Master swimmers with shoulder pain and disability have altered functional and structural measures

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Abstract

Context: Supraspinatus tendinopathy and shoulder pain are common in competitive youth swimmers; however, no studies have investigated clinical and structural factors contributing to shoulder pain and disability in master level swimmers. Objective: The objectives of this study were: 1) to determine the prevalence of shoulder pain and disability in master level swimmers, 2) to identify the most provocative special tests for shoulder pain, and 3) to determine if shoulder clinical and tissue specific measures, training variables and volume vary between those with and without shoulder pain, dissatisfaction and disability. Design: Cross-sectional. Setting: Collegiate swimming facilities. Patients or Other Participants: Thirty-nine adult masters level swimmers were evaluated and included in the data analysis. Main Outcome Measures: A survey of demographics, training, and pain and disability ratings using the Penn Shoulder Score and Disability of Arm Shoulder Hand sports module. Swimmers underwent a clinical exam including shoulder passive range of motion (PROM), posterior shoulder endurance test (PSET), supraspinatus tendon structure and posterior capsule thickness. One-way ANOVAs were used to compare demographics, clinical and structural findings between those with significant pain, dissatisfaction and disability (+PDD) and those without (-PDD). Results: Fifteen percent of subjects reported pain at rest, 28% with normal activities (eating, dressing), and 69% with strenuous activities (sports) and 50% reported disability. The +PDD group had less shoulder internal rotation (10°), less ER (8°), and completed less yardage per day and per year. There were significant differences in the supraspinatus tendon structure between the +PDD and –PDD groups. Conclusion: Masters swimmers with pain and disability are able to self-limit yardage and likely why they recorded less yardage. The reduced shoulder motion (IR and ER) without posterior capsule differences may be due to rotator cuff
muscle/tendon restrictions and the supraspinatus tendon structure may indicate degeneration caused by previous overuse resulting in pain.

Key words: swimming, tendinopathy, pain, disability, range of motion, tendon organization

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Key points (2-3, max 280 characters w/ spaces):

- The Jobe empty can test was the most provocative shoulder test for masters swimmers.
- Fifty percent of US masters swimmers reported swimming related disability and 69% reported pain with sports participation.
- Masters swimmers with significant shoulder pain, dissatisfaction and disability had significantly less shoulder internal and external shoulder range of motion and altered supraspinatus tendon structure, and they swam less yardage than their less symptomatic counterparts.

Introduction

It is estimated that there are over 3 million individuals swimming on competitive teams in the United States. The repetitive nature of training has been associated with a high rate of shoulder
pain, with a reported prevalence ranging from 40% to 91%. In addition, the combination of both training volume and load that occurs in the shoulder during swimming can lead to both clinical and tissue specific adaptations, ultimately resulting in the presentation of symptoms. Clinical differences between swimmers with and without shoulder pain and disability include decreased shoulder strength and range of motion (ROM) and reduced shoulder/core endurance, while tissue specific adaptations include reduced pectoralis minor length. However, other tissue specific alterations such as posterior capsule hypertrophy and supraspinatus tendon structure, have not been examined. Posterior capsule hypertrophy and increased stiffness have been demonstrated in the shoulders of baseball players but have not been examined in swimmers. A tight and hypertrophied posterior capsule can decrease glenohumeral internal rotation. In addition, a tight posterior capsule in cadaver shoulders has been shown to shift the humeral head in an anterior/superior direction during internal rotation motion which could increase subacromial impingement demonstrated during the hand entry/early catch and recovery phases of the freestyle stroke. Over time this repetitive compression could potentially lead to rotator cuff degeneration and tearing.

The supraspinatus tendon has been a cause of pain and disability in swimmers, who are often diagnosed with impingement, and/or supraspinatus tendinopathy/tears. Researchers have suggested that the development of tendinopathy in swimmers is volume induced, which stem from chronic repetition during practices, over a season, and throughout years of swimming. Interestingly, there are currently no studies that have demonstrated structural changes to the supraspinatus tendon in masters swimmers. In addition, due to the abundance of shoulder special tests, clinicians often struggle with the best pain provocation test in swimmers.

Therefore, the objectives of this study were: 1) to determine the prevalence of shoulder pain and disability in master level swimmers, 2) to identify the most provocative special tests for
shoulder pain in masters’ swimmers for future use in screening programs, and 3) to determine if
shoulder clinical and tissue specific measures, training variables, and volume vary between those
with and without shoulder pain, dissatisfaction and disability.

Methods

Research Design

A cross-sectional design was utilized to examine the objectives. The independent variable
was group (+pain and disability [+PDD] vs -pain and disability[-PDD]). The dependent variables
were (glenohumeral ROM, strength, endurance, posterior capsule thickness (PCT), and
supraspinatus tendon structure.

Participants

Thirty-nine adult swimmers 20 male (age = 52 ± 11 yrs old, mass = 84.9 ± 10.5 kg, height =
182 ± 5 cm) and 19 female (age = 41 ± 12 yrs old, mass = 67.9 ± 11.1 kg, height = 168 ± 8 cm)]
from 3 teams currently participating or practicing within a United States Masters Swimming
program completed this cohort study. Prior to data collection, all details of the study were verbally
explained to the swimmers, and volunteers read and signed an informed consent form that was IRB
approved. Participants then filled out a general health history questionnaire which was used to
determine inclusion into the study. Swimmers who had shoulder surgery in the past 6 months were
excluded from the study. Data collection occurred at the swimming teams’ local pool prior to
swimming practice and consisted completion of a written survey, clinical exam, and ultrasound
imaging of PCT and supraspinatus tendon structure. All measures were evaluated bilaterally.

Pain, Dissatisfaction and Disability

Swimmers completed a health history questionnaire to provide demographics, shoulder
injury history, quantity of swim training and other sport and training participation information. In
addition, the pain and satisfaction sections of the Penn Shoulder Score were used to determine pain
levels at rest, with normal activities, and with strenuous activities and the DASH sports module
identified swimming related disability. These self-report measures were also used to stratify
participants into a Negative Pain, Dissatisfaction and Disability Group (-PDD) and a Positive Pain
Dissatisfaction and Disability Group (+PDD), which was based on previous research.
Swimmers were included in the +PDD group if they met 2 criterion: 1) A score of less than 35/40
points on the Penn Shoulder Score pain and satisfaction subsection, and 2) a DASH sports module
score of at least 6 points, which indicates the swimmer had at least mild difficulty in 3 of the 4 areas
or moderate or severe difficulty or inability in at least 1 of the 4 areas.

Clinical Exam

A clinical examination was performed to assess participants for current symptoms. Clinical
tests included both Neer’s and Hawkin’s impingement tests, Infra spinatus test (External rotation
resistance test), painful arc, drop arm, Jobe’s empty can test, and the infraspinatus/external
rotation lag sign. In addition, if the empty can test was positive for pain (rated 1-10 on a numeric
pain rating scale) or weakness, it was repeated with use of the scapula reposition test, and
symptom alteration, if present, was documented. If a painful arc was present, a modified scapular
assistance test was performed to determine if there was a reduction in pain. Tests were performed
by an experienced licensed physical therapist.

Glenohumeral Range of Motion

Glenohumeral IR and ER were measured using a digital inclinometer (Precise Digital
Level/Protractor digital, Precise Tool & Gage Co. Inc., Preston, WA, USA) as previously
described. The subject was positioned supine, with the arm at 90° of shoulder abduction with the
scapula stabilized manually by the examiner to isolate glenohumeral motion. The digital
inclinometer was placed on the ulnar side of the forearm to record both IR and ER. For all PROM
measures, a licensed physical therapist stabilized the scapula and passively moved the shoulder into
position while a second examiner recorded the inclinometer value. The physical therapist was blinded to the inclinometer values. Measurements were repeated 3 times and averaged. Standard Error of Measurement for ER and IR established on athletically active adults and was 3.01° and 3.75° respectively.

Glenohumeral horizontal adduction (HADD) was measured according to Meyers et al.\textsuperscript{17} The subject was positioned supine, with the dominant arm at 90° of shoulder flexion. The subject was then instructed to perform bilateral scapular retraction while the examiner passively stabilized the scapula with one hand and moved the shoulder into HADD with the other hand maintaining neutral humeral rotation until a firm end-feel was felt. A second examiner placed the inclinometer on the lateral aspect of the arm and aligned with the humerus. Standard Error of Measurement for HADD ROM was determined by the authors in a reliability study and was found to be 4.0°.

Posterior Shoulder Endurance

To complete the Posterior Shoulder Endurance test (PSET) the participants were positioned prone on a plinth with the testing arm hanging off the edge of the plinth in a relaxed position as described by Moore et al.\textsuperscript{18} In this position participants held a dumbbell equaling 2% of their body weight (rounded to the nearest half-pound). A moveable clamp placed on a vertically oriented metal rod was adjusted to a height that would limit shoulder HADD to 90 degrees (Figure 1). The participant was then asked to move their shoulder into horizontal abduction until contacting the clamp and then held that position for 1 second prior to lowering back to the starting position. This was continued at a cadence of 30 beats per minute (controlled by a metronome). The test was continued until the participant demonstrated any of the three signs of fatigue: 1) unable to hold the arm at the top of the arc for the required duration (1 second), 2) compensation with elevation of the entire upper torso, and/or 3) inability to continue.
**Posterior Capsule Thickness**

PCT was measured using ultrasound as previously described and validated.\(^5\) The subject was positioned upright in a chair with the arm at the side and forearm resting on the thigh. The examiner positioned a 15-MHz linear transducer LOGIQe (GE Healthcare, Wauwatosa, WI) on the posterior shoulder, visualizing the glenoid labrum, humeral head, rotator cuff, and posterior capsule, defined as the tissue immediately lateral to the tip of the labrum between the humeral head and rotator cuff. A standard B-mode image was captured, and the PCT was measured using ImageJ software (National Institutes of Health, Bethesda, MD, USA). Standard Error of Measurement (SEM) for this technique was found to be 0.2mm.\(^5\)

**Supraspinatus Tendon Structure**

Supraspinatus tendon structure was measured using ultrasound as described previously.\(^16\) The subject was positioned upright in a chair in the modified Crass position. The examiner positioned a 15-MHz linear transducer LOGIQe (GE Healthcare, Wauwatosa, WI) on the anterior shoulder to observe a longitudinal view of the supraspinatus tendon. The transducer was then moved anterior and posterior across the tendon until the center of the tendon was determined and an image was saved. The examiner then moved the transducer anterior from the center position until a clear view of the anterior portion of the supraspinatus tendon was determined and an image was saved. Lastly, the examiner went back to the center region of the tendon then moved posterior until a clear view of the posterior portion of the supraspinatus tendon was determined and an image was saved.

**Supraspinatus Tendon image analysis**

The three ultrasound images from each shoulder were analyzed by the same examiner using custom MATLAB software. For each image the examiner identified the supraspinatus footprint and placed a vertical line at the most medial aspect of the footprint and at the lateral aspect of the
footprint. Next a vertical line was created in the middle of the already created lines. Finally, two remaining vertical lines were created bisecting both the medial and lateral two lines. This created a total of 5 vertical lines throughout the supraspinatus footprint. Care was taken to only include the thickness of the supraspinatus tendon and to keep the vertical lines perpendicular to the longitudinal collagen bundles observed as hyperechoic lines (Figure 2).

A one dimensional Fast-Fourier-Transform (FFT) was then applied to the resulting intensity versus length data from each line, and used to determine the spatial frequency at peak spectral power, termed the peak spatial frequency (PSF) and the banding period (distance between peaks). The peak spatial frequencies (PSF) and banding period for all 5 lines were averaged for each image, and then this average was averaged across all three images (anterior, center and posterior) for each tendon. Since collagen bundles are responsible for increased intensity on the US image, the PSF is inversely related and banding period is directly related to the spacing between collagen bundles. By averaging across the proximal/distal, as well as, the anterior/posterior borders of the supraspinatus, the PSF and banding period represents the average spacing between collagen bundles throughout the thickness and volume of the supraspinatus footprint. SEM for this technique was found to be 0.08 pks/mm. Tendon thickness was measured at the center line for each ultrasound image and followed by averaging the anterior, center, and posterior images for a representative average tendon thickness.

**Statistical analysis**

To assess objective 1, descriptive data was computed for all variables and used to determine the prevalence of shoulder pain and disability amongst all swimmers. To assess objective 2, the frequency of the pain provocation tests was calculated. In addition, the effect of the scapula reposition test on symptom alteration in those with a positive Jobe empty can test and the effect of the modified scapular assistance test on symptom alteration in those with a painful arc was assessed.
For objective 3, a chi-squared test was used to compare the +PDD and -PDD groups’ frequency of pool and land based training variables. Next an age and involved arm control matched one-way ANOVA was used to compare the +PDD and -PDD groups’ demographics, ROM, posterior shoulder endurance, PCT, and supraspinatus tendon structure. For the +PDD group, the data from the more painful shoulder was used if the subject had bilateral pain and if the subject had unilateral pain, the painful shoulder data was used for analysis. Lastly Cohen’s D effect size was calculated for all variables.

**Results**

**Descriptive and Training Data**

As described in the methods section, subjects were categorized based on their responses provided in Penn and Dash scales and there were 13 + PDD subjects and 26 -PDD subjects. There were no differences between the groups for age, BMI, years, months/year, days or hours swam/week (Table 1) or any of the land based training variables (Table 2) except for yards per day (p=0.04, Cohen’s D= 0.82) and yards per year (p=0.013, Cohen’s D=0.991).

**Provocation tests and Pain and Disability**

Table 3 demonstrates the frequency of positive special tests for the right and left shoulders for the 39 swimmers tested. Figure 3 reports percentage of swimmers with pain rated ≥1 at rest, with normal activities and with strenuous activities from the Penn Shoulder Score as well as swimming related disability from the DASH sports module and Figure 4 reports the mean pain ratings under the same conditions.

**Posterior Shoulder Endurance and Range of Motion**

PSET performance did not differ between -PDD and +PDD groups (p=0.1, Cohen’s D=0.548).
However, +PDD swimmers had a 10° decrease in passive internal rotation (p=0.009; Cohen’s D=0.919) and 8° decrease in external rotation (p=0.02; Cohen’s D=0.824) resulting in an 18° decrease in the total arc of motion (p=0.001; Cohen’s D=1.325) when compared to the -PDD group. Consistent with this, the +PDD group had 8° less HADD (p=0.04; Cohen’s D=0.586) (Table 4).

Posterior Capsule Thickness

There was no significant difference between the -PDD and +PDD groups for PCT (p=0.3, Figure 5).

Supraspinatus Tendon Structure

There was a significant increase of PSF (p=0.02, Cohen’s D=0.943) and decrease of banding period (p=0.01, Cohen’s D=1.21) in the +PDD group compared to the -PDD group. There was no significant differences between groups for tendon thickness (p=0.9; Cohen’s D=0.042) (Table 5).

Discussion

Provocation Testing

We found that most subjects had signs of subacromial pain syndrome with 53.8% (21 of 39) and 61.5% (24 of 39) of subjects having at least one positive provocation test on the right and the left sides, respectively. The Jobe empty can test was the most frequently provocative test being positive for pain and/or weakness in 91.1% (41 of 45) of symptomatic cases and improved in 63.1% (12 of 19 on the right) and 77.2% (17 of 22 on the left) of these cases with use of the scapula reposition test during subsequent empty can testing. This data suggests that clinicians performing screening examinations of masters swimmers should incorporate the empty can test into their protocol. The Hawkins test was the next most provocative test, followed by the Neer test. Although the majority of swimmer’s symptoms with a positive painful arc were reduced when the test was repeated using the modified scapular assistance test, there was a low frequency of symptom provocation with the
painful arc test, so conclusions should not be made due to the small sample size.

Pain and Disability

Our results demonstrated that 15% of masters swimmers had pain with rest, 28% had pain with normal activity and 69% had pain with strenuous activities. Previous research investigating symptoms across the lifespan of competitive swimmers found that 19% of female masters swimmers had pain with rest, 19% had pain with normal activity, and 64% had pain with strenuous activities as indicated on the Penn Shoulder Score.\textsuperscript{4} Interestingly, our previous report found 19% of female masters swimmers had +PDD using the same criterion compared to 33% of male and female masters swimmers in our current study in which 51% of swimmers were male, which would imply a higher prevalence of symptoms in males. Wymore and Pronek\textsuperscript{20} did not find a difference in shoulder function between male and female collegiate swimmers using the Kerlan-Jobe Orthopedic Clinic scores and the authors are not aware of any other studies comparing shoulder pain or function between male and female adult swimmers so the effect of sex on symptoms requires further study. Another possible explanation for the higher prevalence of pain and disability in the current study is that the mean age of swimmers was 5 years older. Given that shoulder tendinopathy is commonly related to both intrinsic factors (age) and extrinsic factors (external loading), the differences in age and exposure may explain the findings. In our previous report, the mean years swum were 15 and 22 for the +PDD and -PDD groups, respectively, while the mean years swum in the current study were 21 and 25. It is surprising that in both studies, the +PDD group has less years of swimming participation than their less symptomatic counterparts, although the difference was not significant. This leads one to consider the role of intrinsic factors (age) in symptom production.

Demographics including land and pool based training

We did not find significant differences between the +PDD and –PDD group when
comparing age, BMI, years swam per week, hours swam per week or months swimming each year. However, we did find a significant difference between groups regarding the yardage swam per day and yardage swam per year. The +PDD group swam an average of 2,846 yards per day and -PDD group swam an average of 4,224 yards per day. Therefore, the -PDD group swam on average 1,378 yards more than the +PDD group. Consistent with this, the -PDD group swam on average 77,262 more yards per year than the +PDD group. This is the opposite relationship that has been found in youth swimmers as greater swimming exposure in terms of time and yardage has been associated with shoulder pain and supraspinatus tendinopathy. While youth swimmers may be required to complete the training program provided by their coaches to maintain their status on the team, master’s swimmers can generally self-regulate their yardage as programs are generally less rigorous and allow for individual variations in training volume.

**PSET and ROM**

Differences in the PSET were not found between the + PDD and – PDD groups. We used the method as described by Moore et al. which involved repeated lifting and lowering of a dumbbell. This method was time consuming and, we feel was not strenuous enough to adequately assess endurance in this population of athletes and could explain our lack of group differences. We would suggest in a swimming population the static hold method of the PSET be used since it may better replicate the sustained loading of the posterior shoulder muscles during freestyle swimming. Differences were found in ROM measures between the + PDD and -PDD groups. The +PDD group had a mean 8° less ER and 10° less IR for a total of 18° less total ROM. Consistent with this, there was a 7.8° reduction in HADD in the +PDD group compared to the -PDD group. Given the loss of IR and ER ROM and HADD, there would appear to be restrictions in the soft tissue (joint capsule, latissimus dorsi, posterior rotator cuff, deltoid, and pectoral muscles) of the shoulder. However, it is also possible that the motion loss may be due to humeral retroversion
(which was not measured) or muscle guarding due to pain. One study found an association between swimming volume and humeral retroversion in adolescent swimmers (~12 years old), however this adaptation would occur during skeletal immaturity and there is no way of knowing the participants swimming volume at that time. It should also be noted that no swimmer complained of pain during ROM assessment and the investigator did not perceive muscle guarding at the time of testing.

**Posterior Capsule Thickness**

We did not find a significant difference in PCT between groups (+PDD and -PDD). Previous research and our results have demonstrated decreased glenohumeral IR ROM in swimmers. Thickness adaptations in the posterior capsule have been implicated in the clinical presentation of IR ROM deficits in swimmers but up to this point have not been examined. Research in baseball players has identified increased PCT on the dominant arm, which has been related to the IR ROM deficits and increases in posterior capsule stiffness. However, the mechanics and stress caused by throwing and swimming are known to be very different and likely why PCT results differ between these sports.

**Supraspinatus Tendon Structure**

When examining the supraspinatus tendon, we found there were no group differences in tendon thickness. Previous research has demonstrated increased tendon thickness in a group of upper extremity disabled swimmers compared to those with lower extremity disability and a control group of healthy swimmers. Another study of Division II collegiate swimmers also found tendon thickness to increase with years of experience. These results suggest that the increased tendon thickness may predispose swimmers to subacromial impingement. Our lack of tendon thickness results may be due to our +PDD group of masters swimmers having the ability to limit their yards due to shoulder symptoms. As stated previously, we found that the +PDD group swam significant
less yards per day and year. Previous studies recruited highly competitive collegiate swimmers that did not have the ability to limit their yardage per day or per year.

When examining supraspinatus tendon structure, we found that swimmers in the +PDD group had increased PSF and a decreased banding period compared to the -PDD group. To our knowledge our study is the first to objectively measure supraspinatus tendon structure in swimmers using a custom algorithm. This algorithm used the collagen fascicles imaged with diagnostic ultrasound in the long axis view to objectively quantify the tendon structural. Previous research has used semi-quantitative measures to identify tendinopathy in swimmers, which involve a scoring system based on visually appearance of the tendon. Sein et al.\textsuperscript{3} found that tendinopathy was related to swimming volume and Rodeo et al.\textsuperscript{24} found that tendinopathy was also related to symptoms in swimmers.

Previous research has assessed tendon structure in other tendons and populations using a similar algorithm (2-D FFT) compared to ours (1-D FFT). Kulig et al.\textsuperscript{25} examined the PSF in both the patellar and Achilles tendons and compared painful and non-painful dancers. They did not find any differences between groups in either tendon. Kulig et al.\textsuperscript{26} examined the patellar tendon in volleyball players and compared those with and without symptoms. They found that the symptomatic group had a lower PSF, which they suggested was indicative of tendon disorganization.

In our population of masters swimmers we found an increase in the PSF in the +PDD group. There are likely several reasons for these differences in results. First, we used a 1-D FFT to measure PSF. Therefore, our analysis is specific to the longitudinal axis of the tendon. Since tendons are loaded longitudinally during function our analysis quantified the collagen in the direction that is most important to function.\textsuperscript{27} Second, we assessed the supraspinatus tendon which, because of the design of the glenohumeral joint, experiences significantly different loading environments compared to the patellar tendon and therefore can produce different adaptations.\textsuperscript{28,29} Lastly, our criteria to establish pain and disability involved the use of 2 patient reported outcome measures and its reliability has
been previous established. This may have been more sensitive than the criteria used by Kulig et al.\textsuperscript{26} When comparing our findings to basic science tendon research an increase in PSF potentially does suggest tendon disorganization. Derwin and Soslowsky\textsuperscript{27} examined mouse tail tendon fascicles characteristics in immature, adult, and adult MovI3 transgenic mice. They found a relationship between mean collagen fibril diameter and fascicle stiffness and maximal load. Specifically, they found that mechanically weaker fascicles were comprised of large amounts of fibrils that were smaller in diameter, while mechanically stronger fascicles were comprised of smaller amounts of fibrils that were larger in diameter. Although our measurements are at a tendon and fascicle scale compared to a fibril and fascicle scale in the mouse study, we feel we are observing a similar mechanism of adaptation. The +PDD group had increased PSF and decreased banding period, which could be due to large amounts of fascicles that were smaller in diameter. According to Derwin and Soslowsky\textsuperscript{27} this would be characteristic of a mechanically weaker tendon that can fail at lower maximum loads, therefore placing these swimmers at a greater risk for tendon tears.

**Limitations**

We used the repetitive lift and lower version of the PSET instead of the static hold, which we feel may better replicate the sustained loading of the posterior shoulder muscles during freestyle swimming. Another limitation is that we did not know the swimmers previous swimming volume which could have influenced the adaptations. In addition, we are unsure if the +PDD group limited their yardage due to pain or if it was due to external factors (skill, performance, conditioning, etc).

**Conclusion**

Like youth swimmers, masters swimmers incur a high prevalence of shoulder pain and disability. However, unlike youths, master swimmers with pain and disability swim less yardage, perhaps due to self-imposed limitations or they may lack adequate physical conditioning for the...
repetitive training. Swimmers in the +PPD group exhibited reduced shoulder motion in HADD, IR and ER without PCT differences. This reduction in mobility may be due to rotator cuff muscle/tendon restrictions since we did not observe group difference in PCT and the supraspinatus tendon structure may indicate degeneration caused by cumulative overuse resulting in pain.
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Table 1. Data represents demographic, swimming frequency, and yardage between the +PDD and the -PDD groups with associated p-values and Cohen’s D effect sizes.

| Demographic Variables          | -PDD         | +PDD         | p-value | Effect Size |
|--------------------------------|--------------|--------------|---------|-------------|
| Sample size                    | 26           | 13           |         |             |
| Age                            | 45.8 ± 12.9  | 49.3 ± 11.3  | 0.4     | 0.289       |
| BMI                            | 25 ± 3.1     | 24.6 ± 3.4   | 0.8     | 0.123       |
| Years on team                  | 25 ± 14      | 21.2 ± 14.5  | 0.4     | 0.267       |
| Months swimming each year      | 11.4 ± 1.3   | 11 ± 1.3     | 0.4     | 0.308       |
| Days swam per week             | 3.3 ± 1.2    | 2.8 ± 0.9    | 0.2     | 0.471       |
| Hours swam per week            | 4.5 ± 1.7    | 3.8 ± 1.8    | 0.2     | 0.4         |
| Yards per day                  | 4224 ± 2248  | 2846 ± 773   | 0.04*   | 0.82        |
| Yards per year                 | 167585 ± 101064 | 90323 ± 44217 | 0.013*  | 0.991       |

* indicates significance of ≤ 0.05 between groups
Table 2. Data represents the frequency (measured as a percentage) of dry land training of the swimmers between the +PDD and the -PDD groups with associated p-values.

| Training Variables     | -PDD | +PDD | p-value |
|------------------------|------|------|---------|
| Dry land               | 12%  | 8%   | 0.7     |
| Participant in other sports | 12%  | 8%   | 0.7     |
| Weight training        | 62%  | 31%  | 0.07    |
| Triathlon              | 19%  | 0%   | 0.09    |
| Running                | 42%  | 23%  | 0.2     |
Table 3. Data represents the frequency (measured as a percentage) of positive special tests for the right and left shoulders.

| Provocative Tests | % positive right shoulder | % positive left shoulder |
|-------------------|---------------------------|-------------------------|
| Jobe Empty Can    | 48.7%                     | 56.4%                   |
| Scapula Reposition Test (% of those with + Jobe empty can with a decrease in pain with scapula reposition test) | 63.1% (12/19) | 77.2 % (17/22) |
| Hawkins           | 12.8%                     | 18.4 %                  |
| Neer              | 15.3%                     | 13.1 %                  |
| Infraspinatus/ External Rotation Resistance test | 7.6% | 5.1% |
| External Rotation Lag sign | 2.5% | 0% |
| Painful Arc       | 2.5%                      | 12.8%                   |
| Scapular Assistance Test (% of those with + painful arc with a decrease in pain or significant increase in elevation ROM with modified scapular assistance test) | 100% (1/1) | 80% (4/5) |
| Drop Arm          | 0%                        | 0%                      |
| Presence of at least 1 positive provocation test | 53.8% | 61.5% |
Table 4. Data represents glenohumeral range of motion and posterior shoulder endurance between the +PDD and the -PDD groups with associated p-values and Cohen’s D effect sizes. * indicates significance of ≤ 0.05 between groups

| Range of Motion and Endurance                | -PDD       | +PDD       | p-value | Effect size |
|---------------------------------------------|------------|------------|---------|-------------|
| External Rotation (°)                       | 98 ± 10.4  | 90.1 ± 8.7 | 0.02*   | 0.824       |
| Internal Rotation (°)                       | 36.5 ± 10.6| 26 ± 12.2  | 0.009*  | 0.919       |
| Total Motion (°)                            | 134.5 ± 16.2| 116.1 ± 11.1| 0.001*  | 1.325       |
| Horizontal Adduction (°)                    | 81.8 ± 10.7| 74 ± 15.5  | 0.04*   | 0.586       |
| Posterior Shoulder Endurance Test (reps)    | 40.7 ± 23.8| 29.8 ± 15 | 0.1      | 0.548       |
Table 5. Data represents supraspinatus structure between the +PDD and the -PDD groups with associated p-values and Cohen’s D effect sizes. * indicates significance of $\leq 0.05$ between groups.

| Supraspinatus tendon | -PDD     | +PDD     | p-value | Effect size |
|----------------------|----------|----------|---------|-------------|
| Spatial frequency (peaks/mm) | 1.65 ± 0.12 | 1.75 ± 0.09 | 0.02*   | 0.943       |
| Banding Period (mm)   | 0.68 ± 0.05 | 0.63 ± 0.03 | 0.01*   | 1.21        |
| Thickness (mm)        | 6.02 ± 1.3  | 5.97 ± 1.07 | 0.9     | 0.042       |
Figure 1. Image representing patient position during the posterior shoulder endurance test.
Figure 2. Representative ultrasound image of the supraspinatus tendon (SS), humeral head (HH), and deltoid (D). Vertical lines represent measurement locations along the supraspinatus tendon footprint.
Figure 3. Data represents the frequency (measured as a percentage) of swimmers with a pain rating of $\geq 1$ at rest, with normal activities and with strenuous activities as well as swimming related disability. Data was collected from the Penn Shoulder Score and the DASH sports module.
Figure 4. Data represents the mean ± standard deviation of self-reported pain rating of swimmers at rest, with normal activities and with strenuous activities. Data was collected from the Penn Shoulder Score.
Figure 5. Data represents the mean ± standard deviation of posterior capsule thickness between the +PDD and the -PDD groups.