Pectoralis Major Rupture in Military Academy Athletes

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Investigation performed at the Keller Army Hospital, United States Military Academy, West Point, New York, USA, and the Naval Health Clinic Annapolis, United States Naval Academy, Annapolis, Maryland, USA

Background: Pectoralis major ruptures are rare injuries that can occur at several parts of the muscle. Little is known of the pathoanatomic process and performance following pectoralis major ruptures in young athletes.

Purpose/Hypothesis: The objective of this study was to describe a series of pectoralis major ruptures in military academy athletes at the US Military Academy and US Naval Academy. We hypothesized that military academy athletes will demonstrate a different rupture location than previously reported in older patients.

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

Methods: A retrospective case series was performed by analyzing all electronic medical records and imaging software for consecutive pectoralis major ruptures undergoing surgical repair within the student population at 2 military academies. The primary outcome of interest was rupture pattern and location. We also assessed functional recovery following surgery by analyzing push-up performance on the biannual Army Physical Fitness Test and Navy Physical Readiness Test.

Results: From 2005 to 2017, a total of 19 cases of pectoralis major ruptures occurred in military academy cadets. Patients ranged in age from 19 to 23 years, with a mean age of 20 years. All injuries occurred during sports activity, with bench press as the most common mechanism of injury (n = 10; 53%). The most common rupture location was the musculotendinous junction (n = 10; 53%), followed by pectoralis major tendon insertion (n = 8; 42%), and only 1 bony avulsion was noted. Physical activity performance following the rupture was negatively affected. The mean ± SD number of push-ups preinjury was 73.20 ± 12.10, which decreased following injury and surgery (66.50 ± 11.98; P = .037).

Conclusion: Military academy athletes in our study cohort demonstrated a different type of rupture location than has been reported in older cohorts, with the majority experiencing tearing at a location other than the tendon itself. Performance was also negatively affected immediately following repair, but moderate improvement was observed as time from surgery increased.

Keywords: shoulder injury; pectoralis major; tendon rupture; military academy; push-ups

The pectoralis major muscle is a large and powerful triangular muscle in the chest that originates from the anterior surface of the sternum and the sternal portion of the clavicle, coming together into the pectoralis major tendon, which inserts into the humerus bone of the upper arm.1,6,11,21 Pectoralis major ruptures can occur in several parts of the muscle— the junction between the tendon and the humerus, the junction between the muscle and the tendon, in the muscle belly, or at the junction of the muscle and the sternum.1,4,6,13 Most surgical series have focused primarily on the tendon injuries.3,4,8,13 Little is known about the characteristics of pectoralis major ruptures in the military cadet population, as previous studies have analyzed these tears only in older cohorts.3,10 The rarity of pectoralis major ruptures, especially in younger athletes, can be attributed to the strength of the layered structure of the muscle and its intricate insertion.13

Rupture location will affect surgical management decisions and repair techniques, but not many surgeons are experienced with its repair because of the rarity of the injury. Particularly for the military cadet population, little is known about pectoralis major rupture characteristics and performance measures following surgery, where only isolated cases have been reported in the literature.1,3,5,8,19 The objective of this study was to characterize pectoralis major ruptures and push-up performance following surgery in a collegiate military academy population.

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METHODS

We performed a retrospective analysis of pectoralis major ruptures over the 13-year period from 2005 to 2017 within the student population at the United States Military Academy (USMA) and the United States Naval Academy (USNA). Students enrolled at each service academy must undergo a comprehensive medical evaluation and are required to meet the US Army and US Navy standards of medical fitness. This cohort was chosen because military academies have a closed health care system that includes sports medicine clinics at practice, training, and competition sites as well as orthopaedic clinics at the post hospitals, allowing for the collection of accurate medical records. All pectoralis major ruptures occurring within the student body during the study period were identified through use of a combination of electronic medical records of the 2 academies’ health care systems and Cadet Illness and Injury Tracking System (CIITS) data reviews. CIITS tracks all injuries that occur within the student population. This study was approved by the institutional review board affiliated with both military academies.

In addition to the availability of accurate medical records, a benefit of using this study populations is that students participate in regularly scheduled physical fitness tests, which were used as a standard to measure preinjury and postsurgery performance. USMA students must take the Army Physical Fitness Test (APFT) each semester, consisting of timed sets of push-ups, sit-ups, and a 2-mile run. USNA students must take the Physical Readiness Test (PRT), consisting of timed sets of push-ups, curl-ups, and a 1.5-mile run.

All patients with a confirmed pectoralis major rupture diagnosis were clinically assessed by a sports fellowship-trained orthopaedic surgeon. Rupture was diagnosed based on physical examination findings and magnetic resonance imaging (MRI), and operative reports were used to confirm location of injury. Figures 1 and 2 are select MRI cuts demonstrating a pectoralis major rupture at the musculotendinous junction. All cases reported injury location, extent, and grade based on the Tietjen classification of pectoralis major injuries. The Tietjen classification is an anatomic classification traditionally used to grade injuries to the pectoralis major to guide conservative versus surgical management. Within the Tietjen classification, type I injuries include contusions or strains, type II injuries are partial ruptures, and type III injuries are complete ruptures at the muscle origin (III-A), muscle belly (III-B), musculotendinous junction (III-C), or tendinous insertion (III-D). The views expressed in this article are those of the authors and do not reflect the official policy or position of the US government.

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Figure 1. T1-weighted axial magnetic resonance imaging of pectoralis major rupture at musculotendinous junction (arrow).

Figure 2. T2-weighted axial magnetic resonance imaging of pectoralis major rupture at musculotendinous junction (arrow).
Students’ medical records and CIITS data were used to collect information regarding demographics, past medical history, injury mechanism, physical examination findings, diagnostic imaging, surgical treatment record details, length of physical profile, and push-up performance on the biannual APFT and PRT before injury and after surgical repair. We used the last physical fitness test available prior to injury and the first physical fitness test taken after the patient was cleared following surgery. Information regarding any pending or completed Medical Evaluation Board (MEB) or Physical Evaluation Board (PEB) was also collected. If a student’s physician finds that a medical or physical condition may permanently interfere with the student’s ability to serve on active duty, the treating physician may recommend the student to the MEB and PEB.18

Postoperatively, the patient is placed in a sling for 6 weeks. Gentle range of motion and passive pendulum exercises are started the first week. The patient is restricted from active abduction, forward elevation, and external rotation. At 6 weeks, the patient starts advancing to full range of motion exercises, and light resistance exercises are initiated. Around 3 months, the patient should have full range of motion. Around 3 to 4 months, the patient may perform push-up progressions and begin weight training with light resistance. The patient is not allowed to participate in contact sports until after 6 months postoperatively, and the goal is for patients to return to full, unrestricted activity between 6 and 12 months.

A paired Student $t$ test was used to analyze statistical differences between push-up scores preinjury and scores following surgical intervention. A subgroup analysis of only APFT push-up scores from USMA was performed because of inconsistency in reporting PRT push-up scores. A Pearson product-moment correlation coefficient was performed to determine whether the differences in push-up scores postoperatively were correlated with return-time participation in the APFT. All analyses were performed by use of Stata v 10.1 (StataCorp), and statistical significance was set at $P < .05$ for all comparisons.

**RESULTS**

From 2005 to 2017, a total of 19 students with a pectoralis major rupture underwent surgical repair at Keller Army Community Hospital and Naval Health Clinic Annapolis. We identified 14 cases of pectoralis major ruptures in USMA students and 5 cases in USNA students. All the patients were male, with ages ranging from 19 to 23 years and a mean age of 20 years. Of the 19 patients, 14 (74%) were white and 5 (26%) were African American. All patients were collegiate athletes, and all of the injuries were reported during sports-related activity. Bench press was reported as the most common injury mechanism ($n = 10; 53\%$), followed by football ($n = 4; 21\%$). For the remaining patients, injuries resulted from participation in practice or competition of their respective sport. Table 1 presents the age, military academy, and mechanism of injury for each study patient.

All the injuries were first-time injuries, and 8 patients (47%) had associated shoulder injuries, none of which had to be addressed surgically. Of these, 6 patients described posterior shoulder pain, 1 patient sustained an anterior shoulder dislocation during a wrestling tournament, and 1 patient had a posterior shoulder subluxation event while bench pressing. No patients reported anabolic steroid use. The mean interval between injury and surgery was 18 days, with a range of 0 to 64 days. Only 1 patient was fixed outside of the acute window at 9 weeks and was able to be primarily repaired with surgery. The most common type of pectoralis major rupture was type III-C (rupture at the
musculotendinous junction) (n = 10; 53%), followed by type III-D (avulsion of the tendon at the site of insertion) (n = 8; 42%). A bony avulsion was seen in 1 case. Figure 3 is an axillary radiograph demonstrating this bony avulsion. In total, 7 ruptures (37%) were repaired by use of the cortical button technique, 7 ruptures (37%) were repaired with the suture anchor technique, and 5 ruptures (26%) were repaired with the bone trough technique. No patients required any augments, and no postoperative complications were noted. Most of the operations were performed by the senior authors (B.D.O, J.-P.H.R., C.A.H).

Performance was analyzed through push-up scores. The push-up scores available at the time of data collection before injury and scores following surgical repair are listed in Table 2. APFT push-up scores following surgery were not recorded for 5 students, and PRT push-up scores were not recorded in the PRT transcripts for 4 students. The mean ± SD number of push-ups preinjury was 73.20 ± 12.10, with lower push-up numbers (66.50 ± 11.98) following surgery (P = .037). A weak positive correlation (R = 0.49, P = .07) was found with respect to time after surgery (difference from surgery to first performed APFT or PRT) and push-up score (difference preinjury and postoperatively). However, in a subgroup analysis of only APFT push-up scores from 1 military academy, a moderate positive correlation was found (R = 0.68, P = .04). Figure 4 demonstrates this moderate positive correlation with respect to time (days) and push-up score (repetitions). The mean ± SD interval from surgery to first physical fitness test following surgery was 214 ± 110 days. At the time of the study, none of the patients had an MEB or PEB on record.

DISCUSSION

Our study showed that pectoralis major rupture does occur in a military cadet population and that the location of injury may be different from that found in older patients more commonly experiencing this injury. Understanding the causes of these ruptures can be important in preventing future injuries. Rupture of the pectoralis major often occurs as a result of an eccentric contraction, when the arm is extended and outwardly rotated, such as during bench press exercises. There are concerns that specific military training activities such as parachute landing could cause major tendon ruptures, but a study by White et al did not support this theory, indicating that eccentric contraction without maximal contractile force was not sufficient to result in tendon ruptures. In fact, the literature has consistently shown that the majority of pectoralis major tendon ruptures in a military cohort occurred from bench pressing. Our study further supports this, where more than 50% of the injuries were due to weightlifting.

Our study also sheds light into the characteristics of pectoralis major rupture location in the collegiate military academy population, which was previously unclear. Pectoralis major ruptures can occur at several parts of the muscle, such as the junction between the bone and tendon, the junction between the muscle and the tendon, within the muscle, or even at the sternal junction. Previous investigators have reported that ruptures at the tendon or tendon insertion accounted for most cases overall. Bak et al found that 65% of the ruptures were located at the tendon insertion, while ElMaraghy and Devereaux found that 45% of the ruptures were at the tendon insertion and 22% were located at the musculotendinous junction. However, our study found that the majority of ruptures were injuries to nontendon structures, either the musculotendinous junction or bony avulsion at the pectoralis major tendon insertion. This may be because of the absence of tendinopathy in our young population compared with older populations. Previous studies have also found that the mechanism of pectoralis major ruptures with work injuries resulted in injuries at the musculotendinous junction, while insertional ruptures were more common in sports injuries.

![Figure 4. Pearson correlation coefficient subgroup analysis of Army Physical Fitness Test push-up scores in cadets](image)
The main risk factors for pectoralis major ruptures include older age and anabolic steroid use. Although anabolic steroid use is a well-documented risk factor, no cadets in our study group reported using steroids in the preoperative period. We believe there may be bias toward underreporting because in our military academy population, steroid use can result in severe disciplinary actions including ineligibility and loss of playing time. Regardless, we believe that repetitive overuse of the muscle may be a reason for pectoralis major ruptures in this young population. Although we do not have data about specific hours of training per week for our population, military academy cadets are expected to participate in athletic training at least 5 days a week. Our young cohort experienced repetitive overuse of the muscle from increased weight training or sports participation, which can result in tendon weakness. Older age is a risk factor for major tendon tears because of the weakening of collagen, the main composite of tendons, with age. Patients with pectoralis major ruptures in our study had a mean age of 20 years, whereas most patients with pectoralis major ruptures reported in the literature are 30 years or older. The youngest cohort that we found in the literature entailed 13 athletes with an average age of 28.6 years. Those researchers found that the majority (77%) of ruptures were at the tendon insertion.

Currently, no consensus is available in the literature regarding a standard performance measure for pectoralis major injuries following surgical repair. Studies have used 1 or a combination of the following examples of performance measurements: physical examination (range of motion, muscle strength), isokinetic strength testing, and various questionnaires (Disabilities of the Arm, Shoulder and Hand; visual analog scale; Work Module; Sports Module). However, these studies did not analyze functional requirements in a cohort similar to our study.

Functional requirements are an important consideration because young military academy athletes and active-duty military personnel have a higher level of baseline requirements than the general population. One study analyzing reported preoperative and postoperative strength in a military population found that deficits in postoperative strength were more obvious and limiting for active-duty military personnel. In that study, patients reported a mean 34% reduction in 2-minute push-up scores. The same study acknowledged the difficulty of obtaining objective strength measurements after surgery in a dynamic active-duty wartime population. For our study, APPT and PRT push-up scores provided an objective performance measurement where the study population had incentive to receive high scores. The trend toward lower push-up numbers following injury was not surprising, and it may be a helpful tool to explain to high-performance athletes that there will be slight decrease in pectoralis major strength postoperatively. A subgroup analysis was performed with only APPT push-up scores from 1 military academy because of the inconsistency in reporting of PRT push-up scores (80% of the cadets were missing push-up scores) and potential variability between grading standards among service academies. The moderate positive correlation between interval from surgery and push-up score was important, because high-level performance athletes and military personnel are concerned with return-to-sport and return-to-duty time.

Factors found in the literature that affect outcome include age, type of intervention, location of rupture, and length of time from rupture to treatment. Younger patients have been found to have better outcomes than older patients. Immediate surgery has been cited as the best treatment for pectoralis major injuries, with these patients most likely to result in return to full-level activity. Patients with ruptures located near or within the muscle have been found to experience worse outcomes. Additionally, worse results have been seen in patients who had a delay in receiving surgery.

Our study had several limitations. First, the follow-up was limited in this study because time spent at the service academies is typically limited to 4 years. Second, pectoralis major ruptures remain an uncommon injury in this age group. Even though a young military academy population has increased risk exposures in repetitive use of the muscle, we were able to collect data on only 19 cadets over a 13-year study period. A larger prospective study would eliminate bias characteristic of retrospective studies and likely yield more statistically significant conclusions. Despite these limitations, we were able to determine that young military academy athletes demonstrate a different type of rupture location to those previously reported in older patients and that performance was affected following injury, although there was moderate improvement as time from surgery increased. We believe that pectoralis major ruptures are underreported in the literature, and we hope this study will prompt additional research to better understand the characteristics of this injury in the young athletic population.

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