Functional Outcomes and Complications Following Pectoralis Major Tendon Allograft Reconstruction in a Military Population

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Background: There are limited data available regarding outcomes following pectoralis major tendon (PMT) reconstruction with allograft.

Purpose: To evaluate the functional outcomes and complication profile following PMT reconstruction with allograft in a military population.

Study Design: Case series; Level of evidence, 4.

Methods: All active duty military personnel who underwent PMT allograft reconstruction between 2008 and 2013 were identified. Demographics, injury characteristics, and surgical technique were recorded from the electronic medical record. Self-reported pain scores and manual strength were evaluated pre- and postoperatively, as recorded in physician electronic medical record notes, in addition to the ability and degree to which each patient was able to return to function. Standardized outcome measures included the Bak criteria; visual analog scale for pain; Disabilities of the Arm, Shoulder and Hand (DASH) score; American Shoulder and Elbow Surgeons (ASES) score; and 36-Item Short Form Health Survey (SF-36). Complications, including rerupture and reoperation, were additionally recorded.

Results: Nine male patients (mean ± SD age, 35.7 ± 5.8 years) underwent allograft PMT reconstruction. Mean improvement in self-reported pain score at a mean 53.5 months (range, 31.1-110.9 months) was 2.1 ± 1.3 points ($P = .08$). Improvements in manual strength during forward flexion (0.5 ± 0.7; $P = .03$), adduction (0.6 ± 0.6; $P = .01$), and internal rotation (0.5 ± 0.7; $P = .03$) were significant. Seven patients (78%) returned to full preinjury level of occupational function, and 88% returned to performing the bench press, although maximum weight decreased by a self-reported mean of 141.3 lb. According to the Bak criteria, 5 (56%) patients had excellent outcomes, 2 (22%) had fair outcomes, and 2 (22%) had poor outcomes. Mean visual analog scale for pain (1.9 ± 2.8), DASH (10.8 ± 17.4), ASES (88.1 ± 20.3), and SF-36 scores (96.3% ± 6.9%) were obtained for the 8 patients available at final follow-up. Complications included 2 cases (22%) of persistent shoulder pain leading to military separation, 1 rerupture (11%), and 1 (11%) surgical scar revision.

Conclusion: While allograft reconstruction is a reliable option to decrease pain and improve function in patients with tears not amenable to primary repair, patients should be educated about the risk profile and fitness limitations after surgery.

Keywords: pectoralis major tendon; reconstruction; allograft; functional outcomes

The optimal management of acute ruptures of the pectoralis major tendon (PMT) has been well-described in the literature. Primary surgical repair is usually recommended, as delayed and conservative treatment leads to notable decreases in strength and inferior functional outcomes.[1,3,4,9,12,26] However, acute primary repair may not be possible in the setting of delayed presentation or diagnosis and ruptures with significant retraction. Such cases can present a dilemma for surgeons, leading to more difficult index surgical management and a potential requirement for graft augmentation.

Ruptures of the PMT have become increasingly prevalent over the past 3 decades.[1,3,9,11,12,15,22,26,30] During this time, literature evaluating surgical techniques, outcomes, and complications of primary PMT repair has also demonstrated a corresponding rise[‖]; however, limited data exist regarding PMT reconstruction with allograft augmentation. The available literature evaluating reconstruction is

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replete with smaller case series that rarely report validated outcome data or complication rates.[¶]

The purpose of this study was to evaluate the functional outcomes and complication profile following PMT reconstruction with allograft augmentation in a military population. We hypothesized that allograft PMT reconstruction would demonstrate good to excellent functional outcomes and low complication rates.

METHODS

After institutional review board approval, we retrospectively reviewed all US active duty personnel who had undergone PMT rupture reconstruction with allograft augmentation (Current Procedural Terminology code 24341) from 2008 to 2013 using the Military Health System through use of the Management Analysis and Reporting Tool (M2). The M2 is a health care management database that can be utilized to perform clinical outcomes research related to a variety of musculoskeletal conditions.[16,27-29] PMT procedures were identified from other upper extremity tendon procedures manually via electronic medical record (EMR) review after identification from the M2 database.

Our inclusion criteria consisted of patients who underwent surgical reconstruction of the PMT with allograft, were of active duty military status at the time of both injury and surgery, and had clinical follow-up of at least 2 years. Patients who underwent primary PMT repair, had other major tendon repairs of the upper extremity, were nonmilitary or retired at the time of surgery, or had follow-up of less than 2 years were excluded.

A thorough review of the military EMR (Armed Forces Health Longitudinal Technology Application) was performed, and patient demographic data were collected, including age, sex, military rank, and branch of service. Also collected were patient variables (injury laterality, hand dominance, body mass index, military occupational specialty, tobacco use, and anabolic steroid use), injury characteristics (location of rupture, time from injury to surgery, mechanism of injury, injury setting), and surgical variables (fixation construct, graft type). Military occupational specialty defines a servicemember's job in the military and can consist of (1) combat arms, which includes tactical combat, or (2) combat service support, which includes jobs that provide support to combat occupations, such as supply or medical care. Self-reported pain score (0, no pain; 10, unbearable pain) is documented as a vital sign in every encounter in our EMR and was recorded from pre- and postoperative charts. Manual strength of internal rotation, adduction, and forward flexion (Medical Research Council; range, 0-5)[2] was available and recorded from the EMR as measured by the operative surgeon at the preoperative and follow-up appointments. Return to preinjury function, postsurgery overseas deployments, military separations, and postsurgical complication rates were also extracted during our EMR review. Patients were contacted via telephone to collect validated outcome scores, including visual analog scale for pain (0-10); Disabilities of the Arm, Shoulder, and Hand (DASH); American Shoulder and Elbow Surgeons (ASES); and 36-Item Short Form Health Survey (SF-36). Visual analog scale is a method for grading a subjective experience—in this case, pain. Patients rate their pain from 0 to 10, with 0 being no pain and 10 maximum pain.[17] For the DASH, a score is generated between 0 and 100, with 0 being no disability and 100 being completely disabled. A score of 10 has been established to be a normal score in the general population, with scores <30 considered to be little to no disability of the limb and >69 considered highly limiting.[13] For the ASES, the score is weighted 50% pain and 50% function and ranges from 0 to 100, with 100 representing no disability and 0 full disability. In their study, Sallay and Reed[23] found mean ASES scores of 92.2 in healthy patients. The SF-36 is a survey of overall patient health consisting of 8 sections. Each section is weighted equally, and a score from 0% to 100% is generated, with higher scores indicating lower levels of disability.[21] At the time of telephone interview, data such as return to performing the bench press and pre- and postinjury bench press maximums were recorded.

The primary outcomes of interest included functional outcomes, rerupture rates, and complications following PMT reconstruction. Rerupture rates were extracted from the EMR records as documented at postoperative follow-up visits; patients with physical examination findings concerning for rerupture were definitively diagnosed via magnetic resonance imaging (MRI). Each patient's outcome was classified using the Bak criteria.[4] Per the criteria outlined in the article by Bak et al,[4] excellent outcomes were recorded for patients who exhibited full strength on manual assessment, no pain, and no cosmetic concerns and who returned to their prior activity levels. Good outcomes were given to patients with only mild deficits in movement or strength and fair outcomes for patients who were medically separated from the military owing to pain and/or weakness or had cosmetic concerns. All patients who experienced

[¶]References 6, 8, 10, 14, 18, 19, 24, 25, 31, 32.

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Ethical approval for this study was obtained from the William Beaumont Army Medical Center Institutional Review Board (393632-1).

rerupture or underwent additional surgery for wound complications were classified as poor.

Return to full occupational function requires servicemembers to maintain a level of physical fitness that often exceeds that of the average person. Standards are specific to each military branch but typically include maintenance of rigorous height and weight standards and completion of a semiannual physical fitness test, which includes timed push-ups and sit-ups as well as a timed aerobic fitness event. Servicemembers are also routinely involved in daily aerobic fitness activities, tactical exercises, field training, and periodic overseas combat deployments, depending on their branch of service and military occupational specialty. Those who cannot perform fitness events are either placed in activity-limiting profiles or separated from the military.

RESULTS

Demographics and Injury Characteristics

During the study period, a total of 933 patients were identified who had undergone upper extremity repair or revision procedures from Current Procedural Terminology code 24341. Of these, 299 patients with 302 PMT tears were identified. Of the 299 patients, 9 underwent PMT allograft reconstruction, and all met inclusion criteria (Figure 1). At final follow-up, 8 (89%) patients were available for telephone interviews. The mean ± SD patient age was 35.7 ± 5.8 years. All patients were male, 7 (78%) were military officers, and 44% of procedures consisted of dominant-sided injuries. Six patients (67%) reported alcohol consumption on at least a weekly basis, 2 (22%) reported tobacco use, and 1 patient reported a history of fluoroquinolone antibiotic use (ciprofloxacin) prior to rupture. No patients admitted to use of performance-enhancing drugs. The most commonly reported medical comorbidity was a history of psychiatric disorder (44%), with the most frequent diagnoses being anxiety disorders. Mean body mass index was 27.4 ± 1.7 kg/m^2, and all but 1 patient had a body mass index <30.0 kg/m^2. The mean preinjury bench press weight for this active duty military cohort was 366.3 ± 93.1 lb (range, 260.0-500.0 lb) (Table 1).

Most injuries (89%) occurred in a nondeployed setting, and nearly half (44%) were sustained while performing the bench press. The mean time from injury to diagnosis was 3.5 ± 3.6 months, and the mean time from injury to surgery was 14.5 ± 21.0 months. Over half (56%) of the injuries were complete ruptures of the PMT with involvement of the sternocostal and clavicular heads, and the remainder (44%) were partial ruptures involving only the sternocostal head. The most common tear location was at the musculotendinous junction (56%), whereas 3 additional injuries were insertional (33%) ruptures that could not be primarily repaired owing to tendon retraction.

All patients underwent a standard deltopectoral incision and reconstruction with allograft; after identification of any residual tendon or muscle and fascia, the fibers were circumferentially released, and the allograft was laid over the remaining tendon, muscle, or fascia and secured with

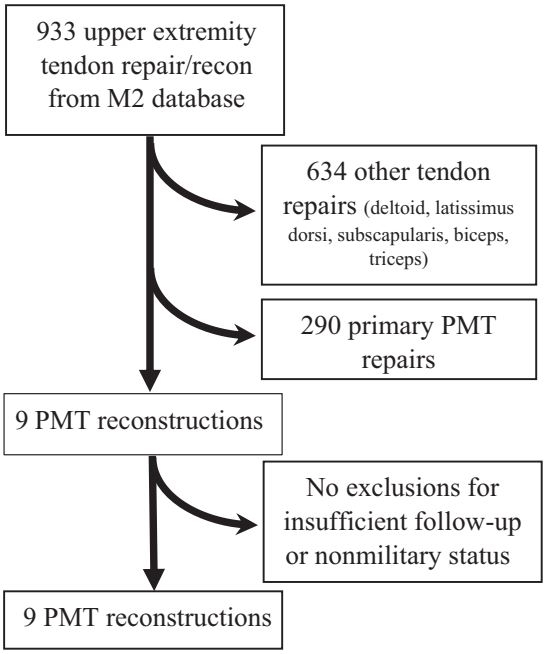

Figure 1. Exclusion criteria flowchart. All patients who underwent upper extremity repair/revision procedures were identified on the basis of Current Procedural Terminology code 24341. Patients undergoing pectoralis major tendon (PMT) repair or reconstruction were identified via electronic medical record review. After exclusion of all other upper extremity procedures and primary repairs, 9 patients who underwent PMT reconstruction with allograft remained. Every patient identified who underwent PMT allograft reconstruction met the inclusion criteria.

Krackow sutures. The allograft was then fixed to the humerus. Six (67%) reconstructions utilized Achilles tendon allograft, 2 (22%) used posterior tibialis tendon allograft, and 1 (11%) utilized an acellular dermal matrix allograft. Two-thirds of the reconstructions (67%) utilized suture anchors for fixation of their graft-tendon constructs (Tables 1 and 2).

Clinical and Functional Outcomes

At a mean final follow-up of 53.5 ± 25.9 months (range, 31.1-110.9 months), the mean improvement in self-reported pain score was 2.1 ± 1.3 points. Strength of forward flexion improved by a mean 0.5 ± 0.7 points, adduction by 0.6 ± 0.6, and internal rotation strength by 0.5 ± 0.7. The increases in strength of forward flexion, internal rotation, and adduction were all statistically significant ($P = .03$, $P = .01$, $P = .03$, respectively). Seven patients (78%) were able to return to full military duty without profile restrictions, and 88% were able to return to performing the bench press; however, their maximum bench press weight decreased by 141.3 ± 133.0 lb. This decrease in postsurgical bench press strength was statistically significant ($P = .02$). Four (44%) patients deployed at a mean 78.5 weeks after surgical reconstruction, and 3 additional patients were

TABLE 1
Demographics and Injury Characteristics

Characteristic	Patients, n (%)
Age, y	
<30	2 (22)
≥30	7 (78)
Male sex	9 (100)
Laterality	
Right	3 (33)
Left	6 (67)
Dominant side involved	
Yes	4 (44)
No	5 (56)
Body mass index, kg/m^2	
<30	8 (89)
≥30	1 (11)
Branch of military service	
Air Force	3 (33)
Army	2 (22)
Marines	1 (11)
Navy	3 (33)
Rank	
Enlisted	2 (22)
Officer	7 (78)
Military occupational specialty[a]	
Combat arms	7 (78)
Combat service support	2 (22)
Tobacco use	2 (22)
Alcohol use	6 (67)
Steroid use	0 (0)
Fluoroquinolone use	1 (11)
Preinjury bench press weight,[b] lb	
<200	0 (0)
200-400	4 (50)
>400	4 (50)
Injury setting	
Deployment	1 (11)
Military training	2 (22)
Recreation	3 (33)
At home	3 (33)
Mechanism of injury	
Bench press	4 (44)
Military training event	2 (22)
Trauma	2 (22)
Other exercise	1 (11)
Tear type	
Complete	5 (56)
Sternal head (partial)	4 (44)
Clavicular head (partial)	0 (0)
Location of tear	
Tendon insertion	3 (33)
Musculotendinous junction	6 (67)
Graft type	
Achilles allograft	6 (67)
Posterior tibialis allograft	2 (22)
Acellular dermal matrix allograft	1 (11)
Reconstruction technique	
Anchors	6 (67)
Cortical button	1 (11)
Transosseous tunnels	2 (22)

[a]Combat arms consists of military occupations that engage in tactical combat. These can include infantry, artillery, and aviation, among others. Combat service support includes jobs that support combat units and can include supply, medical, and dental services, among other support services.

[b]Only 8 patients reported doing bench press weight lifting before injury.

eligible for deployment at the time of follow-up. Only 2 (22%) patients underwent military separation owing to persistent work-related activity pain attributable to the operative extremity (Table 3).

According to the Bak[4] classification, 5 (56%) patients had excellent outcomes, 2 (22%) had fair, and 2 (22%) were classified as poor. At final follow-up, telephone interviews yielded mean scores as follows: visual analog scale for pain, 1.9 ± 2.8; DASH, 10.8 ± 17.4; ASES, 88.1 ± 20.3; and SF-36 survey, 96.3% ± 6.9% (Table 3).

Complications

There were 4 complications seen in 4 patients: 2 cases (22%) of persistent shoulder pain leading to military separation, 1 PMT rerupture (Achilles allograft) following reconstruction, and 1 case of cosmetic surgical scar revision for keloid formation. There were no postoperative nerve palsies or infections (Table 4).

DISCUSSION

We demonstrated that the majority (78%) of individuals with intense daily upper extremity demands were able to return to full preinjury levels of occupational activity following PMT allograft reconstruction. Nearly one-half (56%) of patients achieved excellent functional outcomes via the Bak criteria[4]; validated outcome scores were close to those observed for a normal shoulder; and nearly all patients were able to return to performing the bench press, albeit with considerable decreases in maximum strength. Complications, including persistent shoulder pain and rerupture, were seen more commonly than in primary PMT repair.

Multiple authors have shown the benefit of acute primary repair in young active populations.[1,3,4,9,12,26] In their 20-patient cohort, de Castro Pochini et al[9] demonstrated that primary repair yields 90% good to excellent outcomes, as opposed to only 20% good outcomes for patients treated nonoperatively. In active duty servicemembers, Antosh et al,[3] Balazs et al,[5] and Nute et al[20] showed that the majority of patients undergoing primary repair experience good to excellent functional outcomes and excellent return-to-duty rates. Despite these findings, there are few reports evaluating outcomes of PMT allograft reconstruction.

The majority of studies evaluating PMT allograft reconstruction consist of smaller case series that often do not provide validated outcome scores, return-to-function data, or complication profiles.[¶] Our study demonstrated that over three-fourths of patients who underwent PMT reconstruction with allograft were able to return to full preinjury levels of occupational function. In addition, patients experienced statistically significant increases in manual strength of forward flexion, adduction, and internal rotation after reconstruction as compared with their preoperative strengths. Mean scores for the DASH, ASES, and SF-36 were each near values observed for a normal shoulder[29-31] in our study population. Seven (88%) patients

[¶]References 6, 8, 10, 14, 18, 19, 24, 25, 31, 32.

TABLE 2
Individual Patient Injury and Surgical Reconstruction Data

Patient	Age, y	Risk[a]	Rupture Pattern[b]	Allograft Type	Fixation Construct	Rerupture
1	35.9	None	Partial	Acellular dermal matrix	Anchors	No
2	37.9	Fluoroquinolone	Complete	Posterior tibialis	Transosseous tunnels	No
3	33.8	None	Complete	Achilles	Anchors	No
4	29.6	None	Complete	Achilles	Anchors	No
5	25.2	None	Partial	Achilles	Anchors	No
6	42.9	None	Complete	Achilles	Cortical button	No
7	36.5	None	Complete	Posterior tibialis	Anchors	No
8	36.1	None	Partial	Achilles	Anchors	Yes
9	43.2	None	Partial	Achilles	Transosseous tunnels	No

[a]Risk factors for tendon rupture examined included prerupture use of steroids or fluoroquinolone antibiotics. No patients reported steroid use, and only 1 patient reported fluoroquinolone (ciprofloxacin) use.
[b]All partial ruptures were of the sternocostal head; the remaining ruptures were complete and included both the sternocostal and clavicular heads.

TABLE 3
Patient Outcomes[a]

Outcome	Mean ± SD or n (%)
Self-reported pain score (0-10)	
Preoperative pain	4.0 ± 2.8
Final pain	1.9 ± 2.8
Strength[b] (0-5)	
Adduction	
Preoperative	4.1 ± 0.4
Final	4.7 ± 0.5
Internal rotation	
Preoperative	4.2 ± 0.5
Final	4.7 ± 0.5
Forward flexion	
Preoperative	4.2 ± 0.5
Final	4.7 ± 0.5
Functional outcomes	
Return to full duty	7 (78)
Return to performing bench press[c]	7 (88)
Postoperative deployment[d]	4 (44)
Failed to return to full duty	2 (22)
Bak criteria	
Excellent	5 (56)
Good	0 (0)
Fair	2 (22)
Poor	2 (22)
VAS	1.9 ± 2.8
DASH	10.8 ± 17.4
ASES	88.1 ± 20.3
SF-36, %	96.3 ± 6.9

[a]ASES, American Shoulder and Elbow Surgeons; DASH, Disabilities of the Arm, Shoulder and Hand; SF-36, 36-Item Short Form Health Survey; VAS, visual analog scale.
[b]Strength values are reported via the Medical Research Council Muscle Strength Grading Scale.
[c]Only 8 total patients reported doing bench press weight lifting before injury; postoperatively, 7 were able to return to performing the bench press.
[d]Three additional patients were eligible for deployment following surgery but never got the opportunity.

TABLE 4
Complications

Complication	Patients, n (%)
Persistent shoulder pain	2 (22)
Pain leading to military separation[a]	2 (22)
Complications requiring surgery	2 (22)
Rerupture requiring reoperation	1 (11)
Cosmetic scar revision	1 (11)
Infection	0 (0)
Nerve palsy	0 (0)
Total complication rate	4 (44)

[a]A total of 2 patients experienced persistent anterior shoulder pain following pectoralis major tendon reconstruction. Both patients separated from the military owing to persistent shoulder pain that prevented them from performing their jobs.

returned to performing the bench press, and all patients returned to some form of weight lifting or fitness-related activity. This is consistent with previous studies following allograft reconstruction.[8,10,14,18,19,24,31] In a study of 6 patients who underwent PMT reconstruction with allograft, de Castro Pochini et al[8] reported that all patients returned to weight lifting, and 100% of patients exhibited good to excellent outcomes via the Bak criteria.[4] Our study's outcomes with the Bak criteria fall short of this mark, with 56% excellent outcomes; however, this number likely underrepresents our actual rate of excellent outcomes, as patients who experienced rerupture or required any additional surgery were automatically classified as having poor outcomes, even though they were able to return to full preinjury levels of occupational function.

Despite the significant increases in postreconstruction manual strength testing, at final follow-up, one of the most common findings was a decrease in maximum bench press weight. Our results show that on average, maximum bench press weights decreased by 141.3 lb, representing a loss of nearly 39% of bench press strength. The majority of the

available literature on PMT reconstruction does not compare pre- versus postreconstruction bench press maximums, but findings point toward decreases in bench press strength being common. In their study on active duty military servicemen, Zacchilli et al[31] reported that only 1 of their 3 patients who underwent allograft PMT reconstruction returned to full bench press strength postoperatively. Merolla et al[18] reported that patients undergoing PMT reconstruction experienced statistically significant decreases in strength of internal rotation with isometric strength measurements as compared with those who underwent primary repair. It is imperative that expected outcomes, including a significant loss of bench press strength, be discussed with patients during preoperative counseling, given that this was one of the most common and significant postoperative complaints.

Complications were experienced in 4 (44%) patients, with the most common being persistent shoulder pain leading to military separation. The available PMT reconstruction literature has not explored complication rates, but similar rates of debilitating shoulder pain have been seen in patients following primary repair.[3,20] Antosh et al[3] reported that subjective pain in the operative shoulder during activity was common after primary repair in their 14-patient cohort. Nute et al[20] reported a 7.8% rate of persistent shoulder pain following primary PMT repair, as well as 8 cases of pain leading to military separation. While our 44% complication rate may be interpreted as high, only 2 patients (22%) required a return to the operating room, with 1 case of rerupture requiring revision reconstruction and the other of scar revision for cosmetic reasons. These findings are likely higher than those reported for the general public because of the significant activity-related demands required of active duty military members; however, this may be extrapolated to competitive athletes or weight lifters.

This study comprises a retrospective analysis of functional outcomes and complications following PMT reconstruction among one of the largest patient cohorts to date. Its strengths include midterm follow-up, determination of validated outcome scores, and evaluation of complications seen following PMT reconstruction. Also, our study demonstrated increased external validity to civilian athletic cohorts, given the considerable activity and fitness demands of active duty military members. Weaknesses related to the retrospective nature of this study must also be acknowledged. Such studies are subject to detection and selection bias, and data extraction from EMR systems can be susceptible to reporting error. In addition, although manual strength reports were obtained via EMR review, quantitative assessments of strength and range of motion were not available; bench press strength recorded during telephone interview is also subject to recall bias. Validated outcome scores were recorded at final follow-up, but preoperative scores were unable to be collected for comparison. Also, because every patient identified with a PMT rupture underwent surgery, no control group was available for comparison between nonoperative and reconstruction outcomes. Suspicion of rerupture was based on physical examination findings and then confirmed with MRI, which may have led to underreporting of rerupture rates. Despite being one of the largest studies to date reporting on PMT reconstruction, this study is underpowered, and univariate and multivariate analyses were not able to be performed. Last, surgery was performed by 8 surgeons at 8 treatment facilities, which may have played a role in the relatively high complication rate (44%) seen in this study population. However, given the relative infrequency of PMT reconstruction procedures, in contrast to those procedures performed at a large referral center, the outcomes and complications seen in our patient population may be more representative of expected outcomes seen for a community surgeon.

CONCLUSION

While PMT reconstruction with allograft demonstrates good results and can restore function in patients with tears not amenable to primary repair, patients should be educated about complication rates—most commonly, pain that can impair activity and significant postoperative decreases in maximum bench press strength.

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