Isokinetic performance and shoulder mobility in elite volleyball athletes from the United Kingdom

Hsing-Kuo Wang, Alison Macfarlane, Tom Cochrane

Abstract

***Objectives*—To evaluate the differences in strength and mobility of shoulder rotator muscles in the dominant and non-dominant shoulders of elite volleyball players.**

***Methods*—Isokinetic muscle strength tests were performed at speeds of 60 and 120°/s, and shoulder mobility was examined in ten players from the England national men's volleyball squad. The subjects also completed a questionnaire that included a visual prompt and analogue pain scale.**

***Results*—The range of motion of internal rotation on the dominant side was less than that on the non-dominant side ($p<0.01$). The average peak strength at 60°/s external eccentric contraction was lower than that of internal concentric contraction in the dominant arm, but was higher in the non-dominant arm. Six of the ten subjects reported a shoulder problem, described as a diffuse pain located laterally on the dominant shoulder.**

***Conclusions*—These elite volleyball players had a lower range of motion (internal rotation) and relative muscle imbalance in the dominant compared with the non-dominant shoulder.**

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Keywords: volleyball; shoulder; rotator muscles; isokinetic testing; muscle imbalance

Volleyball, like other sports that involve repeated forceful arm actions such as baseball, javelin throwing, tennis, and swimming, produces a high incidence of shoulder injury.[1] The ballistic action in these sports puts a great deal of eccentric load on the shoulder rotator cuff muscles predisposing them to injury.[2] Injured rotator cuff muscles may lose the ability to maintain a balanced relation with their antagonists, as a result of accumulated microtrauma from forceful repetitive movement. This imbalanced force couple around the shoulder area may exacerbate the injuries caused by eccentric overload or may induce secondary shoulder impingement or instability.[3]

Isokinetic muscle strength measurement has been well studied and reported in muscle imbalance studies in other athletes, but few studies have addressed the sport of volleyball.[4–6] Shoulder rotator strength ratio (internal/external or external/internal) has been proposed as an important predictor of the likelihood of shoulder injury, especially secondary shoulder impingement and instability.[4 7] The objectives of this investigation were to establish the profiles of shoulder rotator performance, strength ratios, and shoulder mobility of elite volleyball players.

Sheffield Institute of Sports Medicine and Exercise Science, University of Sheffield, United Kingdom
H-K Wang
T Cochrane

Northern General Sports Clinic, The Northern General Hospital, Sheffield, United Kingdom
A Macfarlane

Correspondence to: Professor T Cochrane, Sport, Health and Exercise, University of Staffordshire, Leek Road (Brindley Building), Stoke on Trent ST4 2DF, United Kingdom.

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Materials and methods

SUBJECTS

Written consent was obtained from ten athletes from the England national men's volleyball squad. All subjects used the right arm as their dominant side, the dominant arm being defined as the arm used to spike and serve. There were no specific exclusions, as all the members of the elite squad were participating fully in competition and training and were able to complete all aspects of the study. However, it was agreed in advance that, during the tests, subjects who reported or complained of shoulder pain would be excluded from further participation in this study. No subjects were excluded on this basis. Subjects also completed a brief personal history questionnaire and read through information sheets before the tests. They were also asked to indicate on the questionnaire if and where they had any musculoskeletal pain, discomfort, or known weakness in the shoulder area. Visual prompt anatomical figures containing front and back views of the shoulders and analogue scale questionnaire were used to help subjects to describe their present pain and its location.

RANGE OF MOTION

Active and passive shoulder internal and external rotation range of motion were recorded bilaterally using standard goniometer technique.[8]

ISOKINETIC TESTING

Concentric and eccentric parameter measures on the dominant and non-dominant shoulder were performed on a Kin-Com AP Muscle Testing System (Chattecx Corp, Hixson, Tennessee, USA) at speeds of 60 and 120°/s. The subjects completed three to five submaximal contractions trials to familiarise themselves with the procedure and to warm up their muscles. During the test, the subjects were supine and restrained by straps across their shoulder girdle and chest, with the shoulder abducted at 90°, and the elbow flexed at 90°; 0° of shoulder rotation was defined with the forearm in the neutral position. The range of test was between 50° external rotation and 50° internal rotation. For example, in the internal concentric/external eccentric tests, the test started from 50° external rotation and the movement rotated through to 50° internal rotation.

A programme in Kin-Com was chosen to carry out shoulder rotator tests in the order of concentric/eccentric test. In this study, for

Table 1 Physical characteristics and experience of volleyball players

	Height (cm)	Weight (kg)	Experience (years)	Mean no training hours a day during season	Age (years)
Mean	195.0	85.9	5.5	2.4	20.4
SD	5.7	7.7	1.9	0.8	1.2

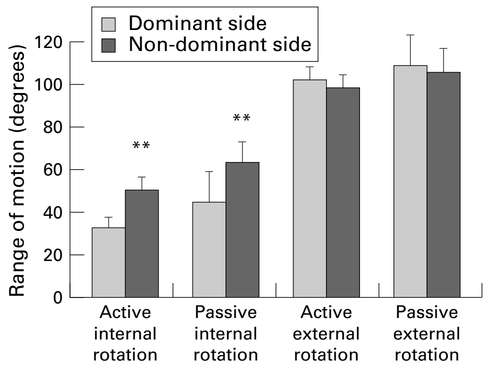

*Figure 1 Active and passive internal and external rotation range of motion of dominant and non-dominant arms. Error bars indicate SEM. **p<0.01 compared with dominant side.*

example, tests started from internal rotator concentric contraction at the speed of 60°/s and then eccentric contraction at the same speed. Test speed was increased to 120°/s when the tests at low speed were finished. The external rotation test at 60°/s followed the internal rotation tests. Again, the external rotation concentric test was started first, then the eccentric test, and the speed was increased to 120°/s when the tests at low speed were finished. The dominant arm was assessed first, then the non-dominant arm. Subjects were given a 10 second and 30 second rest between each trial and two speeds respectively, and performed at least three maximal contractions in each test to obtain a consistent result. In this study, the lengths of the lever arm were taken into account, by converting all torque measurements to force or strength. Gravity compensation was not included in any parameters in these tests because the testing movements were not parallel with the direction of gravity and it has not been used in recent similar research.[9]

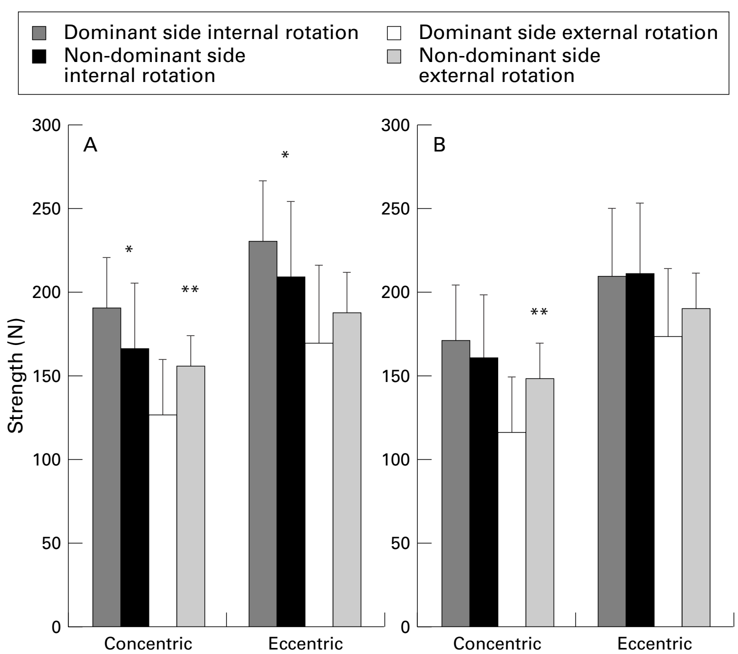

*Figure 2 Isokinetic profile of average peak strength at 60°/s (A) and 120°/s (B) in the dominant and non-dominant shoulders. Error bars indicate SEM. **p<0.01, *p<0.05 compared with the dominant side.*

VISUAL INSPECTION

Subjects were kept in the standing anatomical position and assessed visually to identify any asymmetry in the muscular border of the shoulder between the dominant and non-dominant sides.

STATISTICAL METHODS

Paired *t* tests (with 95% confidence limits) were used to analyse the relation between the data of the dominant and non-dominant shoulders. Correlation coefficients were calculated by Pearson bivariate correlation test to determine the relation between the shoulder flexibility and shoulder pain.

Results

MEAN PHYSICAL CHARACTERISTICS

Table 1 gives the physical characteristics of the players who took part in this study.

RANGE OF MOTION

Figure 1 shows that the ranges of internal rotation on the dominant side were significantly smaller than those on the non-dominant side ($p<0.01$). There was no significant difference in the active and passive ranges of external rotation between the two sides.

MUSCLE STRENGTH

Figure 2 summarises the results of the mean peak strength of internal/external, concentric and eccentric contraction at speeds of 60 and 120°/s in the dominant and the non-dominant shoulders. In the 60°/s test, the mean strength values of internal rotation concentric ($p = 0.017$) and eccentric ($p = 0.05$) contractions on the dominant side were greater than those on the non-dominant side. These data also indicate at both rotation speeds that the external rotators in the dominant arm were weaker in concentric contraction than those in the non-dominant arms ($p = 0.009$ and 0.007 respectively). The mean peak strength values of the external rotation eccentric test were similar to those of the non-dominant side.

STRENGTH RATIOS

The ratio was lower in both types of muscle contractions and speed testing in the dominant arms than the non-dominant arms. The ratios for the concentric group were significantly different from the non-dominant arms ($p = 0.004$ and 0.003) (table 2).

QUESTIONNAIRE ANALYSIS

From the completed questionnaires, six of ten subjects indicated a shoulder pain problem, with diffuse pain located laterally on the dominant shoulder. However, only three of them were receiving treatment. The range of the analogue pain scale was from 0 to 10. The mean (SEM) value of the pain scale was 6.4

Table 2 Mean (SEM) strength ratio between internal and external rotation (ER/IR) in dominant and non-dominant shoulder.

	Dominant side ER/IR	*Non-dominant side ER/IR*	*p Value*
Concentric			
60°/s	0.67 (0.16)	0.98 (0.22)	0.004
120°/s	0.69 (0.17)	0.97 (0.24)	0.003
p value	NS	NS	
Eccentric			
60°/s	0.74 (0.17)	0.93 (0.17)	NS
120°/s	0.84 (0.12)	0.92 (0.17)	NS
p value	NS	NS	

(3.6). Three subjects believed the pain had already influenced their sports performance, and four thought the intensity and incidence of the pain had been increasing.

VISUAL INSPECTION

The subjects' upper trunk and extremities were checked by visual inspection. There was no obvious difference between the dominant and non-dominant side, but two subjects showed muscle atrophy in the infraspinatus on the dominant side.

Discussion

SHOULDER PAIN IN VOLLEYBALL PLAYERS

The positions of shoulder pain in this study are similar to the descriptions in the publication of Hawkins and Mohtadi[10] on the syndromes of rotator cuff impingement. Although the pain syndrome cannot be used as strong and direct evidence for rotator cuff impingement or shoulder instability, these two conditions have been shown to account for most shoulder pain in overhead athletes.[11 12] It is accepted that impingement and instability are often secondary phenomena in athletes and are caused by eccentric overloading of the cuff and glenohumeral joint capsule when an overhead sport is played.[10]

A report on chronic shoulder pain in the German national volleyball teams has been published with similar findings for pain location.[13] This study also indicated that shoulder pain syndrome occurs in elite volleyball players from different countries and this highlights the importance of pain management.

MUSCLE STRENGTH AND RATIOS

The results reported here also showed that there was a statistically significant difference between dominant and non-dominant arms in the internal and external rotators. Internal rotators in the dominant arm were stronger than those in the non-dominant extremity for the concentric and eccentric tests. Likewise, the external rotators were weak in concentric testing of the dominant arm at the low speed tests. This profile has been reported in baseball pitchers by Cook *et al*.[14] Some studies, however, did not find any difference between the dominant and non-dominant sides in the sports population.[6 15–17] A different type of sport, speed, and range of test are possible reasons for these differences.

The difference between sides in shoulder internal rotators may also result from regular training.[18] Most volleyball players use one arm as the dominant arm to practice a lot of forceful spikes and overhead serves during the training season. These movements are predominantly on concentric internal rotation and eccentric external rotation. Concentric training has been shown to increase the concentric and eccentric strength, but eccentric training does not increase concentric strength.[19] Meanwhile, such training increases the potential of muscle damage or degeneration from eccentric overload.[20] This is because eccentric contraction of the cuff muscles generates higher tensions in controlling concentric muscle contraction of the agonists during the deceleration period of the spike or overhead serve action. The degenerative rotator cuff tendon shows weakness because of discontinuity of the tendon fascicle and thinning of fascicles with irregularly distributed tenocytes.[21] This is a possible reason why the internal rotators in the dominant arm become stronger and the external rotators become weak through the specific training.

In this study, volleyball players were significantly weaker in concentric but not eccentric contraction in external rotation during low speed testing. However, mean peak external eccentric strength was less than concentric internal strength in the dominant side during low speed testing. If the eccentric strength of shoulder external rotators affects the capacity to control the agonists during spiking or throwing, weaker eccentric strength may suggest poor control and increase the likelihood of injury. In other words, for these volleyball players, the control of external rotators in the dominant arm is less than in the non-dominant arm. No research has been carried out that combines the isokinetic testing of shoulder rotators with a longitudinal study to assess the relation between strength ratio (imbalance of) and shoulder injury. Thus we cannot yet predict the value of strength ratio and low eccentric strength of external rotators as predictors of shoulder injury for overhead athletes.

Strength ratios of external to internal rotation in the dominant and non-dominant arms showed a significant difference in concentric contraction, but not in eccentric contraction (table 2). These mean strength ratios did not change significantly when the speed of testing was increased. Mikesky *et al*[6] have also reported this profile. The non-dominant external to internal rotation strength ratios showed a tendency to be higher than those in the dominant side. This is because the strength of concentric contraction in the dominant shoulder was stronger in internal but weaker in external rotation. There was no significant difference in these ratios between the dominant and non-dominant arms in eccentric contraction. One possible reason for this is that this study was designed to measure strength in the functional range (50° internal rotation to 50° external rotation) of shoulder internal and external rotation rather than in the more extreme range used by Ellenbecker *et al*[22] (70° internal rotation to 90° external rotation).

The results of Mayer *et al*[23] indicated that normal ratios for the general population at 60°/s testing of external to internal rotation were 0.57 (dominant side) and 0.61 (non-dominant side) for the concentric test and 0.65 and 0.66 respectively for the eccentric test. Another study on competitive swimmers indicated 0.70 (dominant side) and 0.71 (non-dominant side) for the 60°/s concentric test.[24] As table 2 shows, the values of the ratio of external rotators to internal rotators were 0.67 and 0.98 in concentric and 0.74 and 0.93 in eccentric tests for the dominant and non-dominant arms. Although these values cannot really be compared with this study because the level of subjects, sport, and range of test were different, these ratios showed that the differences in strength between the internal and external rotators in dominant arms are close to those found in previous studies.[23] The ratios in the non-dominant arm were near to 1, and this observation has been reported for healthy tennis players.[5]

RANGE OF MOTION, SHOULDER PAIN, AND STRENGTH RATIO

In the range of motion tests, the active and passive range of motion of internal rotation in the dominant side was smaller than in the non-dominant side (fig 1). External rotation was not statistically different between the two sides. These findings are similar to those for baseball pitchers in a previous study.[14] Pappas *et al*[25] hypothesised that limited internal rotation was the result of reactive fibrosis of the capsular tissue due to repetitive microtrauma in people with shoulder impingement. However, not all the volleyball players had impingement syndrome, but all of them showed a limited range of internal rotation in the dominant shoulders. There was little correlation between hypomobility and shoulder pain in this study ($r = 0.5029$, $p>0.05$). It seems reasonable to propose that the variation in mobility in the dominant arm was a physiological adaptation to the repetitive overhead spiking action. This may induce microtrauma, leading to selective stretching of the anterior capsule and tightening of the posterior capsule, which are predisposing factors to instability and impingement.

In this study, a lower eccentric external/concentric internal ratio, the poor flexibility (decreased range of internal rotation), and the reduced strength of external rotators (of the supraspinatus, infraspinatus, teres minor complex) in the dominant arm seem to suggest that the throwing or spiking action itself may evoke disproportionate concentric internal rotator strength in the dominant shoulder, which is not matched by external rotator eccentric strength. This may mean that volleyball players are at risk of developing external rotator muscle strains. It may be suggested that training exercises for athletes to maintain a favourable external/internal rotation strength balance and to increase the flexibility of internal rotation may prevent or lessen the severity of repetitive overload injuries. These strengthening exercises should include ones for the rotator cuff muscles and scapular stabilisers. Exercises to increase flexibility must also increase control over the new active range.

VISUAL INSPECTION

In this study, two subjects were found to have infraspinatus muscle atrophy and showed weakness of external rotation in the dominant arm in their strength tests. These symptoms were similar to those in a report by Holzgraefe *et al*[26] on a suprascapular neuropathy. These researchers postulated that the nerve is subjected to friction at the suprascapular notch, with subsequent development of the syndrome. It was also suggested that the deceleration in the volleyball spike can result in a superior labral lesion, which can lead to ganglion cyst formation.[27] Parascapluar muscle strengthening exercises are recommended in their rehabilitation.

CONCLUSION

Functional weakness in external rotators, mobility impairment in internal rotation, and muscle imbalance have been shown in the dominant arm of these elite volleyball players. These findings have been suggested to be intrinsic risk factors and may relate to shoulder overuse injuries.

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Take home message
High level volleyball players had restricted range of motion and relative muscle imbalance in their playing arm; these two factors are commensurate with a risk of shoulder injury.