ASSESSMENT OF THE SHOULDER FUNCTION OF THE DOMINANT LIMB IN FEMALE VOLLEYBALL PLAYERS AGED 18-25

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Abstract

The assessment of the shoulder function of the dominant limb in female volleyball players aged 18-25 is a research work aimed at determining the relationship between the motor, postural and support function of the dominant and non-dominant limb in volleyball players and non-training women of the same age. Is the arm of the dominant located higher in relation to the other? Is it dependent on the position on the pitch? The research was carried out on 40 women, 20 in each of the research and control groups. During the examinations, each participant was made 4 photos on the posturographic grid, which were then analyzed according to selected methods and specific anatomical points. This allowed for an accurate assessment of the height of the acromion, and with this analysis of the posture of the female volleyball players. There were also 4 functional tests focused on the strength of the shoulder muscles and deep stabilizing muscles to show differences between the dominant and non-dominant limb. The results of the study show statistically differences in the positioning of the shoulder joint between groups, where p= 0.0009. In 17 of volleyball players the left joint is higher than the right one by an average of 1.60 cm. The group of volleyball players in all functional tests obtained a better average score, differing statistically significantly between groups. The obtained results allow to state that volleyball is a sport that largely affects the development of the shoulder girdle muscles on both sides of the body with attention to the increase in strength in the dominant shoulder.

Key words*: shoulder complex, dominant limb, volleyball, women*

Introduction

Volleyball is a non-contact team sport that has existed for over 120 years [Grządziel, 2012; Adamczyk, 1988]. When playing volleyball, the shoulder girdle is subjected to unilateral loads. The introduction of the ball into play and attack are two basic asymmetrical movement patterns in which the main loads are overcome by the dominant limb [Grabara, 2015].

The main function of the upper limb is dynamic movement, the basis of which is the grip. The functions of the upper limb are many: it allows manipulation, making movements, responding to resistance in the form of external forces, thanks to muscle chains. The interconnection of muscles and their association with the fascia has been called by Myers a muscle chain. This is important in the global perception of the movement and structure of the human body [Myers, 2014]. It is worth noting that the upper limb is an open biokinematic chain, therefore, to maintain adequate mobility of the shoulder, proper work of passive and active stabilizers is necessary [Bochenek, 2016; Skolimowski, 2009; Tsvieli, 2018; Kwiatkowski, et al. 2016].

Movements associated with volleyball play leads to the asymmetry of tension in the muscle chains of the upper limb, which may affect the development of disorders in the superficial and deep band of the upper forelimb, which usually shows increased muscle tone in the dominant limb [Grabara, 2015]. Muscles belonging to the superficial and deep muscle chains of the upper limb also show changes in tension - in the upper part an increased tonus can be observed, in the lower a reduced one [Myers, 2014].

The shortening of the serratus anterior muscle, which often occurs in volleyball players, causes muscular imbalance leading to protraction of the scapula and excessive stretching of the minor and major rhomboid, which in turn affects the deepening of thoracic kyphosis. Other muscles that are involved during the game and are of great importance for the proper functioning of the scapula are: trapezius and the pectoralis minor. These muscles show an appropriately disturbed muscle tone, in the case of the pectoral muscle it is increased concentric activity, keeping it shorter than the norm, while the trapezius muscle is kept in eccentric activity, setting it in the elongated position [Myers, 2014; Harput, et al. 2016; Brittany & Castilla, 2015].
Asymmetrical strikes, servos, defenses or ball rebounds can cause disturbances in the muscular balance of the upper limb, which in turn leads to overloads, which increase the risk of damage to the

structures of the complex, which, in turn, can lead to changes within the spine [Grabara, 2015]. Players training about 20 hours a week, hit the ball on average 40,000 times during the season, which means that attacking, receiving and middle players will be much more vulnerable to the pain and dysfunction of the shoulder complex than other players on the field. This relationship results from the different field positions and specific, automatic movements associated with each position. [Reeser, Fleisig & Bolt, 2010].

Among athletes practicing sports, where the blow is performed with the dominant hand above the head, such as: volleyball, tennis, baseball, there are restrictions on the range of rotational movements in the shoulder. Among these players there is an increased range of external rotation and a reduced range of internal rotation [Reeser, Fleisig & Bolt, 2010]. According to Regan's research, the range of external rotation examined on the upper limb visited up to 90º in the shoulder joint is 47º on average, whereas the internal rotation 32º. The above changes may result from the technique of striking the ball on the visited upper limb and may occur mainly when attacking [Reeser, Fleisig & Bolt, 2010; Thomas, Swanik & Swanik, 2010; Zawadka, Kloc & Fijewski, 2016; Papandreou et al. 2018]. Trigger points located in the infraspinatus and teres minor (these muscles are responsible for the external rotation in the joint) lead to the limitation of the internal rotation [Muscolino, 2016; Janiszewska, 2013; Hawrylak, Wojna & Chromik, 2015; Hurd, Kaplan & ElAttrache, 2011; Kurokawa, Yamamoto & Ishikawa, 2017; Barczyk-Pawelec, 2012].

Aim

The aim of the study was to examine and visualize the shoulder position relative to the upper body in players playing volleyball at the age of 18-25 and their non-training peers in the same age group. Torso and dorsal muscle strength as well as shoulder stabilization were examined. Both shoulder girdles were analyzed and their significance in the whole body postural function was assessed.

Material and Methods

40 women took part in the study, 20 in the study group and 20 in the control group. The study group consisted of volleyball players from the Konin Volleyball Society, AZS of the Medical University of Karol Marcinkowski in Poznań, in turn non-training women of the same age were included in the control group. The criteria for inclusion of the study group were detailed and included: - gender: women, - age: 18-25 years, - volleyball training for a minimum period of 3 years, - membership in a volleyball club. The rules for selecting the control group included appropriate age (18-25 years) and gender. The detailed information on the examined group is presented in Table 1.

The basic exclusion criterion for the control group was the fact of training sport in which one side of the body is involved much more than the other. Other exclusion criteria for both groups included: - injuries to soft tissue injuries in the upper limbs, - scoliosis, - fractures and surgeries in the upper limbs, - pain within the shoulder complex, - shoulder instability.

Table 1. Basic data on the study and control group.

	Players group		
	Average ±SD	Median	min-max
Age [years]	20.55±2.06	20	18-24
Weight [kg]	61.05±7.54	60	46-76
Height [cm]	172.5±6,96*	173,5	160-185
	Control group		
	Average ±SD	Median	min-max
Age [years]	21.6±1.98	22	19-24
Weight [kg]	57.9±6.54	57	43-71
Height [cm]	167±5.25	168	157-178

*$p<0.05$

The next part of the study were photos on a posturographic grid. 16 Mpx camera placed on a tripod, 4 pictures were taken: front, right side, left side and back. The examined person stood in a sports shirt and shorts at a distance of 1.4 m from the camera set at a height of 1.0 m. While analyzing the results, the focus was on assessing the upper body posture. The following factors were observed: the position of the shoulder joints and the length of the sides on the right and left sides of the body. The picture taken at the back focused on the difference in height of shoulder complex structures. During the analysis, one perpendicular and one vertical line was drawn. A vertical line ran from the center of the head through the center of the spine, dividing the body into two parts - right and left. The perpendicular straight line is drawn at the height of the outer ear lobe, so that it intersects with the first at a right angle. Thanks to such lines, it was possible to calculate the distance between the acromion and the horizontal line, which was the basis of the study. In the photo from the front, differences in the length of the sides were observed. Two perpendicular lines are marked, one along the sagittal plane, passing through the center of the head and navel, and the other horizontal line is perpendicular to the previous one, crossing with it at the level of the navel. The distance from the horizontal line to the point marked in the armpit on the right and left was calculated. The Figure 1 below shows the diagram that was used when analyzing the photos. Pictures taken from the sides made it possible to observe the occurrence of shoulder protraction. Through the opening of the hearing canal straight line was perpendicular to the ground, then it was assessed whether there was a deflection of the shoulder joint from the marked straight.

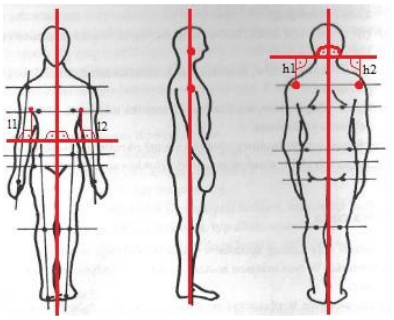

Fig.1. Diagram of assessing photos in standing position.

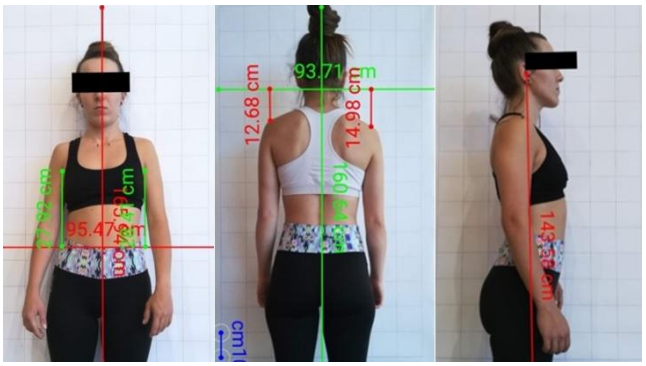

Fig.2. Sample photo analysis on a posturographic grid front, back and side.

The study carried out muscle and functional tests. The first of these was a pressure soreness test with an algometer (Digital Force with a tip applied to the body 1cm^2 in size) at three selected trigger points on the trapezius, infraspinatus and pectoralis major. The test was performed in a natural, uncorrected sitting position. The Algometer was applied perpendicularly, directly to the body to a selected point on the muscle, with a steadily increasing force at a speed of 500 g / s until the first pain sensations of the subjects. The unit in which the results are given is kg / cm^2. In the absence of pain and tenderness, no value was recorded and the study proceeded to the next points. The device was calibrated to record results in grams. The examination was performed in specific places of trigger points formation within selected muscles of the right and left shoulder complex described by Travell and Simons. The following trigger points have been selected:

- trapezius muscle of the back, the point is located in the middle of the muscle, on the border of the course of the upper fibers and the middle of the muscle,
- infraspinatus, the selected point is closest to the upper angle of the scapula, in the place of its attachment to the dorsal scapula,
- pectoralis major, the point located in the sterno-costal part.

Then a provocation test for the suprascapular nerve was performed [Lafosse, Piper & Lanz, 2011]. During the test, the patient sat in a chair, then the physiotherapist performed lowering of the shoulder of the dominant limb and asked the patient to rotate the head in the opposite direction to the examined shoulder. The test was considered positive when radiating pain spread from the cervical spine towards the shoulder joint.

After the nerve test, the participants performed three functional tests focused on the specificity of volleyball. The first of these was the throw of a medicine ball (TEST 1) weighing 2 kilograms from before the chest, with arms visited up to 90 degrees and elbows bent so that they were parallel to the axis of the humerus. This test was used to visualize the strength of the shoulder and chest muscles, excluding the force from the abdominal press. The women made two attempts to throw the ball.

The second test (TEST 2) lasted 15 seconds and consisted of supporting the plank position with shoulders in front of the hands with shoulder-width apart hands, feet wide with the width of the hips, while simultaneously making as many touches of the dominant hand as possible to the non-dominant hand, then returning to the position from putting down the hands and returning to the starting position with a careful even load on both upper limbs. Then the same procedure was performed starting from the non-dominant limb (TEST 3).

The last test (TEST 4) was to perform the maximum number of pump repetitions in 30 seconds. The pump, as an exercise using the exerciser's own weight, is an excellent test for diagnosing the condition of the shoulder girdles, elbow joints and wrists. The examined person was in the support position with hands shoulder-width apart, while the feet were joined. The head was in the extension of the spine, the eyes looked at the floor, picking a point in front of the wrists. The movement began with external rotation in the joint, which is maintained throughout the movement, followed by torso drop by flexion in the elbows. The ability of taking the correct starting position was observed, which showed whether the subject was able to keep the spine in a neutral position, thus activating the deep stabilizing muscles [Starret & Cordoza, 2013].

Results

In the research and control group, all participants were right-handed. Among volleyball players, 4 out of 20 respondents reported a feeling of instability within the shoulder complex, while 2 women confirmed a feeling of shoulder instability.

Reported pain intensifies when attacking and serving the ball, which players consider to significantly impede their play. None of the person in players group has ever suffered an injury within the shoulder complex. The control group also did not have shoulder injury. Reported pain occurs both during training, at various stages, sometimes the pain makes it difficult to play the match and often affects the points scored by the players. The research group was divided according to their position on the field (chart 2). This division shows the diversity among the research group, thanks to which, it is possible to show whether the difference

in the height of shoulder complexes is observed for each player, regardless of their position on the field.

In the study group, it was observed that 8 of 20 subjects had shoulder protraction, while in the control group only 3 women. The calculated difference in shoulder height reveals that in 17 out of 20 volleyball players the left appendix is set higher than the right one by an average of 1.60 cm. The right one is set higher only in 3 subjects and the average is 0.53 cm. The statistical tests carried out showed a significant statistical difference in the height of acromion placement in the study groups, where $p = 0.0009$.
Elongation of the left side was observed in 10 volleyball players and it was on average 1.22 cm, while elongation of the right side occurred in the remaining 10 women with an average of 0.95 cm. In the studies between the groups, no statistically significant difference in body lengths was found.
One of the goals was to illustrate the occurrence of shoulder girdle elevation among volleyball players who occupy different positions on the pitch. In the conducted analysis, it was noticed that only in the group of players playing in the position of attack in three out of five the right shoulder complex is set higher, in the other two left. The exact data is presented in the table below.
The test of pre-chest medicine ball throwing in a straight position showed that in the study group, the women threw an average of 0.381 meters away. The exact results of the throw test are presented in Table 4. During the study of differences between the groups, it was noticed that the results differ statistically significantly between the groups $p = 0.005$. In the study group, it was also checked if the distance between the ball was statistically significantly different among volleyball players who have pain and those who lack it. The study shows that the test results do not differ statistically significantly for $p = 0.637$.

The relationship between the position on the pitch and the throw distance was also examined. Here, too, no statistically significant differences were found, $p = 0.214$. The values described are presented in Table 4 below. In addition, the players did an average of 7.4 pumps more than their non-training peers. The results of statistical tests confirm the significance of differences in the given test between the groups, where $p = 0.000175$. The test in the forward support position shows that stabilization on the dominant limb allows to achieve more movements with an unsupported hand in both groups. This may be due to better shoulder joint prioprioception on the dominant side of the body, which allows to move with other hand without losing stability.

All functional tests carried out, differ statistically significantly between the group of volleyball players and their non-training peers. The volleyballers obtained higher average results in each test. Algometer measurements at selected trigger points are presented in the tables above.

With the analysis of the statistical significance between the groups, it was found in the case of the right trapezius, the left major pectoral muscle and the left sub-dermal muscle. The results are shown in Table 5. For the left diarrheal muscle, the Mann-Whitney U test was used, where $p = 0.013803 < p = 0.05$. The provocation test for the suprascapular nerve was negative in both the study group and the control group.

Discussion

Millions of people around the world do sports, for some it's work, for others it is amateur entertainment. While paying attention to sports with the main use of upper limbs, one should not forget about volleyball. Serving the ball, playing, attacking - all these movements involve the muscles of the shoulder girdle to a great extent, thus exposing it to possibly more frequent pain, damage and injuries.
In 2015, Grabara evaluated the posture of volleyball players aged 14-16 years. The study showed that the right arm was positioned higher than the left ≥ 5 mm in 37% of the respondents. The analysis of the posture towards forward and lateral symmetry did not show any significant differences between volleyball players and their peers [Grabara, 2015].
In this study, the left arm is positioned higher than the right arm by 1.60 cm on average. This difference can be seen in as many as 17 out of 20 female volleyball players aged 18-25.
In 2016, Mrozkowiak et al. analyzed body posture among 151 wrestling, judo, volleyball, fencing and football players. An appropriate posture was created for each of the studied disciplines. It turned out that volleyball players had their left shoulder elevated and the left shoulder blade located much closer to the spine than the right one [Mrozkowiak, Sokołowski & Kaiser, 2016].

Research conducted by Zawadka et al. in 2016 shows that 43% of the examined volleyball players had their right shoulder complex set higher up. The left joint was set higher in 34%, of the participants, yet the rest of the players had symmetry. The study involved 88% of the players with the dominating right upper limb. They analyzed the shoulder height setting with a centimeter tape. The results of the study by Zawadka et al. show the opposite situation to the results of the research presented in this study. This difference may result from the measurement methods used in both studies, the length of play, training methods or individual anatomical factors [Lafosse, Piper & Lanz, 2011]. The next study shows a correlation between a higher position of the humeral joint and shoulder blade on the left side of the body as compared with the right one. A shortening of the left side was also observed. Such an posture was observed in 80% of the examined female volleyball players using palpation and angular measurements collected from the acromion [Vařeková, 2011].
The functional tests carried out were similar to those of the study by Borms and Cools in 2018 [Borms & Cools, 2018]. They applied, among others, the test of throwing a medical ball from

before the chest in a seat and the test of stabilization of the shoulder girdle in a closed kinetic chain. In the studies presented, the same throw test was chosen, the results are similar, although among the tested female volleyball players distances are much longer. There is very little information in the literature on the relationship between the position occupied on the pitch and the characteristic posture of the body. This is a relationship that is worth examining and analyzing [Skazalski, Whiteley & Bahr, 2018]. During the research, an interesting result was noted; three out of five attacking players had their right arm placed higher. This is a kind of anomaly compared to the rest of the female volleyball players whose left joint is higher. It may be associated with more frequent ball attacks or it is an individual feature, but these are only assumptions.

The control group in the study included women who did not practice asymmetrical sports; therefore, their posture did not show a clear tendency in the uneven setting of the structures of shoulder complexes.

Algometer was used to measure pressure pain of the selected trigger points. Relevant differences in statistical significance between the groups were observed in the case of right trapezius muscle, left greater pectoral and left infraspinatus. These muscles have a lower mean value for causing pain in the study group than in the control group. In a study conducted by Linde et al. in 2017, 33 healthy individuals with trigger points in the right supraspinatus muscle area were tested. The points were found by palpation, then the point on the skin was marked with a marker. A pressure algometer was used, which was applied three times at specific points on the muscle. Three values of low (15N/s), medium (35N/s) and high (55 N/s) force were determined and applied to the examined area. The authors demonstrated a linear positive correlation between the strength of the algometer and the pain threshold (Linde, Kumbhare, Joshi & Srbely, 2017). In 2016, Taleb et al. examined 46 students of physiotherapy with homotopic pain in the descending part of the trapezius back muscle. The most painful trigger point was determined and marked with a marker. An electric algometer was applied to the marked area to determine the pressure needed to induce pain. The device used in the test with a head of $1cm^2$ showed the values in kilograms, as used in the above work. The results of the study indicate that the treatment of trigger points in the trapezius muscle by relaxing with an algometer is more effective than manual relaxation [Abu Taleb, Rehan Youssef & Saleh, 2016]. In 2019, Schleichardt et al. analyzed shoulder complexes among young volleyball players. Their research shows that the greater pectoral on the dominant side has a reduced range of horizontal abduction by 7 degrees compared to the non-dominant side. The result of the reduced range of mobility may be an increased tension in this muscle, resulting from the repetition of strikes and serves overhead [Schleichardt et al. 2019]. The above-mentioned studies and articles demonstrate the effective use of algometry in the study and treatment of trigger points within the structures of the shoulder complex. However, there are still very little research on the study itself, especially its use among volleyball players and athletes.

In the study, a photographic method was used to depict and determine the specific silhouette of female volleyball players. The photos were taken on the author's posturographic grid, each of the research participants had four photos taken at the front, back and both sides. The photos were analyzed using the "Prime Ruler" application on a smartphone. Marked points accurate to within millimeters showed differences in the setting of the acromion. As a result of the analysis, an elevation of the left shoulder complex was observed in the posture of 17 volleyball players, while 3 players had their right complex elevated. There are not many studies based on the traditional photographic method. Most of the current studies are based on the study of posture and balance using platforms equivalent to the sensors on the athlete's skin. In the 2013 study, Agostini et al. examined 46 male and female volleyball players, comparing them with a control group of 42. They examined the body's center of gravity deflection in ten tests on a platform. A volleyball-specific model of sensory integration can be deduced from the studies, which is observed during elliptical deflections of the body's center of gravity [Agostini et al. 2013]. In the Papendreon et al study, 20 athletes from disciplines such as volleyball and swimming were analyzed. The measurements were performed three times with the use of a caliper in the standing and lying position on the back. Significant differences were observed in the values taken from the acromion in the standing position between the group of volleyball players and the group of swimmers. The differences in the height of the shoulder blades in relation to each other are greater in the measurement for the group of volleyball players than the group of swimmers while standing against the wall; in the case of volleyball players, the difference is on average 15 mm [Papandreou et al. 2018]. The results of Papendreon et al. and the study on the basis of which the above paper is written, confirm the asymmetry in the setting of the blades in the posture of volleyball players, which results from the nature and character of sport [Papandreou et al. 2018].

Due to the observation of trigger points in the infraspinatus muscle, a test for the nerve that innervates it was decided. It was a test of the suprascapular nerve and the results were negative in all examined women, both in the study and control groups. There were no problems with peripheral nervous structures in the study. In 2017, Contemori and Biscarini investigated the possibility of suprascapular nerve neuropathy in male volleyball players. For this purpose, they chose the test of repeated movement within the shoulder joint, which is most often used to visualize the deep sensation and position of the joint structures. The

study was divided into two groups - a study of 12 men with damage to the supraspinatus muscle tendon and a control study of 12 men without injury to the muscle. The results of the study indicate a reduced sense of proprioception in the dominant limb, which may be associated with neuropathy of the suprascapular nerve [Contemori & Biscarini, 2017].

In this study, seven out of twenty athletes experience pain within the dominant limb. None of them was injured within the structures on the painful side. The character of the pain was described as stitch and homotopic pain, appearing most often after training. According to the 2017 study, shoulder joint injuries are about 5-20%. The biggest factor leading to damage is the number of trainings and their intensity, to which attacking players are most exposed. They are characterized by the ability to generate a very high maximum speed (28 m/s) during the "attack" movement in the shoulder joint [Verhagen, 2017]. Seven of the examined volleyball players confirmed pain in the shoulder joint structures during serving and attacking. Reeser et al. observed that non-traditional ball serving styles (without foot contact with the ground) introduce an increased risk of injury, especially for midfielders, left-wingers and right-wingers. Due to the large number of asymmetrical movements, injuries related to the shoulder joint are the most common for those players. In these studies, pain occurred in case of the players occupying positions: one quarterback, one attacker, one midfielder and four receivers. This indicates an increased risk of pain in case of athletes occupying similar positions (mainly attackers) and characterized by analogous rules and movement patterns performed during training [Reeser et al. 2010].

In the survey, 9 out of 20 volleyball players marked the past injury of ankle joint. These were different degrees of joint torsion. According to a study by Lachlan et al., ankle joint injury is one of the most common. More than 80% of players have experienced this injury at least once [James, Kelly & Beckman, 2014]. The most common mechanism causing damage is crossing the midline after the attack, which results in contact with the opponent and a bad stepping on the foot [Reeser et al. 2010]. The survey did not examine the circumstances in which the injury occurred in the ankles mortise.

In a 2016 study by Zawadka, Kloc and Fijewski, they noted that the position of the shoulder girdle significantly affects the function of the cervical segment. The relation between the shoulder complex and spine cervical segment should be analyzed together during the training and rehabilitation plans [Zawadka, Kloc & Fijewski, 2016; Migliorini et al. 2019].

In the question about the awareness of uneven shoulder position, 9 athletes notice the difference. Two athletes think that the right shoulder is higher, two also think that the left shoulder is higher, while five volleyball players are unable to determine which side is higher.

Volleyball is a team sport with a relatively low degree of contact between players. It is also considered by some researchers to be a non-contact sport and therefore not often analyzed in terms of traumatism. According to research, 43.9% of shoulder joint injuries occur during the attack. Many prevention programs have been developed that include technical training, proprioceptive training, eccentric strength training, flexibility training, kinesiotaping, blade stabilization training and core muscle strengthening training. [Cuñado-González, Martín-Pintado-Zugasti & Rodríguez-Fernández, 2019; Brittany & Castilla, 2015; Baugh et al. 2018].

Conclusion

The postural assessment carried out shows the specific silhouette of volleyball players. It is characterized by a significant difference in the position of the left shoulder joint. This confirms the thesis made before starting the research. The non-dominant complex is increased by an average of 1.60 cm compared to the second in 17 out of 20 players. Shoulder protraction was observed in 8 of 20 volleyball players. All of the players group get better average results in functional tests compared to the reference group. The most painful trigger points in volleyball players are located in the right greater pectoral muscle. Research has noted that stabilization on the dominant limb is stronger, which allowed more movements with the other hand. Further research and analysis of the shoulder complex among volleyball players are needed.

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