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Original research papers

STRENGTH OF THE SHOULDER ROTATORS IN SECOND-LEAGUE VOLLEYBALL PLAYERS

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Abstract

Introduction. The main aim of the study was to assess the strength of the shoulder rotator muscles of a group of second-league volleyball players. These muscles are assumed to have a crucial impact on attack effectiveness in volleyball. Strength was assessed based on peak torque values obtained for the rotator muscles measured using the maximal voluntary contraction (MVC) method. Torque was measured in both limbs and the differences between the two limbs were examined. The torque values obtained for the volleyball players were also compared against those measured in a group of students who had never trained any sports. ***Material and methods.*** The study involved 20 students (mean age = 20 ± 1 years) who played in the second league when the study was conducted. Their results were compared with those of a control group consisting of 30 students (mean age = 20 ± 1 years) who had not trained any sports. Peak torque of the shoulder rotator muscles was measured during external and internal rotation of the shoulder in isometric conditions. The assessment was performed on a special measuring station with the forearm in a vertical and horizontal position. The following basic statistics were calculated for the torque values obtained in the measurement: the mean, standard deviation, minimum value, and maximum value. The data were then subjected to statistical testing. ***Results.*** Compared to the students, the volleyball players had higher torque values of the internal and external rotators of the right and left shoulders, in both positions of the forearm. When the results obtained for the right and left limbs were compared for the group of volleyball players, it was found that the torque values for the right limb, which was the dominant limb, were significantly higher than those recorded for the left limb. The study also showed that the position of the forearm had an impact on torque values: when the forearm was in a horizontal position, higher mean values were obtained for the external rotators of the right ($p < 0.05$) and left ($p < 0.01$) limbs, and when it was in a vertical one, the internal rotators were stronger compared to the external rotators. ***Conclusions.*** The shoulder rotator muscles of the volleyball players were found to be considerably stronger than those of the students, and the rotators of the dominant limb were significantly stronger than those of the non-dominant limb in the group of volleyball players. The position of the forearm had a considerable impact on the strength of the internal and external rotator muscles. The maximal voluntary contraction method used in the study can be helpful in measuring the strength of the shoulder rotator muscles in any phase of the training process.

Key words: volleyball, shoulder complex, shoulder rotator torque

Introduction

In volleyball, most points are gained by attacking, and the efficacy of an attack is determined by the player's strength, technique, and tactics [1]. A volleyball attack is divided into the following four phases:

1) The approach (run-up) phase, which depends on the player's position on the court. The player swings the upper limbs backward. In this phase the centre of gravity of the body is the lowest.
2) The jump (take-off) phase, which starts when the lead foot touches the ground. The upper limbs swing upward. The player usually uses a two-step approach, which helps rotate the trunk and position of the body sideways to the net.
3) The flight phase, which starts when the feet leave the ground. The knees are flexed behind the player, the back is arched, and the shoulder girdle and trunk are rotated. The upper limbs work asymmetrically.
4) The landing phase, during which the player usually lands on both feet.

The technique of attack in volleyball is described using the concept of the open biokinematic chain, in which the attacking limb has a direct impact on the ball [2]. The upper limb is impacted by muscle forces, which determine the velocity of

its movement and stabilise the joints, including the shoulder joint. Since the movement of the arm during the attack is extensive and strong, the shoulder joint is exposed to very high loads.

A high level of strength and coordination of the muscles acting on the shoulder joint is necessary for the player to avoid suffering from overloading of the joint and the resulting pain and to be able to perform effective attacks. The main group of muscles and tendons which stabilise the shoulder joint during movement are the so-called rotator cuff. It consists of muscles arising from the scapula whose tendons are fused to the capsule in the shoulder joint. These muscles are: the supraspinatus muscle, infraspinatus muscle, the subscapularis muscle, and the teres minor muscle. The muscles work in conjunction with the deltoid during shoulder movement. They maintain the head of the humerus in an appropriate position in the glenoid cavity and play a major role in controlling the position of the arm [3, 4].

For the purposes of the current study, we selected the directions of the movement of the upper limb which engage the shoulder rotators [5] and performed measurements that made it possible to assess the torque of the shoulder rotators of the volleyball players and the students.

Material and methods

The study involved 20 students who played volleyball in the second league and had been training for at least 4 years and 30 students of the Józef Piłsudski University of Physical Education in Warsaw who had never trained any sports. Some basic statistical data regarding the characteristics of the participants of the study are shown in table 1. All of the participants were right-handed and declared they were in a good physical state when the measurement was performed.

Table 1. Participant characteristics

Students (n = 30)			
	Age [years]	Mass [kg]	Height [cm]
$\bar{\chi}$ + SD	20 ± 1	76 ± 6	180 ± 5x
min-max	19-23	64-112	171-200
Volleyball players (n = 20)			
	Age [years]	Mass [kg]	Height [cm]
$\bar{\chi}$ + SD	20 ± 1	79 ± 8	185 ± 3
min-max	19-22	72-94	180-192

Before the assessment was carried out, each participant did a short warm-up, which mostly engaged the shoulders. The participants were then informed how the assessment would be performed. The assessment was conducted on a measuring station (JBA Staniak, Poland) designed for measuring the torque of the shoulder rotators in isometric conditions. The station was connected to a computer, which made is possible to control the measurement and collect data. The participants were in sitting position during the assessment, and the two limbs were assessed individually. The knee, hip, and elbow joints were bent at an angle of 90°, and the shoulders were abducted to 90° [6]. The forearm was positioned vertically and horizontally. The participants' position during the measurement is shown in figure 1. The participants performed isometric internal and external rotation of the shoulder joint in each position.

The measurements were conducted in the following order:

1) the measurement of torque during internal rotation, with the forearm in a vertical position, for the right and left limbs;
2) the measurement of torque during external rotation, with the forearm in a vertical position, for the right and left limbs;
3) the measurement of torque during internal rotation, with the forearm in a horizontal position, for the right and left limbs;
4) the measurement of torque during external rotation, with the forearm in a horizontal position, for the right and left limbs.

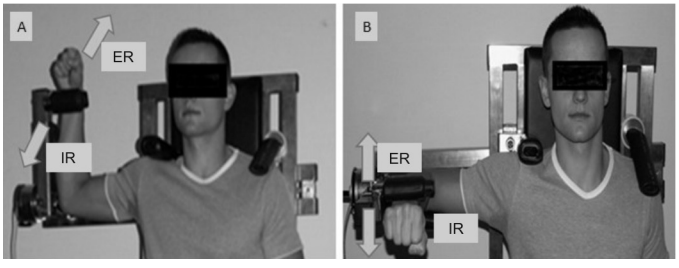

Figure 1. The method of measuring the torque of external rotation (ER) and internal rotation (IR) with the forearm position vertically (A) and horizontally (B)

After the measurements were taken, the mean values and standard deviations were calculated. We then performed a statistical analysis of the results using Statistica (version 10). The data were tested for normality of distribution using the Shapiro-Wilk W-test. The mean values obtained for the groups were compared using Student's t-test for dependent and independent samples if the distribution of the data was normal and using the non-parametric Mann-Whitney U test if the data was not normally distributed.

Results

The mean values of the torque of shoulder rotation obtained for the right and left limbs for the students and volleyball players are shown in figures 2 and 3, respectively, and those measured in the volleyball players for the two limbs are presented in figure 4.

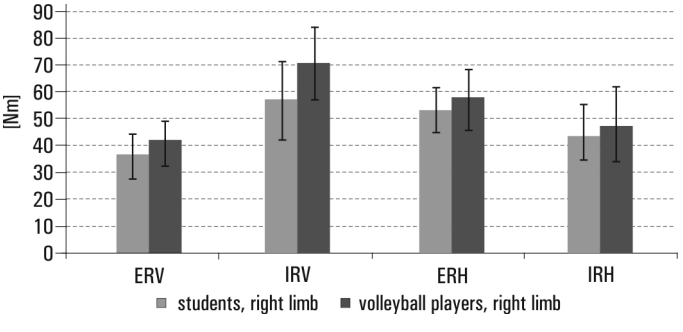

Figure 2. Mean torque of the rotation of the right (dominant) limb of the volleyball players and students obtained for: external rotation with the forearm in a vertical position (ERV), internal rotation with the forearm in a vertical position (IRV), external rotation with the forearm in a horizontal position (ERH), internal rotation with the forearm in a horizontal position (IRH)

As shown in figure 2, the results of the measurement of internal and external rotation for the dominant (right) limb proved that the muscle groups responsible for these movements were stronger in the volleyball players than in the students, both in the vertical and horizontal positions. The difference between the values obtained for internal rotation in the two groups with the forearm positioned vertically were statistically significant with a *p* value of less than 0.01.

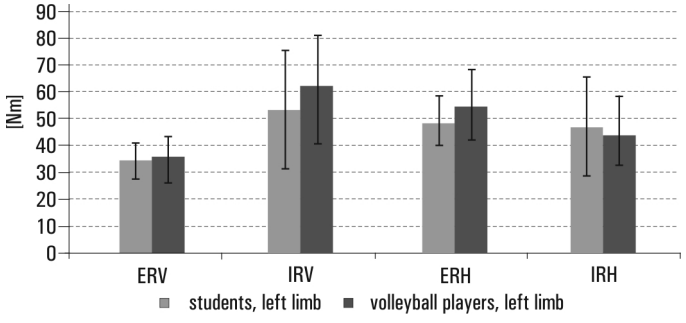

Figure 3. Mean torque of the rotation of the left (non-dominant) limb of the volleyball players and students obtained for: external rotation with the forearm in a vertical position (ERV), internal rotation with the forearm in a vertical position (IRV), external rotation with the forearm in a horizontal position (ERH), internal rotation with the forearm in a horizontal position (IRH)

As far as the left limb (fig. 3) is concerned, torque values in the group of volleyball players were also higher than in the group of students. The difference between the values obtained for external rotation with the forearm positioned horizontally were statistically significant with a *p* value of less than 0.05.When it comes to the comparison of the results obtained for the left and right limbs in the group of volleyball players (fig. 4), peak torque values were higher for the right limb both in external and internal rotation in both positions of the forearm ($p < 0.05$). There were significant differences between the results obtained for the internal and external rotators for both limbs. It was found that the position of the forearm had an impact on the results: when the forearm was in a horizontal position, higher mean values were obtained for the external rotators of the right ($p < 0.05$) and left ($p < 0.01$) limbs.

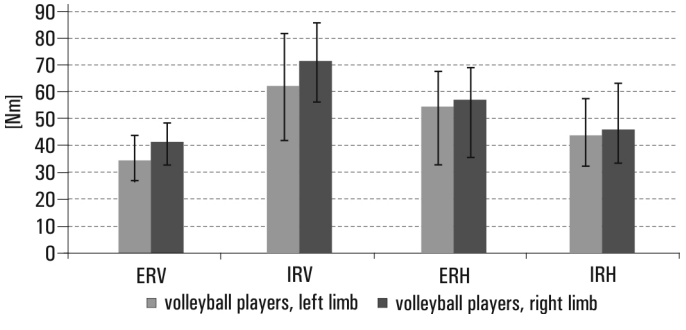

Figure 4. Mean torque of the rotation of the left and right upper limbs of the volleyball players obtained for: external rotation with the forearm in a vertical position (ERV), internal rotation with the forearm in a vertical position (IRV), external rotation with the forearm in a horizontal position (ERH), internal rotation with the forearm in a horizontal position (IRH)

It was established that the shoulder complex range of motion in the volleyball players (group 1) was much wider than the norm, except for the range of internal rotation and horizontal extension of both arms. In both groups, the range of horizontal flexion and internal rotation did not reach the levels of physiological parameters, and poorer flexibility was observed in the group of girls practising volleyball. The differences between the shoulder girdle ranges of motion of the groups (tab. 3) were found to be statistically significant and highly statistically significant in all of the examined ranges.

Discussion

In the past few years, the technical elements performed by elite volleyball players have changed considerably. Some of them are not used any more, and others have become more frequent in the game. In modern professional sports, more and more attention is being paid to details which impact the effectiveness of the training process and the players' performance. Coaches need to be aware of the importance of such factors as equipment, rest, diet, quality of the exercise performed, supplementary individual training, and the state of particular components of the players' locomotor system [7, 8, 9].

In a paper concerning the biomechanical assessment of attack efficacy in volleyball, Tabor et al. [10] found that the speed at which the limb is drawn back before hitting the ball is crucial for the effectiveness of the attack. This speed can be achieved by implementing an appropriate type of training [11], aimed at increasing the strength of the muscles acting on the shoulder joint and improving the mobility of the entire shoulder complex. Rotator cuff muscles are of particular importance in volleyball as they not only have a great impact on the technique of the attack, when the limb quickly switches from external to internal rotation, but they also stabilise the joint [12].

The small number of research studies and publications concerning the role of the rotator muscles of the shoulder joint in volleyball has motivated the authors of the current article to investigate this issue. The results of the measurement of the torque of internal and external rotation in the group of volleyball players conducted in isometric conditions reflect the effects of specific strength training, whose impact on the strength of professional volleyball players has been proven in a study comparing elite and novice players [13]. Assessing shoulder mobility in volleyball players, Lizis [14] found that it can improve through training already in players aged 16-17 years, and greater functional differences in the shoulder joint can be observed the more time passes and the more advanced the training process is. Thus research involving the same volleyball players who continue to train professionally should show greater torque values of the shoulder rotators.

Some authors [15, 16] have emphasised the fact that repeated movement of the upper limbs can cause substantial overload and microtrauma, resulting in instability of the shoulder joint. It has also been strongly recommended that maintaining a balance between the external and internal rotators should be considered a priority in sports training and injury prevention, assuming that the latter muscles are stronger [17]. In a study on the biomechanics of pitching in baseball, Hurd and Kaufman [18] found a strong relationship between the strength of the internal rotators of the shoulder joint and the torque of the external rotators during pitching. The authors state that athletes in disciplines where internal and external rotation alternate are characterised by lower ratios of external to internal rotator strength.

In the current study, differences in the strength of the external and internal rotators were also found. However, the domination of one type of muscles over the other changed de-

pending on the position of the forearm. When the forearm was positioned horizontally, the external rotators, whose strength plays a major role in preparing for the attack, dominated. On the other hand, when the players' forearm was in a vertical position, the internal rotators, whose strength determines the precision and effectiveness of the attack, dominated. If balance is to be maintained between the strength of the external and internal rotators, it needs to be considered that this ratio depends on the position of the forearm; this is important, for instance, in choosing the position for performing exercises which strengthen the muscles that stabilise the shoulder joint.

In this study, significantly higher torque values were obtained for the rotators of the right upper limb, that is the dominant limb, compared to the left limb. An interesting question, which is beyond the scope of the study, is whether the parameters of the non-dominant limb or side of the body can influence the technique of movement during an attack in volleyball. It seems that functional training can be effective in helping achieve a balance between the external and internal rotators in disciplines which are asymmetrical, such as volleyball, handball, tennis, the javelin throw, etc. [19, 20].

The shoulder rotators play an important role in stabilising the shoulder joint and protecting it from injury and have a considerable impact on attack technique in volleyball. The results of the measurement of the torque of the shoulder rotators in this study can be useful in preventing injuries of the shoulder joint in other players. Monitoring the differences in the strength of particular groups of muscles can help coaches develop a suitable training strategy and track the players' progress.

Conclusions

The analysis of the results of measuring the strength of the shoulder muscles in isometric conditions has made it possible to formulate the following conclusions:

1. The volleyball players achieved higher results in the assessment of the strength of the shoulder rotators compared to untrained persons.
2. In the group of volleyball players, the torque of the dominant limb was significantly higher than that of the non-dominant limb in all of the measuring positions.
3. The position of the forearm had a significant impact on the torque of the internal and external rotators of the shoulder joint.
4. The maximal voluntary contraction method used in the study can be useful for measuring the strength of the shoulder rotator muscles in any phase of the training process.

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