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# Evaluation of Patients with Acute PM Tendon Rupture Using Microscopy and MRI

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## Abstract

**Hypothesis:** This study presented a pioneering investigation of the changes in the MRI images of PMM tendon rupture compared with the contralateral side among weightlifters and histologically analyzed ruptured PMM tendons to determine the presence of changes.

**Methods:** 36 men were evaluated, 26 with acute total PMM rupture (<3 months since injury) with a mean age of 37.3 years (SD=9.7 years) and ten control patients with a mean age of 32.6 years (SD=4.2 years). All cases were caused by the bench press exercise. The patients were evaluated preoperatively using a Siemens 1.5 Tesla Magnetic Resonance Imaging (MRI) machine. On the contralateral side to the PMM injury, chest MRI images were obtained to evaluate possible PMM tendinopathy. The evaluation of the tendon PMM injuries was based on the MRI exam, the histological analysis performed in this study.

**Results:** MRI of the surgically treated patients in the case group, two (7.1%) contralateral sides were normal, 16 (57.1%) showed superior tendinopathy, and 10 (35.7%) had total tendinopathy. Inferior tendinopathy was not observed. Histology Two fragments could not be analyzed for insufficient tissue. The tendinopathy evaluations of the tendon fragments revealed degenerative changes in 16 (66.7%) fragments, with 12 (50.0%) considered as mild (< 25%), and four considered as (16.7%) high (>50.0%) tendinopathy.

**Conclusion:** Total acute rupture of the PMM tendon among weightlifters might be associated with changes in the MRI signal and tendinous degeneration prior to injury, especially following bench press exercise, which is historically associated with the use of anabolic steroids.

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## Introduction

The incidence of Pectoralis Major Muscle (PMM) injury has increased considerably among weightlifters over the last 20 years. Failure to promptly recognize the injury described as "total PMM tendon rupture" among exercise practitioners typically leads to chronic injury phases with an important sequela (i.e., chest deformity) and decreased adduction strength, which usually bothers patients practicing weightlifting or other physical activities [1-24]. Treatment during the acute phase is typically and technically easier, although the literature describes positive results among patients operated on during the acute or chronic PMM injury stages [1-23]. In general, the treatment of acute cases involves the surgical fixation of the PMM tendon to the humerus with suture anchors, cortical buttons, or bone tunnels [1-3,7,9,12-24]. In chronic cases (i.e., time since injury >3 weeks) [25], the muscle can have difficulty being positioned in the region lateral to the biceps brachii, especially among weightlifters using anabolic steroids who present with complex injuries and medial retraction. In these cases, the use of autografts [6,8,9,19-25] or allografts [15] is necessary, and the PMM tendon is reconstructed, which is technically more difficult but has positive results. For many years treating this injury, our group has surgically treated acute and chronic cases ranging from 2 to 5 years with positive results. We have observed that these patients have satisfactory aesthetic and functional clinical results months after PMM reconstruction. Some studies have shown the use of magnetic resonance for injuries to the tendon of the pectoralis major muscle, but none have addressed possible previous changes to rupture [15-17,21]. Until now we have not identified additional Magnetic Resonance Imaging (MRI) signs suggesting evidence of tendon injury (tendinopathy), beyond those indicated on ultrasound [21]. In other tendons (e.g., the rotator cuff and calcaneal tendon) [24,26], the MRI visualization of degenerative changes such as thickening and hyper signal within the tendon showing the proliferation of vessels and cells is possible. A better identification of the degenerative process in recreational or competitive weightlifters might help improve patient management. This study conducted a pioneering investigation of the changes in the

MRI images of PMM tendon rupture compared with the contralateral side and among weightlifters and histologically analyzed ruptured PMM tendons to determine the presence of changes.

## Materials and Methods

Between 2014 and 2018, 36 men patients were prospectively assessed, 26 with acute total PMM rupture (<3 months since injury) with a mean age of 37.3 years (SD=9.7 years) and tencontrol patients with a mean age of 32.6 years (SD=4.2 years). All cases were caused by the bench press exercise and treated at the Sports Trauma Orthopedics Center (Centro de Traumato-Ortopedia do Esporte; CETE) at the Federal University of São Paulo (Universidade Federal de São Paulo; UNIFESP). This study was approved by and registered at the Brazil Platform (Plataforma Brasil) under ethical committee CAAE number 20959813.0.0000.5505. The patients were evaluated using a Siemens 1.5 Tesla MRI system. Patients with PMM rupture were operated on using a previously described technique and a ruptured tendon sample was obtained from the injured side for histological evaluation. On the contralateral side to the PMM injury, chest MRI images were obtained to evaluate possible PMM tendinopathy.

### MRI evaluation

Patients and controls underwent a bilateral MRI protocol to directly evaluate the PMM tendon. All exams were performed using the same 1.5-T instrument (Siemens, Erlangen, Germany) with the parameters described in Table 1.

MRI scans were evaluated using Osirix v6.0 (Pixmeo, Bernex, Switzerland). A radiologist specialized in musculoskeletal imaging evaluated the images, considering a PMM injury to be present when abnormal morphology and hyper signal intensity were observed in the muscle and tendon structures on the T1-weighted sequences without fat saturation and the T2-weighted images with Fat Saturation (T2FS). Changes related to the tendinopathy of the PMM included the presence of tendon thickening and signal changes in at least two consecutive axial images on the T1 or T2FS sequences. Because of the difficulty of differentiating the sternal and clavicular components of the PMM tendon near its insertion, tendinopathy was also classified based on the location of the tendon injury: The upper half of the tendon, the lower half of the tendon, or the full extension of the PMM tendon. Tendinous or myotendinous junction ruptures of the PMM were evaluated using axial T1 and T2FS sequences through the partial or complete discontinuation of the muscle and/or tendon fibers as well as the presence or absence of associated edema. Chronic changes such as the scarred thickening of the muscle or tendon fibers and possible areas of muscle liposubstitution were recorded. The images were considered as normal/controls in the absence of structural changes with the signal intensity of the MRI protocol directed toward the PMM evaluation.

### Optical microscopy

The sample consisted of 26 fragments from the patients undergoing surgery. In this study, only the tendons were analyzed via histological analysis of the remaining tendon attached to the retracted muscle (Table 2). The specimens were fixed in buffered formalin and embedded in paraffin for a hematoxylin and eosin analysis. The slides were evaluated by the General, Systemic, Forensic, and Bioethics Pathological Anatomy Department of UNIFESP.

### Statistical analysis

The numerical variables were described by mean and Standard Deviation (SD) and the categorical variables by absolute and relative frequencies. Generalized Estimation Equation (EEG) models were adjusted considering the dependence between the sides of the same individual. The models were fitted with gamma distribution and log link function and the results presented by estimated mean values and 95% confidence intervals and the p values were obtained by multiple comparisons corrected by the Bonferroni method. The analyzes were performed using SPSS® software version 19, adopting a significance level of 5%.

## Results

The control group of patients who underwent magnetic resonance imaging consisted of ten healthy participants with a mean age of 32.6 years (SD=4.2 years). The group with previous PMM tendon injury was composed of 26 individuals with a mean age of 37.3 years (SD=9.7 years). The bilateral measurements of all participants in the control group were obtained (10 measurements). The measurements of the case group were performed on the contralateral side (26 measurements) to determine the presence of degenerative changes due to long-term weightlifting. All 26 patients practiced weightlifting, specifically suffering a PMM injury during the bench press exercise. All cases had a history of anabolic steroid use, which is typical of PMM rupture cases engaged in recreational or competitive bench press exercise. All cases were men. Of the surgically treated patients in the case group, regarding the images, two (7.1%) contralateral sides were normal, 16 (57.1%) showed superior tendinopathy and 10 (35.7%) had total tendinopathy. Inferior tendinopathy was not observed. The tendinopathy classification revealed that all control patients were classified as normal (Table 3, 4).

### Tendon samples

Two fragments could not be analyzed for insufficient tissue. The tendinopathy evaluations of the tendon fragments (Table 4) revealed degenerative changes in 16 (66.7%) fragments, with 12 (50.0%) considered as mild (<25%), and four considered as (16.7%) high (>50.0%) tendinopathy. None of the fragments showed calcifications, whereas 16 (66.7%) presented with neovascularization, and only two (8.3%) presented with a fissure. Other findings were observed, including four fragments (16.7%) with inflammatory infiltrate, ten

**Table 1**: MRI parameters.

| Pulse sequence | TR (ms) | TE (ms) | NEX | Matrix | Thickness (mm) | FOV (cm) | Bandwidth (Hz) | Echo train |
|---|---|---|---|---|---|---|---|---|
| Coronal FSE T2FS | 3,000 | 49 | 1 | 512 x 256 | 4 | 22 | 250 | 6 |
| Axial FSE T1 | 600 | 11 | 1 | 512 x 256 | 4 | 26 | 296 | 3 |
| Axial FSE T2FS | 3,000 | 49 | 1 | 512 x 256 | 4 | 26 | 250 | 6 |
| Sagittal FSE T2FS | 3,600 | 52 | 1 | 512 x 256 | 4 | 22 | 250 | 6 |
| Coronal T1 | 500 | 15 | 1 | 512 x 256 | 4 | 30 | 122 | 1 |

**Legend:** TR: Repetition Time; TE: Echo Time; NEX: Number of Excitations; FOV: Field-of-View; FSE: Fast Spin Echo; T2FS: T2-Weighted with Fat Saturation

**Table 2**: Classification used for histological analysis of tendons.

| Tendinopathy | Classification |
|---|---|
| 1 = Degenerative changes (myxoid changes of the filamentous substance) | 0 = absent |
| | 1 = mild <25% |
| | 2 = moderate 26%-50% |
| | 3 = high >50% |
| 2 = Calcifications | 0 = absent |
| | 1 = present |
| 3 = Neovascularization | 0 = absent |
| | 1 = present |
| 4 = Fissures | 0 = absent |
| | 1 = present |

**Table 3:** PMM tendon measurements obtained via MRI in both cases and controls.

| | Group | | | P-value | | |
|---|---|---|---|---|---|---|
| | Control (G1) | Case: operated side (G2) | Case: contralateral side (G3) | G1 x G2 | G1 x G3 | G2 x G3 |
| Tendon size | 3.39 (2.90; 3.88) | 4.39 (3.34; 5.44) | 3.83 (3.52; 4.14) | | 0.273 | |
| Larger PMM area | 52.1 (38.7; 65.6) | 51.2 (43.6; 58.8) | 56.4 (50.1; 62.7) | >0.999 | | 0.251 |
| PMM volume | 647.7 (447.3; 848.2) | 615.7 (499.4; 731.9) | 624.5 (543.6; 705.3) | >0.999 | | >0.999 |
| Humeral area at PMM insertion | 3.88 (3.39; 4.37) | 4.46 (4.18; 4.73) | 4.33 (4.08; 4.57) | 0.134 | | 0.136 |

(41.7%) with lymphomononuclear infiltrate, three (25.0%) with the foci of recent hemorrhage, and two (8.3%) with the presence of granulation tissue.

## Discussion

Most PMM injury studies report cases of tendon rupture, a majority of which are associated with the bench press exercise, men, and users of anabolic steroids. No case of PMM tendon rupture has been described in women during weightlifting events in the literature [2-7]. Doubt existed regarding whether PMM injury can be caused by the previous tendinopathy of the PMM tendon, especially among weightlifters using anabolic steroids (which increases muscle strength and leads to a relative increase in tendon load, consequently predisposing to the PMM tendon to rupture) [15-17]. This overload might occur over months or years, thereby leading to tendon degeneration that might be able to be visualized on MRI, as in the cases of the supraspinatus (shoulder), patellar (knee), or calcaneal (foot) tendons. In this study, the fragments analyzed in histology showed an important presence of signs of overload typical of tendinopathy even if not compared to a control group showing that the overload of weight lifting associated with the use of anabolic steroid, extremely common in these practitioners may be one of the explanations for the rupture of the pectoralis major [5,6,18,19]. The tendinopathy evaluations of the tendon fragments (Table 4) revealed degenerative changes in 16 (66.7%) fragments, with 12 (50.0%) considered as mild (<25%), and four considered as (16.7%) high (>50.0%) tendinopathy. As for the magnetic resonance study of the contralateral tendon in patients who ruptured the tendon of the pectoralis major muscle, the image can be used to better visualize changes such as thickening of the tendon in their most cranial or upper portions, but the better understanding of these changes takes time and careful observation of the image examination. One barrier to visualization is the particular feature of the PMM tendon, 15 to 17 which is a lamina with two walls in which the fibers from the clavicular portion are inserted more caudally (inferior), and the fibers of the sternal portion are inserted more cranially (superior), forming a 90-degree angle between them. This feature hinders visualization using conventional MRI. To visualize PMM tendon injury using this type of exam, we typically used chest sequences. MRI scans of the

**Table 4:** Tendinopathy findings from the pathological analysis of the tendon fragments of weightlifters with PMM tendon rupture.

| **Tendinopathy** | |
|---|---|
| Degenerative changes (myxoid changes of the filamentous substance) | |
| Absent | 8 (33.3%) |
| Mild (<25%) | 12 (50.0%) |
| High (>50%) | 4 (16.7%) |
| **Calcifications** | |
| Absent | 24 (100.0%) |
| **Neovascularization** | |
| Absent | 8 (33.3%) |
| Present | 16 (66.7%) |
| **Fissures** | |
| Absent | 22 (91.7%) |
| Present | 2 (8.3%) |
| **Other findings** | |
| Foci of chronic inflammatory infiltrate in adjacent structures + foci of recent hemorrhage and lymphomononuclear infiltrate | 2 (8.3%) |
| Recent hemorrhagic foci | 2 (8.3%) |
| Inflammatory infiltrate | 2 (8.3%) |
| Lymphomononuclear infiltrate | 2 (8.3%) |
| Lymphomononuclear infiltrate + recent hemorrhages | 2 (8.3%) |
| Lymphomononuclear infiltrate + tissue granulation | 2 (8.3%) |
| Chronic lymphomononuclear infiltrate | 2 (8.3%) |

shoulder do not enable satisfactory visualization of PMM tendon rupture. These images revealed evidence of the onset of tendon degeneration in 92.9% of the 26 weightlifters, whereas no abnormal images were found with regard to the control patients. Of the patients with abnormal MRI scans, 57.1% had an image suggestive of superior tendinopathy, and 10 (35.7%) had an image suggestive of total tendinopathy. No imaging evidence of inferior tendinopathy was found. This finding might be associated with the insertional pattern of the PMM tendon, in which the fibers of the sternocostal portion (i.e., the region most affected by the rupture) are represented by the most superior or cranial portion of the tendon, whereas the clavicular portion, which is much less affected by tendon rupture among bench press practitioners, is represented by the lower or caudal portion of the PMM tendon [27]. Therefore, we believe that the patients in our study have a type of injury that differs from the PMM tendon rupture observed among patients without a history of anabolic steroid use and injuries not associated with weightlifting training and the classification from that described by Tietjen [28]. In one of the studied patients, there was a rupture of the pectoralis major on the left side after exercising the bench press, which, even acute, required the reconstruction of the tendon [29]. On the right side after 2 years there was a rupture of the contralateral pectoral tendon in the movement of the ring and the tendon repair was easily performed. Chang showed that magnetic resonance imaging is very useful to show acute injury to the tendon, but not to chronic injuries. In chronic injuries there is degeneration of the tendon and muscle retraction is observed in MRI. This study analyzed the PMM tendon using MRI and histology among weightlifters engaged in bench press exercise, which represents case series in the international literature. We believe that a similar varying degree of retraction also occurs in injuries associated with the use of anabolic steroids even in other sports such as the ring muscle up exercise in CrossFit® training, where PMM rupture is common, or in jiu-jitsu practitioners using anabolic steroids. These drugs seem to produce a relative overload of the PMM tendon by causing a substantial increase in muscle strength without increasing the tensile strength of the tendon. It is suspected that patients who use anabolic steroids show an important gain in postoperative muscle strength with a rapid improvement of postoperative discomfort. The accelerated improvement results from their rapid strength gain in, among other muscles, the deltoid muscle, the major agonist of shoulder elevation and movement. Thus, psychological factors are likely driving the search for muscle growth primarily during the postoperative period when intense muscle atrophy occurs, which represents improvements in the physical and psychological conditions of the current study's weightlifters associated with the resumption of the use of anabolic steroids, typically between the second and third postoperative months. Thus, after 20 years of research on this type of injury, the use of prohibited substances (anabolic steroids) is ubiquitous because they are strongly associated with injuries when the load and overload of the PMM tendon increase as well as faster returns to improved muscle strength after shoulder injury compared with conventional patients. At the time of surgery, we were occasionally surprised by the degree of retraction of the PMM injury in patients using anabolic steroids, even when operated on within the first week of injury. In at least four cases, PMM tendon reconstruction using autografts was necessary to surgically treat acute injury. Thus, the surgeon should be prepared for cases in which the MRI suggests retractions that are more medial than the axillary line in bench press athletes and anabolic steroid users. In these cases, the patient and family should be alerted to the possible need for PMM reconstruction rather than repair. Why does PMM tendon injury not occur in weightlifting women? Some believe that women do not use as many anabolic steroids or lift weights as heavy as men. For 20 years, we have been following the Brazilian Confederation of Basic Weightlifting, and several women compete with heavy weights relative to their body weights, similarly to men, as represented by lifting attempts with maximum load or bench press repetition. During clinical assessment, several women also reported the use of anabolic steroids similar to men who had ruptured tendons. Only the numerical value of the maximum tensile strength varies. In men, PMM injury loads ranging from 120 kg to 300 kg are reported after bench press attempts. These loads are uncommon among women; however, several female bench press athletes lift more than 120 kg in the higher body weight categories. Thus, a genetic or hormonal factor might confer women with a musculotendinous advantage to their upper limbs under maximum load compared with men. Another interesting factor is that reinjury due to overload is extremely uncommon among patients who undergo surgery. The majority of weightlifters change the intensity of their training and regular practice using maximum loads after surgery as well as become more aware of the effect of this overload on their bodies compared with before surgery. Although they resume competitive weightlifting, patients often report greater concern with and knowledge of the limitations of weightlifting overload. The clinical and imaging classification of the PMM injuries was based on the MRI exam, the histological analysis performed in this study, and a clinical follow-up study of total of 115 patients with PMM rupture that began in 2000, 25 of whom 65 underwent surgery (35 repairs and 30 PMM tendon reconstructions). Between 10% and 15% of our patients of the following cases 115 PMM injuries (acute and cronic) had histories of other musculo tendinous ruptures, including to the proximal biceps, distal biceps, triceps, or quadriceps. In addition to the characterization of this injury, it is important to describe the profile of these patients, some of whom were competitive weightlifters and others were gym-goers seeking increased muscle strength and volume *via* the use of anabolic steroids. Importantly, many of these patients, even after their injuries and corrective surgeries might benefit from psychological follow-up evaluations if they want to stop using anabolic steroids. Some recreational practitioners have body-image disorders associated with anabolic steroid abuse related to childhood issues such as bullying and domestic violence according to psychologists from our sports medicine outpatient clinic. Some of our patients, especially the gym-goers, seek muscle strength gain and the perception of self-protection that results from their new physical condition.

## Conclusion

Total acute rupture of the PMM tendon among weightlifters might be associated with changes in the MRI signal and tendinous degeneration prior to injury, especially following bench press exercise, which is historically associated with the use of anabolic steroids.

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