Original Article

Clinical Outcomes of Pectoralis Major Tendon Repair with and without Platelet-Rich Plasma

Jared A. Hanson, B.A., Marilee P. Horan, M.P.H., Michael J. Foster, M.D., Kaitlyn E. Whitney, B.S., Justin J. Ernat, M.D., Dylan R. Rakowski, M.D., Annalise M. Peebles, B.A., Johnny Huard, Ph.D., CAPT, Matthew T. Provencher, M.D., M.B.A., M.C., U.S.N.R (ret.), and Peter J. Millett, M.D., M.Sc.

Purpose: To assess clinical outcomes following pectoralis major tendon (PMT) repairs and to compare outcomes of PMT repairs augmented with and without leukocyte-poor platelet-rich plasma (LP-PRP). **Methods:** A retrospective review of prospectively collected data was performed of patients who underwent a PMT repair from May 2007 to June 2019 with a minimum of 2-year follow-up. Exclusion criteria included revision PMT repair, PMT reconstruction, and concomitant repair of another glenohumeral tendon/ligament. LP-PRP was injected surrounding the PMT repair before wound closure. Patient-reported outcome (PRO) data were collected preoperatively and evaluated at final follow-up using the American Shoulder and Elbow Surgeons Score (ASES), Single Assessment Numeric Evaluation Score (SANE), Quick Disabilities of the Arm, Shoulder and Hand Score (QuickDASH), and Short Form 12 physical component summary (SF-12 PCS), patient satisfaction with outcomes. **Results:** Twenty-three men (mean age, 38.6 years; range, 20.5-64.3 years) were included in the final analysis. Mean time from injury to surgery was 30 days (range, 3-123 days). Follow-up was obtained for 16 of 23 patients (70%) at a mean of 5.1 years (range 2.0-13.0 years). Significant improvement in PROs was observed (ASES: 59.0 → 92.4, $P = .008$; SANE: 44.4 → 85.9, $P = .018$; QuickDASH: 44.4 → 8.5, $P = .018$; and SF-12 PCS: 42.5 → 52.6, $P = .008$). Median satisfaction was 9 of 10 (range, 6-10). Patients receiving LP-PRP had superior ASES (99.6 vs 83.0, $P = .001$), SANE (94.8 vs 74.6, $P = .005$), QuickDASH (0.24 vs 19.1, $P = .001$), and patient satisfaction (10 vs 9, $P = .037$) scores compared with those without PRP. PROs were unchanged based on chronicity, mechanism of injury, or tear location. One patient had revision surgery at 3.4 years due to adhesions. **Conclusions:** PMT repair produces improved PROs at final follow-up when compared with preoperative values. **Level of Evidence:** Level III, retrospective comparative therapeutic trial.

Rupture of the pectoralis major tendon (PMT) is a relatively uncommon injury that has been increasing in incidence due to greater levels of athletic activity and weightlifting, particularly bench pressing.[1-3] Most commonly, injury to the PMT occurs with a rapid eccentric load on a maximally tensioned muscle

From the Steadman Philippon Research Institute, Vail, Colorado (J.A.H., M.P.H., M.J.F., K.E.W., J.J.E., D.R.R., A.M.P., J.H., M.T.P., P.J.M.); The Steadman Clinic, Vail, Vail, Colorado (M.J.F., M.T.P., P.J.M.); and University of Utah Health, Salt Lake City, Utah (J.J.E.), U.S.A.

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Address correspondence to Peter J. Millett, M.D., M.Sc., Steadman Philippon Research Institute, The Steadman Clinic, 181 W Meadow Dr., Ste 400, Vail, CO 81657. E-mail: drmillett@thesteadmanclinic.com

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with the shoulder in an abducted and externally rotated position.[2,4] While PMT ruptures can be treated nonoperatively, this has been demonstrated to result in reduced muscle strength and worse patient outcomes compared with operative intervention, and thus acute repair is often recommended in the young, active population.[5-7]

Although acute repair is preferred over nonoperative management in appropriately indicated patients, issues with postoperative complications exist, including PMT re-rupture. From basic science data, platelet-rich plasma (PRP), an autologous blood product containing a high concentration of platelets, growth factors, and cytokines, in general may improve tendon healing and reduce re-rupture rates.[8-11] In particular, PRP containing low concentrations of leukocytes has been shown to reduce the production of inflammatory factors and promote the formation of normal collagen.[12] By promoting angiogenesis, cellular migration, and matrix deposition, it is postulated that PRP may lead to increased tenocyte proliferation and possible augmentation of surgical repairs.[8,9]

While evidence exists suggesting PRP reduces incomplete tendon healing and retear rates in rotator cuff repairs,[8,10,11] there is a paucity of literature that investigates the effects of PRP in PMT repairs. The purposes of this study were to assess clinical outcomes following PMT repairs and to compare outcomes of PMT repairs augmented with and without leukocyte-poor PRP (LP-PRP). We hypothesized that patients would experience significant improvement in clinical outcomes following surgical repair and that there would be superior outcomes in patients who had LP-PRP augmented repairs when compared with those without LP-PRP augmentation.

Methods

A retrospective review of prospectively collected data was conducted following institutional review board approval (Vail Health Hospital #2021-071). Patients who underwent PMT repair by 2 high-volume sports medicine fellowship-trained surgeons (P.J.M. and M.T.P.) from May 2007 to June 2019 with at least 2 years' follow-up were included. Patients were excluded if they had a previous PMT repair, concomitant repair of another tendon or ligament of the shoulder, underwent repair augmentation with an allograft, died during the follow-up period, or had previously refused to participate.

Patient Demographics, Examination, and Operative Data

Patient demographics including sex, age, arm dominance, mechanism of injury, activity participation, time to surgery, tear characteristics, and operative data were collected from our institutional database. PMT integrity was assessed by 2 high-volume sports medicine surgeons (P.J.M. and M.T.P.) using physical examination and imaging. Inspection often revealed a loss or thinning of the axillary fold in the case of both acute and chronic PMT tears. In addition, disruption of the PMT can be identified by careful palpation.[2] Weakness with adduction, internal rotation, and forward flexion are common findings of strength testing.[2] All patients were evaluated with magnetic resonance imaging that extended caudally beyond the level of the PMT insertion site. An acute PMT tear was defined as having occurred less than 6 weeks before surgery.[13] Surgical complications were recorded. Failure was defined as revision PMT repair and symptomatic retear diagnosed clinically and/or confirmed on magnetic resonance imaging.

Surgical Technique

Surgical repair techniques of PMT tears have previously been published[4,14] and are briefly reviewed here. The patient was placed in the beach-chair position with the operative extremity in a pneumatic arm holder (Tenet T-MAX Beach Chair and Spider arm positioner; Smith & Nephew, Memphis, TN) that positions the humerus in a flexed and internally rotated position. An approximately 6-cm incision was made inferiorly and slightly medial to the standard deltopectoral approach. Medial and lateral tissue planes were then developed to reach the clavipectoral fascia which was sharply incised. At this level, the deltoid was able to be retracted laterally to reveal the PMT humeral insertion site, and the ruptured PMT stump could be identified and mobilized. The PMT often was retracted proximally with varying degrees of scarring dependent on tear chronicity. Adequate releases by blunt dissection were performed to free the tendon from surrounding tissue and to ensure the tendon could be reduced to its anatomic location (Fig 1A). Invariably, the sternal head was torn while the clavicular head remained intact.

Repair of the ruptured tendon was then performed based on tear pattern. Tendons avulsed from the humeral insertion site were repaired with unicortical pectoral buttons (Arthrex, Naples, FL). First, the tendon stump was prepared with a combination of #2 FiberWire (Arthrex) and #2 FiberTape (Arthrex) in a Mason-Allen fashion (P.J.M.) or by whipstitching (M.T.P.). Notably, the inclusion of the posterior tendon fascia is integral to the repair as this is typically the most robust fascia.[14] A bleeding bony bed was then created just lateral to the bicipital groove at the footprint of the PMT, and a 3.7-mm spade tip drill (Arthrex) was used to drill 3 equidistant holes for cortical button fixation. The pectoral buttons were then loaded and inserted into the previously drilled holes beginning inferiorly and progressing superiorly (Fig 1B). The tendon was then reduced to its anatomic insertion site with the arm

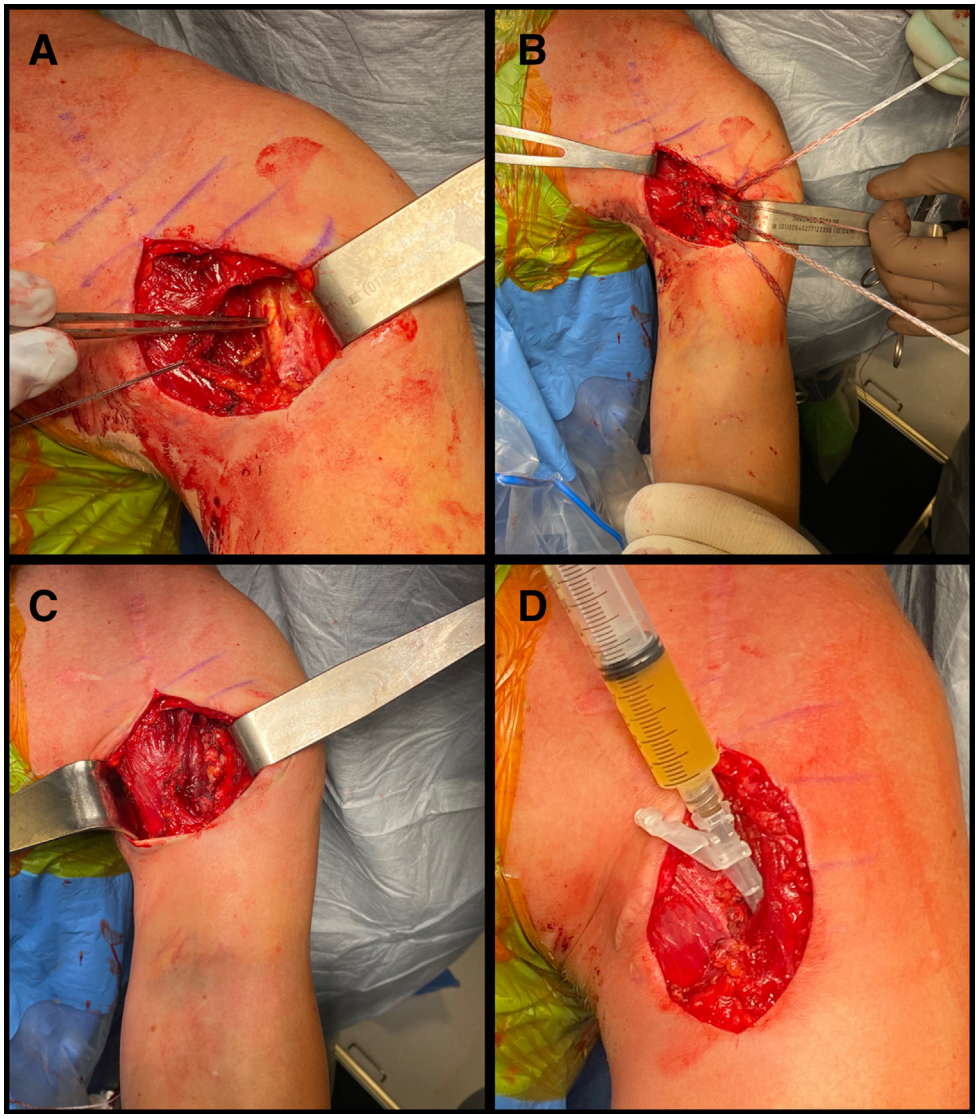

Fig 1. Intraoperative images of surgical repair of a left pectoralis major tendon avulsed from native humeral insertion site. Site of refixation humeral is demonstrated (A) with properly spaced pectoralis buttons (B) and finally the sternal head of the pectoralis major tendon is shown reattached to the humerus (C). PRP injection is performed to allow PRP to surround the surgical repair (D). (PRP, platelet-rich plasma.)

in a slightly abducted and externally rotated position. Next, the FiberWires and FiberTapes were tied (Fig 1C). PMT tears at the musculotendinous junction were repaired with a combination of #2 FiberTape and #2 Ethibond sutures (Ethicon, Somerville, NJ). The FiberTape and Ethibond sutures were used on both the lateral tendon stump and the medial, retracted pectoralis major muscle; they were placed in a Mason-Allen fashion alternating on the medial and lateral side to allow for reduction of the stump as they were tied. All sutures were hand tied to ensure excellent tendon length and tissue apposition. Commonly, 5 FiberTapes and 5 Ethibond sutures were used in the primary repair, which was then oversewn with one additional #2 Ethibond suture.

After the PMT was properly reduced to its native position (both tear patterns), the wound was thoroughly irrigated and an examination under anesthesia was performed to evaluate the tension of the repair in flexion, external rotation, and abduction. In patients receiving LP-PRP, the injection was administered following this examination. LP-PRP was injected at the interface between the tendon and humeral insertion site in the case of humeral avulsion type tears and surrounding the muscle–tendon repair site in musculotendinous junction tears (Fig 1D). Wound closure was then performed in standard fashion.

PRP Augmentation

Peripheral blood was collected on each patient electing to undergo LP-PRP injection at the time of the PMT repair procedure. Using a standard venipuncture or intravenous blood collection procedure, approximately 60 to 120 mL of peripheral blood was drawn in a syringe prefilled with 5 to 10 mL of anticoagulate citrate dextrose. In brief, LP-PRP products were produced

using a double-centrifugation method, manual extraction, and separation methods using sterile processing procedures. Approximately, 800 μL of peripheral blood and LP-PRP were transferred to a microcentrifuge tube using a hematology analyzer (CellDyn Ruby; Abbott Diagnostic Division, Abbott Park, IL) to assess erythrocyte, platelet, and leukocyte with differential counts, including neutrophils, lymphocytes, monocytes, eosinophils, and basophils. LP-PRP products were administered within 4 hours from peripheral blood harvest. Products were stored on a rocker at room temperature until intraoperative delivery. No coagulation products were used to clot the LP-PRP samples.

Postoperative Rehabilitation

Patients were maintained in a sling positioned in internal rotation and were non−weight-bearing for 6 weeks postoperatively. Passive range of motion was initiated immediately and limited to 30° of external rotation, 30° of abduction, and 30° of forward flexion through 4 weeks then advanced until full range of motion was obtained. Active nonresisted elbow, wrist, and hand exercises were permitted during this time. Active range of motion was initiated at 6 weeks. Pectoralis stretching and strengthening were initiated 10 weeks after surgery and gradually progressed. Patients should not lift more than 50% of their one repetition maximum for 6 months and then may progress gradually.[15] Return to activity and sport was expected at approximately 6 months.

Questionnaire Administration and Patient-Reported Outcomes (PROs) Assessment

Patients completed questionnaires pre- and postoperatively. If minimum 2-year follow-up was not available in our institutional database, patients were contacted at the time of conducting this study regarding their willingness to participate. If participants had greater than 2-year follow-up, follow-up data furthest from their surgery were used. After we obtained consent, questionnaires were sent to participants via e-mail. Questionnaires contained the following PROs: American Shoulder and Elbow Surgeons (ASES; 100 = best score) score, Single Assessment Numeric Evaluation (SANE; 100 = best score) score, Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH; 0 = best score) score, Short Form−12 Physical Component Summary (SF-12 PCS; greater scores correspond with better health) score, and patient satisfaction (scale 1-10; 1 = very unsatisfied, 10 = very satisfied).

PMT repair-specific questions and return to sport outcomes were evaluated with additional questions. Level of sport participation was stratified with the question, "At what grade can you now participate in sports?" with 6 answer choices ranging from "equal to or above preinjury level" to "cannot compete in any sports." Strength and endurance were evaluated with the question, "Describe your current strength or endurance when competing of participating in your usual sport?" Patients again chose from six answer choices that ranged from "no weakness or fatigue" to "weakness or fatigue prevents competition in all sports." Patients also were asked to report reasons for activity modification following PMT repair with the answer choices "not modified," "pain," "weakness," "fear," "lifestyle changes," and "other." Patient concerns with cosmesis were assessed

Statistical Analysis

Univariate analyses were performed using an independent *t* test for normally distributed variables. Mann−Whitney *U* or Fisher exact tests were performed for data that was not normally distributed or for bivariate comparisons. Paired *t* tests were used to assess differences between preoperative blood and postoperative PRP component concentrations. Wilcoxon signed-rank tests were used to detect differences between pre− and postoperative variables. The Spearman rank correlation coefficient was used to test for nonparametric correlations. Statistical power was considered vis-à-vis detectable effect size, given the fixed sample size and study design. Assuming 2-tailed nonparametric comparison of central tendency between 2 independent groups (Mann−Whitney *U* test) and an alpha level of 0.05, 9 and 7 subjects in each group is sufficient to detect an effect size of Cohen's d = 1.56 with 80% statistical power. This is conventionally considered to be a "large" effect size (Cohen 1988). Thus, between-group differences that are more subtle than this large effect size of d = 1.56 cannot be ruled out by this study. Statistical analyses were performed using SPSS, version 11.0 (SPSS Inc., Chicago, IL).

Results

Between the dates of May 2007 and June 2019, there were a total of 32 patients (all males) who underwent repair of their PMT. Nine patients were excluded from this study. Reasons for exclusion are detailed in Figure 2. In total, 23 patients met inclusion criteria, with a mean age of 38.6 years (range, 20.5-64.3 years) at the time of surgery. Mean time from injury to surgery was 30 days (range, 3-123 days) with 16 patients having acute tears and 7 with chronic tears. Additional cohort characteristics including mechanism of injury, tear details, and Tietjin classification[16] are detailed in Table 1. One patient underwent revision surgery at 3.4 years. There were no other complications. Minimum 2-year follow-up was obtained on 16 of 23 patients (70%) with a mean follow-up of 5.1 years (range, 2.0-13.0 years).

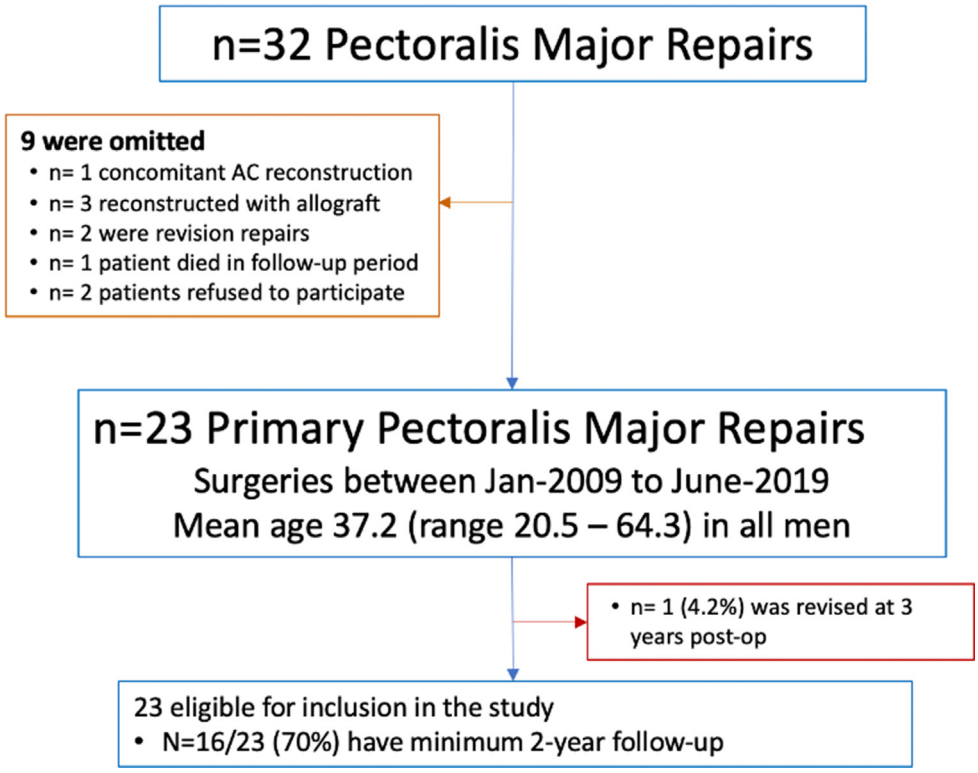

Fig 2. Flow diagram. (AC, acromioclavicular.)

PRO Scores

The collective cohort demonstrated significant improvement in the ASES (preoperative: 59.0, postoperative: 92.4, $P = .008$), SANE (preoperative: 44.4, postoperative: 85.9, $P = .018$), QuickDASH (preoperative: 45.4, postoperative: 8.5, $P = .018$), and SF-12 PCS (preoperative: 42.5, postoperative: 52.1, $P = .008$) scores when compared preoperatively with postoperatively (Table 2). Median satisfaction with outcomes postoperatively was 9 of 10 (range, 6-10). No significant differences were found in PROs between patients with acute and chronic tears or bench press and other mechanism of injury. At final follow-up, 100% of patients returned to exercise and/or weightlifting activities. In total, 71% of patients were able to participate in sports at a level equal to or slightly below preinjury level compared with 30% preoperatively ($P = .041$). A total of 79% reported either no or mild deficits in strength and endurance at postoperative follow-up versus 0% preoperatively ($P = .041$). Eight patients reported modifying their activities due to their PMT repair with the reasons being "fear of reinjury" (5 patients), "pain" (2 patients), and "weakness" (1 patient).

With Versus Without LP-PRP

Follow-up was obtained on 9 of 12 patients receiving LP-PRP and 7 of 11 patients who did not receive LP-PRP. There were no significant differences in age or arm dominance between the 2 groups. There were significant differences in follow-up duration and tear classification. Mean follow-up in those treated with LP-PRP was 2.6 years (range, 2.0-2.9 years) versus 8.5 years (range, 4.1-13.0 years) ($P = .001$) in those without. There were 8 tears at the musculotendinous junction (type III-C) in the LP-PRP cohort and 3 in the group without PRP group ($P = .007$). Postoperative ASES (99.6 vs 83.0, $P = .009$), SANE (94.8 vs 74.6, $P = .005$), QuickDASH (0.244 vs 19.1, $P = .001$), and median satisfaction (10 vs 9, $P = .037$) scores were significantly different between the 2 groups, with those treated with LP-PRP having superior PROs (Table 3). Patients treated with LP-PRP had greater rates of return to sports equal to or slightly below preinjury level (87.5% vs 50%, $P = .017$) and no or mild strength and endurance deficits (87.5% vs 67%, $P = .019$) when compared with those not treated with LP-PRP. There was no significant difference in SF12-PCS scores (Table 3). Notably, length of follow-up was correlated with worse ASES (rho $= -0.709$, $P = .002$), SANE (rho $= -0.534$, $P = .033$), and QuickDASH (rho $= 0.776$, $P < .001$) scores.

Revision Surgery and Clinical Failure

One patient (6%) originally treated with PMT repair for a humeral avulsion type tear underwent partial revision PMT repair and adhesiolysis at 3.4 years to address pain caused by an adhesive band spanning from

Table 1. Cohort Characteristics

	Cohort Characteristics
Age at surgery, y (range)	38.6 (20.5-64.3)
Sex	100% men
Affected arm	74% dominant arm, 26% nondominant arm
Mechanism of injury	11 bench press/power lifting 7 ski or snowboarding fall 5 others (1 college football, 1 rock-climbing, 1 wakeboarding fall, 1 slip and fall, 1 hanging from rope)
Timing of surgery Acute = less than 6 weeks	16 acute (mean, 18 days; range, 3-35) 7 chronic (mean, 66 days; range, 42-123)
Tear details	
Muscular head	23 sternal Head, 0 clavicular
Complete vs partial	20 complete, 3 partial
Location	13 Tendon avulsion off humerus 10 Musculotendinous junction tears
Tietjin classification[16]	11 III-D (complete, avulsion off humerus) 9 III-C (complete, Musculotendinous junction) 3 II (partial, any location)

the PMT to the shorthead of the biceps. There were no additional complications outside of this patient.

Leukocyte-Poor Platelet-Rich Plasma

Aggregated whole blood and LP-PRP CBC results are presented in Table 4. LP-PRP products resulted in a 5.5-fold increase in platelet count ($P < .001$) and a 3.8-fold decrease in total white blood cells ($P < .001$). These results confirm an increase in the number of platelets and a decrease in leukocytes in the final PRP products. We also observed variability in the whole blood and LP-PRP products that may be due to injury, chronicity, and other patient determinants.

Discussion

The principle finding of this study is that at a minimum follow-up of 2 years, patients with PMT tears who were managed with operative treatment had significantly improved PROs compared with their preoperative scores. In addition, patients reported a high level of satisfaction with their surgical treatment (median, 9/10). The current study also demonstrated that surgical repairs of PMT tears that are augmented with LP-PRP injections may result in improved clinical outcomes when compared to those which are not. However, the study also found that PROs decrease as length of follow-up increases, suggesting that the relationship is likely multifactorial. These factors may include the impacts of LP-PRP but also may be the result of the normal aging process, lifestyle changes, intrinsic tendon pathology following surgical fixation, or subsequent injuries to surrounding structures.

Increasing reports of PMT tears can likely be attributed to increased weightlifting and sport participation.[1-3] In the current study, there were a high percentage of PMT tears in young adults that resulted from indirect trauma while bench pressing, or direct trauma during athletics such as skiing. Most commonly, tears occurred in the dominant arm and were avulsions of the tendon from the humerus (type III-D).[16] However, tears also occurred at the musculotendinous junction (type III-C).[16] The mechanism of injury, dominance, and tear characteristics of the current study's patient cohort align with those reported in the literature.[6,17] When analyzed based on these characteristics, namely tear classification (location), there was no difference PRO scores, which is consistent with outcomes reported in the literature.[6]

As discussed, patients evaluated in this study were highly satisfied with their surgical outcomes, reporting a median satisfaction of 9 of 10. These reports are comparable with average satisfaction values reported by Cordasco et al.[7] and Merlin et al.,[18] who reported overall patient satisfaction of 9.6 of 10 and 7.7 of 10, respectively, following PMT repair. High satisfaction

Table 2. PRO Scores Improvement From Preoperative to Postoperative

	Preoperative	Postoperative Mean 5.1 Years (2.0-13.0)	*P* Value
ASES score	59.0 (16.6-84.9)	92.4 (56.6-100)	.008*
SANE score	44.4 (1-84)	85.9 (32-99)	.018*
QuickDASH score	45.4 (15.9- 75)	8.5 (0-59)	.018*
SF-12 PCS score	42.5 (29.5-52.1)	52.6 (25.7-59.2)	.008*
Median satisfaction with outcomes	N/A	9 (range 6-10)	

ASES, American Shoulder and Elbow Surgeons Score; N/A, not available; PRO, patient-reported outcome; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand Score; SANE, Single Assessment Numeric Evaluation Score; SF-12 PCS, Short Form 12 physical component summary.
*Statistically significant.

Table 3. Postoperative PRO Score Comparison Between Those Treated With PRP and Those Who Were Not

	PRP	No PRP	*P* Value
Number of patients	9	7	
PRO Final follow-up, y	2.6 (2.0-2.9)	8.5 4.1-13)	.009*
ASES score	99.6 (96.6-100)	83.0 (56.6-98.3)	0.001*
SANE score	94.8 (79-99)	74.6 (32-94)	0.005*
QuickDASH score	0.24 (0-2.2)	19.1 (2.2-59)	0.001*
SF-12 PCS score	55.8 (46.1-59.2)	48.4 (25.7-57.8)	.100
Median satisfaction with outcomes	10 (range 8-10)	9 (range 6-10)	.037*

ASES, American Shoulder and Elbow Surgeons Score; PRO, patient-reported outcome; PRP, platelet-rich plasma; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand Score; SANE, Single Assessment Numeric Evaluation Score; SF-12 PCS, Short Form 12 physical component summary.
*Statistically significant.

rate is likely a result of improvements in function and pain following repair as indicated by the improvement of 33.4 points in ASES pre- to postoperatively. While the improvement in ASES scores in the current study is greater than what was reported by Mooers et al.[19] (+13.9), the authors reported comparable mean ASES scores at final follow-up (96.7), reinforcing the finding that good subjective outcomes following PMT repair are expected. The patients in our cohort also had encouraging sport-related outcomes, all of whom returned to exercise and/or weightlifting by the time of final follow-up. These findings are consistent with return to sports metrics reported in previous literature, which have been as high as 90% following PMT repair.[6] In addition, after PMT repair, patients commonly have return to previous level of participation rates of 74%.[6] However, despite these promising return to sport metrics, which were also present in our cohort, 8 patients reported modification of their activities due to fear of reinjury (5), pain (2), and weakness (1), indicating patients may benefit from additional counselling or patient specific interventions, such as physical therapy, to optimize outcomes.

Subgroup analysis of patients who did and did not receive PRP indicated that, at the time of follow-up, repairs augmented with PRP resulted in superior PROs (ASES, SANE, QuickDASH, and patient satisfaction). The potential benefit of PRP may be a result of reduced local inflammation and fibrosis secondary to augmented cellular migration, proliferation, and angiogenesis leading to improved tendon healing.[9,20] While the cohort receiving PRP had a greater percentage of tears at the musculotendinous junction compared with the tears of the humeral insertion site, the principles theorized to improve healing as a result of PRP remain at each location.[9,21] The lack of available literature on the impact of PRP on PMT tears is likely a result of the infrequency of the injury and the relatively recent increase in the use of PRP for surgical repair augmentation.[22] However, given the demonstrated benefits of PRP,[11] particularly LP-PRP,[10] in arthroscopic rotator cuff repairs, it is reasonable to infer that a similar

Table 4. Whole Blood and PRP Characteristics

	Whole Blood	Processed PRP	*P* Value
WBC, 10^{e3}/μL	4.8 (3.41-5.47)	1.26 (0.120-2.98)	<.001*
NEU, 10^{e3}/μL	2.93 (1.95-3.75)	0.116 (0.010-.300)	<.001*
LYM, 10^{e3}/μL	1.35 (0.70-2.50)	0.895 (0.080-2.48)	.231
MONO, 10^{e3}/μL	0.371 (0.160-0.650)	0.221 (0.021-0.700)	.036
EOS, 10^{e3}/μL	0.057 (0.020-0.162)	0.006 (0.000-0.002	.028*
BASO, 10^{e3}/μL	0.052 (0.010-0.079)	0.018 (0.000-0.054)	.007*
RBC, 10^{e6}/μL	4.24 (3.6-4.6)	0.066 (0.010-0.200)	<.001*
HGB, g/dL/μL	12.8 (12.1-13.6)	0.09 (0-0.40)	<.001*
HCT, %	38.1 (35.2-39.8)	0.38 (0-1.4)	<.001*
MCV, fL	90.9 (85.5-97.3)	42.1 (0-93.3)	.026*
MCH, pg	30.3 (28.9-33.5)	10.24 (0-22.3)	.003*
MCHC, g/dL	33.3 (31.9-34.7)	13.7 (0-8.6)	.009*
RDW, %	12.14 (11.1-13.3)	12.24 (0-61.8)	.991
PLT, 10^{e3}/μL	182.4 (144-227)	1004.0 (506-1344)	<.001*
MPV, fL	7.15 (5.20-10.0)	6.75 (4.08-10.2)	.056

BASO, basophils; EOS, eosinophils; HCT, hematocrit; HGB, hemoglobin; LYM, lymphocytes; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; MCV, mean corpuscular volume; MONO, monocytes; MPV, mean platelet volume; NEU, neutrophils; PLT, platelets; PRP, platelet-rich plasma; RBC, red blood cells; RDW, red cell distribution width; WBC, white blood cells.
*Statistically significant.

impact may be seen in PMT repairs. Despite the superior PROs seen in our PRP cohort, the impact of PRP must be evaluated with caution, considering the significant differences in follow-up duration and small cohort size. The true impact of PRP augmentation on PMT repairs requires further investigation with larger patient cohorts and longer follow-up.

Limitations

As discussed, our study is not without limitations. One major limitation of our study is the difference in follow-up duration between the cohort receiving PRP versus those who did not, which is a result of the limited duration of use of PRP. The small cohort sizes compounded by the loss to follow-up rate in our study is also a limiting factor that is not unique to our retrospective study design. In addition, the use of available PROs rather than the Bak criteria[17] reduces the ability to compare the results of our study with published outcomes; however, we believe the inclusion of baseline patient scores outweighs this disadvantage.

Conclusions

PMT repair produces improved PROs at final follow-up when compared with preoperative values.

References

1. de Castro Pochini A, Ejnisman B, Andreoli CV, et al. Pectoralis major muscle rupture in athletes: A prospective study. *Am J Sports Med* 2010;38:92-98.
2. Provencher MT, Handfield K, Boniquit NT, Reiff SN, Sekiya JK, Romeo AA. Injuries to the pectoralis major muscle: Diagnosis and management. *Am J Sports Med* 2010;38:1693-1705.
3. ElMaraghy AW, Devereaux MW. A systematic review and comprehensive classification of pectoralis major tears. *J Shoulder Elbow Surg* 2012;21:412-422.
4. Metzger PD, Bailey JR, Filler RD, Waltz RA, Provencher MT, Dewing CB. Pectoralis major muscle rupture repair: Technique using unicortical buttons. *Arthrosc Tech* 2012;1:e119-e125.
5. Thompson K, Kwon Y, Flatow E, Jazrawi L, Strauss E, Alaia M. Everything pectoralis major: from repair to transfer. *Phys Sportsmed* 2020;48:33-45.
6. Yu J, Zhang C, Horner N, et al. Outcomes and return to sport after pectoralis major tendon repair: A systematic review. *Sports Health* 2019;11:134-141.
7. Cordasco FA, Mahony GT, Tsouris N, Degen RM. Pectoralis major tendon tears: Functional outcomes and return to sport in a consecutive series of 40 athletes. *J Shoulder Elbow Surg* 2017;26:458-463.
8. Hurley ET. Editorial Commentary: Platelet-rich plasma for rotator cuff repairs: no evidence for improved long-term outcomes … yet! *Arthroscopy* 2022;38:62-64.
9. Baksh N, Hannon CP, Murawski CD, Smyth NA, Kennedy JG. Platelet-rich plasma in tendon models: A systematic review of basic science literature. *Arthroscopy* 2013;29:596-607.
10. Hurley ET, Colasanti CA, Anil U, et al. The effect of platelet-rich plasma leukocyte concentration on arthroscopic rotator cuff repair: A network meta-analysis of randomized controlled trials. *Am J Sports Med* 2021;49:2528-2535.
11. Hurley ET, Lim Fat D, Moran CJ, Mullett H. The efficacy of platelet-rich plasma and platelet-rich fibrin in arthroscopic rotator cuff repair: A meta-analysis of randomized controlled trials. *Am J Sports Med* 2019;47:753-761.
12. Cross JA, Cole BJ, Spatny KP, et al. Leukocyte-reduced platelet-rich plasma normalizes matrix metabolism in torn human rotator cuff tendons. *Am J Sports Med* 2015;43:2898-2906.
13. Flint JH, Wade AM, Giuliani J, Rue JP. Defining the terms acute and chronic in orthopaedic sports injuries: A systematic review. *Am J Sports Med* 2014;42:235-241.
14. Sanchez A, Ferrari MB, Frangiamore SJ, Sanchez G, Kruckeberg BM, Provencher MT. Pectoralis major repair with unicortical button fixation and suture tape. *Arthrosc Tech* 2017;6:e729-e735.
15. Manske RC, Prohaska D. Pectoralis major tendon repair post surgical rehabilitation. *N Am J Sports Phys Ther* 2007;2:22-33.
16. Tietjen R. Closed injuries of the pectoralis major muscle. *J Trauma* 1980;20:262-264.
17. Bak K, Cameron EA, Henderson IJ. Rupture of the pectoralis major: A meta-analysis of 112 cases. *Knee Surg Sports Traumatol Arthrosc* 2000;8:113-119.
18. Merlin G, Koenig S, Gross J, Edgar C. Functional outcome after pectoralis muscle repair. *Curr Orthop Practice* 2017;28:436-439.
19. Mooers BR, Westermann RW, Wolf BR. Outcomes following suture-anchor repair of pectoralis major tears: A case series and review of the literature. *Iowa Orthop J* 2015;35:8-12.
20. Zhang J, Middleton KK, Fu FH, Im HJ, Wang JH. HGF mediates the anti-inflammatory effects of PRP on injured tendons. *PLoS One* 2013;8:e67303.
21. Li H, Usas A, Poddar M, et al. Platelet-rich plasma promotes the proliferation of human muscle derived progenitor cells and maintains their stemness. *PLoS One* 2013;8:e64923.
22. Zhang JY, Fabricant PD, Ishmael CR, Wang JC, Petrigliano FA, Jones KJ. Utilization of platelet-rich plasma for musculoskeletal injuries: An analysis of current treatment trends in the United States. *Orthop J Sports Med* 2016;4:2325967116676241.