined the significant independent predictors ($p < 0.05$) of the inability to return to the full preoperative level of military function and overall postoperative failure; BMI of ≥30 kg/m^2 had an OR of 1.56 (95% CI, 1.24 to 1.96) for inability to return to the full preoperative level of military function and an OR of 1.26 (95% CI, 1.10 to 1.45) for overall postoperative failure, and active psychiatric diagnoses had an OR of 6.59 (95% CI, 1.41 to 30.77) for inability to return to the full preoperative level of military function and an OR of 2.73 (95% CI, 1.01 to 7.42) for overall postoperative failure (Table V). The most common psychiatric diagnoses included anxiety disorders (e.g., posttraumatic stress disorder), adjustment disorder, and mood disorders (e.g., depression). Conversely, age, rank, hand dominance, branch of service, military rank, occupation, tobacco use, tear chronicity, location and extent of the tear, and method of surgical fixation were not independently associated ($p > 0.05$) with either clinical or surgical failure (Table IV and Table V).

Discussion

This is a comprehensive analysis elucidating functional outcomes, complications, and risk factors for failure following surgical repair of the pectoralis major tendon in a large cohort of young, highly active patients. We found that pectoralis major tendon repair in the young athlete provides reproducible functional outcomes, as 94% of individuals were able to return to full preoperative activities without functional limitations. Furthermore, pain and strength improved at the short-term to intermediate-term clinical follow-up. Rerupture occurred in only 5.4%, with 3.1% requiring a revision surgical procedure, and 88% of these patients returned to function following a revision surgical procedure. Finally, we identified BMI and active psychiatric diagnoses as novel significant independent predictors of inability to return to function and overall failure.

To our knowledge, there have been a limited number of primary clinical studies evaluating outcomes following pectoralis major tendon repair[7,8,10-13,16,20]. Of those series involving athletic cohorts with defined physical demands[7,8,12,16,20], the authors reported 70% to 90% return to pre-injury level of function[8,16,20], 46% to 71% excellent outcomes[8,16,20], and 90% to 100% favorable outcomes[8,16,20]. In a meta-analysis of pectoralis major tendon repairs, Bak et al. found that 88% of the 72 patients who underwent surgical repair experienced good to excellent results, increasing to 90% when excluding those patients

who underwent a failed trial of conservative treatment and elected for delayed repair[1]. We report a comparable 94% rate of return to pre-injury levels of function, as well as 90% good to excellent outcomes using the Bak criteria[1]. The actual rate of good to excellent outcomes in our study is likely higher than our reported value, as patients with reruptures and reoperations for wound complications were automatically classified as having poor scores, despite the majority of these patients returning to full unrestricted function following revision reconstruction.

Despite excellent functional outcomes, the present study highlights relevant surgical site morbidity following primary repair, with 23% of patients experiencing one or more complications. Most complications were minor in nature and included persistent anterior shoulder pain, residual weakness, cosmetic deformity (e.g., muscle asymmetry, keloid formation), wound complications not requiring a surgical procedure, and adhesive capsulitis. There is comparatively minimal discussion of perioperative complications among the existing clinical series[1,7-13,16,20]. Postoperative weakness following pectoralis major tendon repair is most often mentioned and has been described at rates of 12% to 64% in prior reports[1,7,8,10-12,16]. In the current series, the most frequent minor complications were episodic anterior shoulder pain (7.8%) and persistent weakness (4.7%), although these subjective symptoms did not have negative repercussions on military performance and readiness. Given the preponderance of residual symptomatology, patients should be counseled on the potential for mild persistent symptomatology that ultimately should not impact functional outcomes.

Similarly, local wound complications requiring surgical intervention were also not infrequent in our cohort (5.1%). Given the proximity to the axillary region, modifications of the deltopectoral approach may be subject to high local bacterial burden, intertriginous moisture, and poor wound-healing due to preexisting skin atrophy[3]. The current series identified several cases of superficial or deep-space surgical site infections, hematoma formation, and partial wound dehiscence. One patient in our population developed wound dehiscence with subsequent infection with *Propionibacterium acnes,* necessitating two irrigation and debridement procedures and ultimate implant removal prior to clearing the infection. Careful surgical technique, meticulous soft-tissue handling, and watertight closure may mitigate the potential risk of such adverse outcomes.

Rerupture constituted the most common major complication. Our rerupture rate of 5.4% compares favorably with that in the series presented by Kakwani et al., which reported one case of rerupture (7.7%) necessitating a revision surgical procedure[20]. This is likely greater than that presented from the general population because of intense upper-extremity demands inherent to athletic cohorts. Given the limited scope of existing studies, few have evaluated risk factors for inferior outcomes or rerupture following repair of pectoralis major tendon rupture[1,7,12]. Chronicity of injury[1,7] is the only variable that has been suggested to predict inferior outcomes. One meta-analysis further showed that neither age nor location of rupture affected satisfaction or return to function[1]. Our current study corroborates these latter findings, but we did not find any significant impact of chronicity after multivariate analysis. However, our analysis revealed that both BMI and active psychiatric diagnoses were two novel independent predictors of postoperative failure.

Increasing BMI has been previously associated with increased risk of tendinopathy and tendon rupture[27-29]. A case-control study by Titchener et al. demonstrated that the mean BMI of patients with rotator cuff tendinopathy was significantly greater than that of the unaffected control group[29]. Frey and Zamora showed that BMI of ≥25 kg/m^2 significantly increased the chances of Achilles, posterior tibial, and peroneal tendinitis in their 2007 cross-sectional study[27]. Given the fitness requirements in our young, athletic population, increased BMI is more likely attributable to increased muscle mass. However, quantitative measures of adiposity were not included in the medical record, and, therefore, we were unable to specifically evaluate the impact of this variable. The associated greater postoperative weight-lifting demands may predispose these individuals to treatment failure secondary to overload at the repair site prior to complete tissue remodeling. Furthermore, it has been suggested that the adaptive capacity of the tendon may be exceeded by gains in muscle mass, especially in the setting of performance-enhancing substances[30]. Given the likelihood of underreporting anabolic steroid use, we were unable to identify an association between these substances and failure following repair.

Psychiatric comorbidity has been highlighted in recent studies as a risk for inferior outcomes following orthopaedic surgical procedures[31-33]. In a retrospective review assessing the impact of psychiatric conditions on surgical outcomes for femoroacetabular impingement, Ernat et al. determined that active use of mental health medication was associated with decreased postoperative return-to-duty rates and outcome scores among a military cohort[32]. Ellis et al. similarly found that psychiatric comorbidity resulted in lower patient-perceived outcome scores following total knee arthroplasty because of perception of worse functional levels, greater pain, more stiffness, decreased quality of life, and greater disability prior to the surgical procedure[31]. We found similar results in our cohort, in which psychiatric comorbidities were associated with more unrealistic patient expectations, higher patient-perceived levels of disability, and more difficulty for patients rehabilitating and returning to military service.

The merits of this study include its large patient size, closed health-care system, and prerequisite for high-level occupational demands inherent to military service. Given the association of pectoralis major tendon rupture with fitness and sport-related activities, our study more likely captures the upper athletic echelon of this cohort. This increases both the homogeneity of our cohort as well as the external validity to civilian athletic populations. However, certain limitations inherent to a retrospective analysis must be acknowledged. The current investigation was susceptible to selection and detection bias, and the data abstraction may have been subject to reporting error. In addition, patient-reported satisfaction and/or

outcome measures were not obtained, and quantitative assessment of strength and function were not uniformly populated in the electronic medical record. Lastly, despite the large cohort, this study may still be underpowered to elucidate certain underlying risk factors for adverse clinical outcomes. Future research should be focused on prospective analyses with objective data evaluating strength and validated functional outcome scores after pectoralis major tendon repair.

In conclusion, we report a 94% return to the pre-injury level of function following primary pectoralis major tendon repair in a young, athletic cohort at a mean follow-up of 48 months. Despite an overall 23% complication rate and 5.4% chance of rerupture, only 5.8% of patients experienced substantial upper-extremity limitations precluding further military service. Increasing BMI and active psychiatric comorbidities were found to be significant independent predictors of both inability to return to pre-injury levels of function and overall failure. ■

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