Shoulder strength in amateur swimmers

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ABSTRACT

The present study quantitatively investigated the difference in internal and external shoulder rotation strength and endurance in swimmers with painful shoulders compared with those without pain. In previous literature elite swimming athletes have been investigated, however little research has been conducted on the effects of shoulder pain in recreational swimmers.

12 amateur swimmers (5 male and 7 female participants) were recruited from metropolitan swimming squads, 7 with shoulder pain and 5 without shoulder pain. Internal and external shoulder rotation were measured using a Biodex isokinetic dynamometer. Peak torque, internal to external peak torque ratios, peak torque to body weight ratios and work to body weight ratios were recorded at speeds of 60º/sec and at 240º/sec.

There was a significant difference between swimmers with pain and swimmers with no pain for internal rotation peak torque to body weight ratio at 240º/sec. Effect size data demonstrated large to very large differences between those with pain and those with no pain for peak torque to body weight, work to body weight ratios and internal to external ratios for both speeds.

The results suggest that swimmers with pain generally produce lower measures of shoulder strength and endurance, particularly when comparing internal rotation endurance strength. This may indicate that internal rotators should not be neglected when rehabilitating injured shoulders.

Shoulder Strength in symptomatic and pain-free swimmers

INTRODUCTION

Shoulder pain in elite level swimming athlete can cause significant interference with effective training, resulting in decreased performance[1]. If the injury is severe enough it may affect the athlete's national or international ranking as well as hinder chances of receiving financial support or sponsorship. Injuries may progressively worsen or cause functional difficulties, affecting activities of daily living[1,2,3,4]. However, shoulder pain is a broad term used to encompass various types of chronic and acute injuries.

Swimming injuries have been investigated in the past few years to establish common structural or functional abnormalities and biomechanical similarities within symptomatic participants. McMaster stated that elite level swimmers can produce up to one million strokes per year[5,6]. Given this information, it is more likely that elite swimmers in general will experience some level of shoulder discomfort throughout their career than recreational swimmers. However, as recreational swimming is increasing, so is the incidence of swimmer's shoulder in amateur athletes[3,6,7,8].

In swimming (particularly freestyle and backstroke), as with any over head arm action, the scapular and rotator cuff muscles work in synergy to provide relative stability without constriction of movement[6,8]. This is achieved by having the humeral head positioned as centrally as possible into the glenoid fossa. This balance is achieved through the complex combined action of internal and external rotators of the shoulder, adductors and abductors of the shoulder, and scapular protractors, retractors, detractors and elevators.

The rotator cuff muscles create translatory, compression and rotatory forces on the glenohumeral joint, ensuring maximum congruency through the wide range of arm movement necessary for swimming[2,7]. The scapular provides a base of support for the rotator cuff complex and is required to be actively positioned as the humerus moves through its range of motion. The glenoid labrum enables the relatively shallow fossa more depth and gives more accuracy to the ball-and socket description of the glenohumeral joint[6,7].

The term ‘swimmer’s shoulder’ has had vague definitions in the past and various pathologies have been associated with it. Previous literature has identified that muscular imbalance of rotator cuff and scapula stabilising muscles is implicated in symptomatic shoulders[4,6,9-13]. Clinical examination is a common tool used to determine which structures in the symptomatic shoulder are behaving abnormally. These include assessments for multi-directional shoulder laxity, anterior capsule instability (or extent of subluxation of the humeral head) and range of motion limitations – particularly caused by pain or apprehension[3,9,10,14-17]

The relationship between the contribution of muscle imbalance to instability of the glenohumeral joint has been investigated in past research. An imbalance may create a modified resolution of forces on the joint, increasing the risk of secondary impingement or micro-trauma to areas of the glenoid labrum in susceptible individuals[6,15,16,18]. Isokinetic testing of these muscles is a highly relevant examination method of determining muscle imbalances in the shoulder. It has been included in several studies to investigate how differences in shoulder strength may relate to pain[3,6,10,13,14,19,20].

The use of isokinetic dynamometry enables torque of the shoulder to be measured and is thought to be relevant to the phenomenon of pulling the arm through the water in swimming[2,13,20,21]. Results obtained have been somewhat varied. Bak and Magnusson evaluated the difference in functional strength ratios (eccentric external rotation : concentric internal rotation) and discovered that swimmers with pain demonstrated greater ratios than those without. However, when conducting conventional concentric internal versus concentric external rotational strength, they found no significant difference[10].

Similarly, Beach et al examined conventional concentric internal versus concentric external strength ratios between dominant and non-dominant shoulders of symptomatic swimmers and found no significant correlation between strength and pain[20]. They did, however, additionally examine endurance ratios using a high repetition/high speed modification of testing, reporting a high negative correlation between isokinetic endurance ratios and shoulder pain in the same population[20]. This study will implement analysis of several parameters as outlined in the methods section, not just peak torque ratios for internal and external rotation as used in past research. Just as Beach et did in their research, this study will also implement endurance testing in an attempt to discover differences in these parameters.

The present study does not distinguish differences in shoulder flexibility of swimmers with pain or without, however it is an aspect of competitive swimming that may influence (or co-exist with) differences in isokinetic shoulder strength. Rupp et al define laxity as an increased translation of the humeral head on the glenoid surface, whereas instability is the symptomatic expression of excessive glenohumeral translation[14]. Similarly, McMaster et al state that physiological laxity may only exist as increased range of motion with no other recognisable signs or symptoms, whereas pathological shoulder joint laxity is implicated in subluxation and dislocation, labrum tears and rotator cuff impingement. They also mention that physiological laxity may have genetic factors which predispose certain people to be successful in a given sport. This flexibility influences mechanical efficiency in swimming[1].

In swimming, muscular endurance is paramount as there is minimal time for the muscles to recover from one stroke to the next when compared to other overhead sports such as baseball when there is ample time between pitches. Freestyle and backstroke in particular are unique in the fact that the number of arm revolutions are far greater than in any other overhead sport[2,14]. The swimming athlete must pull the body over the arm rather than have propulsion of the upper extremity initiated by ground reaction force, for example in a throwing action[4,8,18].

In previous literature this field of study has involved mainly senior elite level swimmers from several countries, with peak torque ratios being the main measurement used for analysis. There has been little interest into researching amateur swimmers training for open water competition affected by shoulder injuries, particularly the influence of pain on endurance strength, rather than just maximal shoulder strength measured by peak torque. This study aims to determine if a relationship between symptomatic shoulders in swimmers and altered shoulder strength ratios (particularly internal versus external rotational strength) exists when compared to swimmers with pain-free shoulders.

METHODS

Participants

The volunteers consisted of 12 swimmers (5 female and 7 male) recruited from Melbourne metropolitan swim squads (Table 1). The inclusion criteria required that the participants were between 18 and 35 and that they were currently swim training with a squad. 10 of the swimmers were right handed and two were left handed.

	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	12	18.00	35.00	27.41	6.24
Height (cm)	12	165.00	188.00	175.5	8.39
Weight (kg)	12	50.00	93.00	68.91	12.51

Table 1. Mean, standard deviation and range of values for participants.

Each participant signed a consent form detailing the test procedure and possible risks associated. The participants were asked to fill in a brief questionnaire regarding hours of training and distance swum in a week as well as presence of pain. A visual analogue scale was used to rate the level of pain felt while training and competing in sprints and distance, including training with paddles. Those citing pain were considered the test group (n=7) and those not citing pain were considered the control group (n=5). All of the participants apart from one were right-hand dominant.

Exclusion included those experiencing pain which currently disrupted training and/or competing all of the time due to the demands of the testing apparatus. All aspects of the study including written consent from particiants, the testing apparatus and procedures were given approval by the Victoria University of Technology Human Research Ethics Committee.

Testing

Prior to testing the participants underwent a warm-up which consisted of 30 seconds of forward shoulder rotation and 30 seconds of backward shoulder rotation followed by anterior and posterior shoulder girdle stretching[4]. They were also able to become familiarised with the dynamometer by performing three repetitions of the testing speed with each arm prior to testing.

The testing was carried out on a Biodex Multi-Joint Dynamometer (Biodex Inc, Shirley, NY), with accompanying Bidex software. The participant was seated and stabilised with straps extending from either shoulder across the chest to the opposite hip to prevent trunk mobilisation. The testing arm was fixed in a position where it was abducted to 80° and elbow flexed to 90°, which was found to be the most comfortable position and least likely to cause undue strain for the shoulder (See Figure 1)[10]

Figure 1. Isokinetic dynamometer testing postion

The first requirement was to complete three repetitions of maximal effort internal and external shoulder rotation at a speed of 60° per second (as set automatically by the dynamometer), previously described by Bak and Magnusson. This was followed by a minute rest, then 30 repetitions of maximal effort internal and external shoulder rotation at 240° per second[20]. This was repeated for the opposite shoulder. In swimmers with pain, the painful shoulder was tested first, followed by the asymptomatic shoulder. Immediately after testing the participant was encouraged to stretch each shoulder and perform slow repetitive arm circumduction to decrease the likelihood of delayed onset muscle soreness. The presence of pain during testing was noted and accounted for if participants were unable to complete the test.

Statistical Analysis

Data analysis was performed using SPSS for windows (Version 12.0). Mean and standard deviations were calculated for age height and weight as well as external rotation:internal rotation peak torque ratios, internal and external peak torques, peak torque per body weight and work to body weight ratios for both speeds (60°/sec and 240°/sec) and both arms. Peak torque is the greatest force produced by the participant against a given resistance over a given number of repetitions and is measured in Newton metres. It is also standardised as a percentage of body weight and averaged out as percentage of work produced throughout the repetitions as per body weight.

The means from these measures in the affected shoulder of the swimmers with pain were compared to the opposite arm as well as the same side in asymptomatic swimmers using a multiple analysis of variance measure. Effect size (Eta squared) was also calculated to account for proportion of variance in a relatively small sample[22].

RESULTS

In the sample of twelve swimmers studied, sixty seven percent stretched either before or after swimming or both. Fifty percent of the swimmers trained between 10-15 hours a week and the remaining trained less than 10 hours a week. Sixty seven percent of the swimmers trained less than 15 kilometres weekly while 25 percent trained between 15-25 kilometres a week and a remaining eight percent trained between 25-35 kilometres weekly.

Sixty seven percent of the swimmers use paddles in their training with 33 percent using them for less than one kilometre a week, 25 percent for 1-2 kilometres weekly and 8 percent for 2-3 kilometres weekly. Of the sample, fifty eight percent were currently experiencing pain in one or both shoulders. Fifty seven percent of these swimmers experienced pain occasionally during training and the remaining experienced pain rarely during training.

For seventy one percent of symptomatic swimmers the right shoulder was the most problematic. One of those with pain in the left shoulder was left handed, while all of those with pain in the right shoulder were right handed. Of those with no pain one was a left handed while the remainder were right handed.

All of the participants citing painful shoulders indicated an increase in the usual level of pain during training when using paddles, with three rating the pain as greater than 5/10 on the VAS (see Table 2). All of the participants also indicated an increased level of pain while training distance, with four participants rating the pain greater than 5/10 (see Table 2).

The mean and standard deviations for external to internal rotation ratios, peak torque, peak torque to body weight percentages and work performed per body weight for both internal and external rotations at 60°/sec and 240º/sec appear in Table 3 and 4 respectively. One participant could not complete 30 repetitions of the endurance test due to pain.

	Pain while training sprints	Pain while training distance	Pain while training with paddles	Pain while competing sprints	Pain while competing distance
Mean VAS score	1 (± 0.5)	7 (± 2.5)	5 (± 3)	1 (± 0.5)	6 (± 3)

Table 2. Visual Analogue Scale for pain

	ER Peak Torque (nm)	IR Peak Torque (nm)	ER:IR (%)	Peak Torque to Body Weight ER (%)	Peak Torque to Body Weight IR (%)	Work to Body Weight ER (%)	Work to Body Weight IR (%)
Left (no pain) N=10	20.48 (± 10.87)	38.63 (±14.91)	52.30 (±15.86)	28.92 (±11.08)	55.38 (±13.33)	36.61 (±15.25)	80.72 (±21.86)
Left (pain) N=2	24.35 (± 9.12	38.75 (±19.16)	64.95 (±8.55)	36.35 (±5.30)	57.05 (±15.78)	45.65 (±0.78)	74.55 (±8.13)
Right (no pain) N=7	26.02 (±9.57)	38.75 (±14.73)	66.60 (±12.48)	39.12 (±10.62)	56.46 (±14.30)	50.83 (±11.88)	79.71 (±21.79)
Right (pain) N=5	20.52 (±13.45)	32.40 (±11.93)	61.86 (±25.41)	27.32 (±12.25)	45.28 (±9.37)	30.74 (±18.82)	57.52 (±11.81)
Total (no pain) N=17	22.76 (±10.43)	38.68 (±14.37)	58.19 (±15.89)	33.12 (±11.76)	55.82 (±13.30)	42.46 (±15.35)	80.04 (±21.14)
Total (pain) N=7	21.61 (±11.74)	34.21 (±12.87)	62.74 (±21.09)	29.90 (±11.14)	48.64 (±11.53)	35.00 (±17.00)	62.38 (±13.15)

Table 3. Mean and standard deviation for external and internal rotation peak torques, external to internal rotation ratios, peak torque to body weight ratios and work to body weight ratios in left and right shoulders at **60°/sec**.
ER = External rotation, IR = Internal rotation

	ER Peak Torque (nm)	IR Peak Torque (nm)	ER:IR Ratio (%)	Peak Torque to Body Weight ER (%)	Peak Torque to Body Weight IR (%)	Work to Body Weight ER (%)	Work to Body Weight IR (%)
Left (no pain) N=10	18.27 (±9.056)	23.94 (±12.86)	81.5 (±20.76)	25.92 (±8.20)	33.71 (±13.45)	33.46 (±10.05)	39.72 (±19.83)
Left (pain) N=2	23.65 (±3.18)	34.20 (±13.01)	72.65 (±18.31)	36.4 (±3.68)	51.05 (±7.85)	45.80 (±5.09)	61.40 (±3.96)
Right (no pain) N=7	21.64 (±7.07)	30.73 (±12.72)	75.2 (±17.18)	32.64 (±6.85)	45.24 (±12.02)	38.63 (±11.02)	55.57 (±19.78)
Right (pain) N=5	18.52 (±10.21)	20.22 (±12.04)	92.82 (±15.94)	25.62 (±10.67)	27.58 (±11.03)	26.22 (±19.62)	31.74 (±14.89)
Total (no pain) N=17	19.66 (±8.24)	26.73 (±12.87)	78.9 (±19.06)	28.69 (±8.19)	38.46 (±13.79)	35.59 (±10.45)	46.25 (±20.80)
Total (pain) N=7	19.98 (±8.80)	24.21 (±13.09)	87.06 (±17.95)	28.70 (±10.29)	34.29 (±14.92)	31.81 (±18.77)	40.21 (±18.97)

Table 4. Mean and standard deviation for external and internal rotation peak torques, external to internal rotation ratios, peak torque to body weight ratios and work to body weight ratios in left and right shoulders at **240°/sec**.
ER = External rotation, IR = Internal rotation

Parameter measured	F value	Significance (P=0.05)	Eta Squared
ER peak torque at 60°/sec	.425	.737	.060
IR peak torque at 60°/sec	.246	.863	.036
ER peak torque at 240°/sec	.386	.764	.055
IR peak torque at 240°/sec	1.040	.397	.135
ER:IR ratios at 60°/sec	1.092	.376	.141
ER:IR ratios at 240°/sec	1.023	.404	.133
Peak torque to body weight ratio for ER at 60°/sec	1.655	.209	.199†
Peak torque to body weight ratio for IR at 60°/sec	.892	.463	.118
Peak torque to body weight ratio for ER at 240°/sec	1.732	.193	.206†
Peak torque to body weight ratio for IR at 240°/sec	3.112	.049*	.318†
Work to body weight ratio for ER at 60°/sec	2.183	.122	.247†
Work to body weight ratio for IR at 60°/sec	1.682	.203	.201†
Work to body weight ratio for ER at 240°	1.515	.241	.185†
Work to body weight ratio for IR at 240°/sec	2.427	.096	.267†

Table 5. F values, significance levels (where P<0.05) and effect size (Eta Squared where 0.01 is small, 0.06 is moderate and 0.14 is large) for comparison of shoulder pain and no shoulder pain for both left and right shoulders.
ER = External Rotation, IR = Internal Rotation
* Significant result
† Large effect size

Table 5 demonstrates a significant finding at 240°/sec for internal rotation between swimmers with shoulder pain and those without pain ($p=0.049$) associated with a very large effect size (eta squared = 0.318). Large effect sizes for external to internal rotation ratios were found between swimmers with pain and swimmers with no pain at 60°/sec (eta squared = 0.141) and also at 240°/sec (eta squared = 0.133).

Table 5 indicates a moderate to large effect size seen between shoulder pain and no pain for internal rotation peak torque at 240º/sec (eta squared = 0.135). Medium to large effect sizes were found for peak torque to body weight ratios for internal rotation at 60°/sec (eta squared = 0.118) as well as for external rotation at 60°/sec (eta squared = 0.199). Table 5 demonstrates large to very large effect sizes for peak torque to body weight and work to body weight for both speeds (internal and external rotation).

DISCUSSION

The overall results of the study did concur with other research that maximal shoulder strength in swimmers was not significantly influenced by the presence of shoulder pain[9,10,20]. However the original aim was also to investigate whether strength endurance was affected by shoulder pain. The present study indicated predominantly large effects sizes, but variability in participants combined with a small sample prevented most of the relationships investigated from being significant.

While the results obtained for peak external and internal torques, external to internal peak torque ratios and peak torque to body weight were not statistically significant moderate to very large effects sizes were observed when comparing symptomatic shoulders (n=5) to asymptomatic shoulders (n=7). Only two participants presented with symptomatic left shoulders. One of these participants was also left handed, which may suggest a greater strength in that shoulder regardless of pain (n=2). All of the participants with right sided shoulder pain were right handed, thus minimising confounding factors when analysing results regarding right shoulder strength.

This study looked only at shoulder strength in swimmers, whereas other studies have examined the difference in peak torque ratios between non-swimmers and swimmers, with expected differences in internal rotation and adduction strength confirmed[8,13,21,23]. McMaster et al suggest that shifts in the torque ratios of swimmers compared to non-swimmers is indicative of a sport-specific repetitive activity that emphasises adduction and internal rotation[23]. They state that no current evidence exists to suggest that such a torque ratio shift could contribute to shoulder complaints in the swimming athlete, whereas in a lax shoulder this shift may potentiate joint translation[23]. While this combination of altered strength and shoulder laxity can be considerably debilitating for the elite athlete, it is relevant to amateur swimmers as recreational swimming gains popularity and as swimming is often prescribed for health reasons.

McMaster suggests that the need for external rotation rehabilitation only is questionable, regardless of the imbalance between external rotation strength when compared to internal rotation strength. This theory is supported by research indicating that internal rotational strength is greater than external strength by approximately a 3:2 ratio in the normal population[22,23]. The expected ratio of 3:2 (67%) fell between the 60% obtained from 60°/sec (see Table 2) and 81% from 240°/sec (see Table 3).

Table 5 shows a significant difference in the ratio of peak torque to body weight for internal rotation at 240º/sec, suggesting that as the testing progressed internal rotation strength began to falter in those with shoulder pain. This may also help to explain the shift in external to internal rotation peak torque ratio in symptomatic shoulders during the endurance test (87.06% as seen in Table 4). For the maximal strength test the ratio was more toward the norm of 67% for asymptomatic right shoulders (66.6% as seen in Table 3).

The high repetitions required for the endurance test may have influenced the effort produced by participants. This meant inconsistency in peak torque values as some participants put a large amount of effort into the early repetitions only to fatigue throughout the test whereas others produced consistent sub-maximal efforts in order to complete the test. This was particularly so when comparing results of one or two stronger participants to the weaker participants. Thus peak torque appeared to be of questionable value in determining relationship to pain in the endurance test.

Abduction and adduction ratios are considered to be a relevant measure of shoulder strength for swimmers however they were not conducted in this study. They have been addressed in previous research, with little suggestion that significant differences may be found when comparing symptomatic shoulders to asymptomatic shoulders[2,9,10,20,23]. However, Beach et al found moderately high negative correlation for both external rotation and abduction and pain at 240°/sec[20].

Dominance was also noted but not controlled for in this study with each of the swimmers (except one) with pain indicating it was the dominant shoulder affected. Warner et al demonstrated significant differences in peak torque ratios and total work ratios for symptomatic dominant shoulders but not for symptomatic non-dominant shoulders[13].

In the present study levels of pain were measured on a visual analogue scale for those suffering from shoulder pain in training and competition, however correlations between pain and its effect on shoulder strength were not conducted due to inconsistencies in recording pain and lack of numerical representation. In previous research it was found that a high negative correlation between shoulder endurance and level of pain existed in symptomatic swimmers[20].

To examine the type of shoulder injuries sustained by the participants and their relationship to pain was beyond the scope of this study. Previous research has attempted to do so with accepted orthopaedic tests for impingement, excess capsular laxity and loss of capsular flexibility performed by trained professionals[2,7,9,13,14,19,20]. Stability of the shoulder depends not only on the periarticular muscles, but bony anatomy and the capsuloligamentous complex (including glenohumeral ligaments).

Compensation by either of these stabilising structures can be achieved if there is reduced stabilisation in another area, for example a lax capsule may be compensated for by an increased rotator cuff pull. Alternatively weak rotator cuff muscles can be compensated for by scapular positioning. However, the ability to compensate is finite and the situation may progress to subluxation and consequently pain – a situation likely for the participants of this study given that distance (fatigue-inducing) training was the most aggravating factor for their pain[3,15,17,18]. Secondary problems such as labral wear, and impingement of subacromial structures (bursae, biceps and supraspinatus tendons) often ensue.

This is particularly significant to swimmers undertaking gruelling training programs due to repeated shoulder circumduction, compromising the structures again and again[2,3]. Muscle fatigue and training implements that increase stress on the shoulder girdle (for example, hand paddles) have been also been identified as exacerbating or assisting to develop shoulder problems[6,8]. The present study also identified paddle use as being an aggravation for symptomatic participants (Table 2).

Evidence for positive tests and relationship to pain remains inconclusive as it is not simply physiological laxity of ligaments or rotator cuff muscles found on clinical examination that causes instability and predisposes one to shoulder problems. The muscles may still be effective in limiting humeral head translation. However, the symptomatic expression of excessive humeral head translation is defined as instability[1,4,15,20]. Physiological laxity may exist only as increased range of motion with no other recognisable signs or symptoms, whereas pathological shoulder joint laxity is implicated in subluxation, dislocation, labrum tears and impingement syndrome.

This symptomatic laxity is often seen in the anterior capsule, with inflexibility generally more pronounced in the posterior capsule. Physiological laxity may actually predispose certain individuals to be successful in a given sport, particularly influencing mechanical efficiency in swimming[1]. While such considerations were important in analysing patterns of shoulder strength and endurance, they were difficult to directly link to pain in the present study and would have introduced confounding and conflicting variables.

The use of the dynamometer was useful to simulate as closely as possible the forces acting on the shoulder during swimming. The higher resistance (60º/sec) was indicative of effort needed for sprinting and lower resistance (240º/sec) indicative of strength endurance. Changes in muscle activity and strength (of shoulder rotators and stabilizers) have been shown to play an important role in the development of shoulder injuries not only in swimmers, but in other over head athletes (for example pitchers, fast bowlers, tennis players)[9].

However, the mechanisms are quite different; pitchers are subjected to considerably higher forces and velocities, with the posterior rotator cuff muscles needing to decelerate internal rotation of the arm at angular velocities of 6000°/sec. Yet, these athletes have some recovery time between pitches. Swimming is a more endurance-based sport with minimal time available for the muscles to recover from one stroke to the next, thus much easier to evaluate with dynamometry[13,14,20,21].

For a study that was limited by a small sample size (n=12) where other studies have examined up to 28-36 swimmers, large to very large effect sizes were demonstrated, even though the relationships between shoulder pain and strength were not significantly defined[9,10,13,20]. The age range (18-35) and strength of the participants varied immensely however the participants had no prior familiarity with the testing apparatus which meant that there was no learning effect. The peak torque results and work produced were standardised to accommodate for different body weights.

The type of injury and extent of pain was not considered in the analysis of results, however this may be considered for future research into swimmers' injuries. Dominance appeared to overshadow pain in symptomatic shoulders, however when comparing symptomatic dominant shoulders to asymptomatic dominant shoulders, effect sizes were very large. There is scope for further research in the area of painful shoulders, perhaps on a much larger scale (N<50) and with the variables not accounted for in this study considered.

CONCLUSION

The results of this study suggest that shoulder pain may have an influence on shoulder strength and endurance in swimmers when analysing work produced by the muscles of the shoulder rather than maximal strength. The small sample of swimmers may not have been indicative of trends seen with the larger population of swimmers affected by shoulder pain. Results did however show large effect sizes when comparing those with pain and no pain, with those with pain generally demonstrating lower measures of strength and endurance, particularly on internal rotation at 240°/sec. These results may indicate that internal rotators should not be neglected when rehabilitating painful shoulders.

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