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Effectiveness of the Involvement Of Selected Muscles During the Pre-Jump and Wind-Up Phase During the Execution of a Spike In U16 – U18 Female Beach Volleyball Players

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ABSTRACT

Background: „Laterality in beach volleyball is mainly manifested in the attacking activities of an individual (serving, spiking). Functional asymmetry affects the player's movement expression in all movement situations, and laterality is also important for the specialization of individual players.
Objective: The study aims to assess the lateral involvement of selected muscles (deltoideus, biceps femoris semitendinosus) and their efficiency in the phases before the spike jump and in the wind-up phase of the spike.
Materials and Methods: The research group consisted of 12 female players with an average age 16.17 (SD= 1.5). The main method used for data collection was measurement by Noraxon surface electromyography. We entered the transformed data into Microsoft Excel 365 for Mac. To evaluate the data, we used descriptive (frequency, percentage) and inferential (Shapiro-Wilk test, T-test, Man Whitney U test and correlation) statistical methods.
Results: The conclusion of the study is that there is no difference between the right and left sides in the evaluated muscle groups (deltoideus= 0.206; biceps femoris=0.569; semitendinosus=0.792). An interesting finding of the study is the strong correlation between the left deltoideus and the right biceps is interesting (0.812). The efficiency is higher in the wind-up phase of all the assessed muscles. The highest difference in efficiency is in the biceps femoris on the left leg, where the difference in efficiency of engagement in individual phases is over 25%. Conversely, the lowest difference is for the left semitendinosus (5.5%).
Conclusions: The study confirms that the effectiveness of muscle activity is more efficient in the wind-up phase, at the same time we add that in this phase the muscles work more symmetrically.

Keywords: Surface EMG; Hamstrings; Contralateral patterns; Laterality.

INTRODUCTION

Laterality in beach volleyball is mainly manifested in the attacking activities of an individual (serving, spiking). Functional asymmetry affects the player's movement expression in all movement situations. This means that the dominant side is overloaded, especially during the spike and serve (Lake, 2010). It is therefore important for the players to maintain coordination between both halves of their body to execute individual game activities precisely. The mismatch between the right and left halves affects the timing and accuracy of the strike (Lake, 2010; Vavák, 2011).

The spike is the most explosive and complex kinematic chain, whose execution does not occur at the level of a single segment. Instead, the muscles of the lower limbs, trunk, and upper limbs all play a crucial role in its implementation. The timing of individual muscle involvement and overall muscle coordination of the entire body is crucial for the effective functioning of this chain. Therefore, the connection and synchronization of all components is important for a spike. By correctly engaging individual segments and mastering the spike technique, a person can avoid chronic problems, which most often arise from poor technique and the related incorrect execution of the strike or overloading of individual segments (Plawinski, 2008).

The spiral line of the myofascial meridian is important for the spike. This line wraps in a double helix around the entire body. On one side, from the area of the skull around the contralateral shoulder, then from the front to the homolateral side of the trunk, the knee joint, and the arch of the foot (Dylevský, 2009; Myers, 2009).

The spike most commonly begins with a three-step approach (sometimes you can also encounter a two-step approach). The approach to the spike is used to obtain maximum possible height and an optimal position for the execution of the offensive strike (Haník, 2008). The approach in volleyball and in beach volleyball is different. For beach volleyball, a long second step over the heel and an even position of the feet at the time of the jump are typical, because on an unstable surface the player needs to bounce to jump more under the ball, because when he jumps forward, he does not reach maximum height. The height of the jump is caused by the muscles of the lower limbs and the extent of the relaxed swing of the arms, arms that go up during the pre-take-off phase (Plawinski, 2008). Players primarily contract the triceps surae, the quadriceps femoris and the so-called hamstrings (the semimembranosus, the semitendinosus, and the biceps femoris). During the flight phase, mainly the trunk muscles are involved (rectus abdominis, obliquus externus abdominis, obliquus internus abdominis, transversus abdominis).

Akshay (2017) divides the flight phase into 5 parts (wind-up phase, cocking phase, acceleration, deceleration, and follow through phase). The pre- take-off phase makes up 33% of the total time of the offensive strikes. Both limbs are elevated above the horizontal. The supraspinatus and deltoideus are the most active in this phase. The deltoideus is most active around 80°. In the cocking phase, the preparatory phase is characterized by maximum extension and external rotation of the shoulder girdle along with rotation of the spine. In this phase, the supraspinatus, infraspinatus, teres minor and deltoideus work the most. At the time of hitting the ball, the muscle activity of the shoulder girdle muscles decreases. Contact with the ball places enormous demands on the stabilization of the humerus. Mobility in the shoulder joint is very important for these phases. For optimal timing, the stabilization of the shoulder girdle, trunk muscles and shoulder blade is important (Akshay, 2017; Reeser, 2010).

The energy for the offensive strike is already obtained from the rotation of the torso, the shoulder blade then transfers the kinetic energy to the striking while also providing stable support for the shoulder joint. As the shoulder joint is less stable, great emphasis is placed on the dynamic stabilizers of the shoulder blade. Energy is transferred through the upper limb to the clavicle and thoracic spine. This results in rotational and unilateral strain on the back area (Braun, 2009; Escamilla & Andrews, 2009; Vilímek, 2007).

The shoulder girdle is the most mobile segment of our body. At the same time, however, we encounter its instability, and the associated susceptibility to injury. Vilímek (2007) assesses the involvement of the muscles of the shoulder girdle using surface electromyography and points at the greatest loading of the deltoid and supraspinatus muscles during the attack strike. In the maximum range of motion, chronic overloading of the teres minor, subscapularis, supraspinatus, and major and minor muscles can occur during outreach. According to the recording from the surface electromyography, microtraumas of the biceps brachii muscle are caused by repeated impacts with a high number of repetitions of the attacking strike. At the same time, it is proven here that the infraspinatus and teres minor muscles are important stabilizers of the humerus (Vilímek, 2007).

The pre-take-off phase in beach volleyball should be laterally symmetrical, because, unlike volleyball, the contralateral lower limb is not forward, but the feet are parallel with the toes in the direction of the jump. Therefore, there should be a symmetrical involvement of the muscle parts on the lower limbs and on the upper limbs. The most important muscles for the most efficient jump are the quadriceps femoris and the hamstring group. Their performance will be evaluated in this study. The same applies to the pre- jump phase before the outreach phase occurs, in which the trunk rotates. Symmetrical bounce is followed by abduction above the horizontal for both upper limbs. Here, among others, the deltoid muscle plays an important role (Reeser,2010).

The analysis of muscle activity in this study is an innovative approach that should bring practical insights to improve athlete performance and prevent injuries. It is assumed that there will be no statistically significant difference in hamstring activity in the pre-takeoff phase. Additionaly, the activity of the right deltoid is expected to be higher than that of the right left deltoideus.

MATERIALS AND METHODS

Aim of study

The study aims to assess the lateral involvement of selected muscles (deltoideus, biceps femoris, semitendinosus) and their efficiency in the phases before the spike jump and in the wind-up phase of the spike.

Research group

The research group consisted of 12 female players with an average age of 16.17 (SD=1.5). The players were selected from a wider representative selection of these age categories (U16-U18), based on the level of the selected skill. The height and weight of the female players were on average 172.1 cm (SD=4.3), and 58.1 (SD=4.9). Zhese data were obtained through personal anamnesis and somatometry; the instrument for somatic measurements was a medical scale with an integrated meter for measuring height (Tanita WB-3000, Tanita, Japan). Group of the wider selection performance players in the under 16-year category and under 18-year category consists of thirty players born in the years 2006–2010. These players were nominated by BC Strahov based on acquisition of selected skills of this category. The dominant hand of all probands is right. Laterality was judged by the activity of the dominant hand during warm-up. The study was conducted in accordance with the Declaration of Helsinki, the ethical standards of the university were adhered to. The study was implemented with the consent of the players, parents and the coaches of the given selection.

Table 1. Basic characteristics of the research group

	Age (years)	Weight (kg)	Height (cm)	BMI (Body Mass Index)	Experience (years)
1	16	60	167	21.51	4
2	16	63	177	20.11	4
3	18	56	172	18.93	5
4	14	60	170	20.76	3
5	17	64	176	20.66	5
6	16	67	175	21.88	4
7	18	52	171	17.78	4
8	15	57	174	18.83	3
9	17	60	176	19.37	4
10	18	56	177	17.87	5
11	13	51	163	19.20	4
12	16	51	167	18.29	3
SD	1.52	4.97	4.38	1.32	0.71
Median	16	58.5	173	19.28	4

Legend (SD= Standard Deviance)

Methods, Tools

The main method used for data collection was measurement by surface electromyography (hereinafter referred to as EMG). It is an examination based on the electrophysiological principle, which enables the monitoring of skeletal muscle activity (Krobot & Kolářová, 2011). Its gradual development moves away from invasive needle myography to surface EMG, without using needles (Hargrove, 2007). In this study the Noraxon device (USA) was used, along with a Nixon camera system (Nixon, Hong Kong). The Myoresearch program (Noraxon, USA) was used to work with primary data. This software allows reading from 32 channels of the device, also assigns a channel to an individual sensor to a given muscle part. The software further processes the signal by calculating the effective value, moving average, and applying basic digital filters. It stores the measured data in various types of protocols and is able to export data in various formats. The camera system together with the Myo research program allows you to divide the movement into individual phases and interpret the data in these sub-parts of the movement.

The measurement itself was carried out on 23/04/2023 during the afternoon training of the U16 and U18 in an inflatable hall with beach volleyball courts (BC Strahov, Prague).

Procedure

In preparation for the measurements, the skin over the belly of the muscle was shaved and cleaned with alcohol in order to reduce the skin impedance to 5 k. Bipolar surface electrodes (distance between electrodes 1 cm) were aligned with the longitudinal axis of the muscle according to SENIAM recommendations (Hermens, 2000). Electrode placement was confirmed using manual muscle testing.

All players warmed up with the start of testing. Subsequently, the players completed tests to assess the physiological length of the assessed muscles according to Janda (2004). All players had a positive evaluation in this test; therefore, the final number of tested players is 12. These 12 players were in a good state of health had not suffered any serious injuries in the past six months. The movement task itself, which led to the collection of primary data, proceeded as follows. The initial position of the tested player was on the court at the point of preparation for the spike run. The ball was pitched by the coach. The pitch simulated an optimal pass. Therefore, the player reacted to the pitch and the movement task task began upon evaluating evaluating the flight of the ball. For the movement task, only a three-step run to the spike was allowed. On the court, a marked area was designated where the players were required to jump and land, ensuring an optimal pitch. If the player jumped or landed outside the defined area, the attempt was recognized as invalid, due to an error in the thrown ball.

Each player performed this movement task three times, followed by six test repetitions. This activity was filmed by cameras from the side and the front. Subsequently, the 3 best attempts of each player were selected (on the basis of observation according to the correct execution of the task), which were used to obtain data from the EMG device. The pre-take-off and wind-up phases are evaluated in this study." As part of the research, the EMG involvement of the right and left sides was measured for the selected spike phases. „Differences in the values of the right and left halves of the body were examined. It was assumed that there is no difference in the involvement of the muscles of the right and left halves of the body.

In the first part of the results, the maximal voluntary contraction (MVC) of individual muscles was evaluated. It is assumed that the MVC of the evaluated muscles of the right and left side has the same value. MVC was assessed according to Janda (2004). Subsequently, performance in the test was compared with the MVC of individual players to assess the effectiveness of the use of individual muscles during the movement task. In the third part of the results, the involvement of the right and left side in selected phases of the movement task was evaluated. After measurement, the electromyographic signal was adjusted by rectification and smoothed with a mean square value (Root Mean Square parameter) using a window of 100 ms for evaluating muscle timing (Konrad, 2005). From the adjusted signal, 3 stable and best performed movement cycles were selected by expert assessment.

Statistical Data Procesing

For the results part the data were transformed in the Myoresearch program into the Standard EMG report and Symmetry Report protocols The standard EMG report was further subjected to a Point of Interest analysis, which shows individual values in individual parts of the movement. The transformed data were entered into Microsoft Excel. To evaluate the data, descriptive (frequency, percentage) and inferential (Shapiro-Wilk test, T-test, Mann-Whitney U test, and correlation) statistical methods were used.

The tools used were: software Microsoft Excel 2020 (Microsoft Corporation, USA) and Statistica PRO trial version (StatSoft, CR).

RESULTS

The results are divided into three parts. In the first part, the results of maximum voluntary contractions of selected muscles are evaluated according to Janda (2004). For MVC of individual muscle groups, the normality of the data was tested using the Shapiro-Wilk test. All evaluated groups had a normal distribution, so a two-sample t-test was applied. Based on the calculated test criteria (see table 2), it is concluded that there is no difference between the right and left sides in the evaluated muscle groups.

Table 2. T- test results

muscles	t- value	p- value
deltoideus	1.31	0.21
biceps femoris	-0.58	0.57
semitendinosus	-0.27	0.79

As part of the work with the results of MVC, a correlation was performed between individual muscle parts. A higher dependence appears between MVC of both biceps with the left deltoid and also the right biceps with the right deltoid. The high correlation between the left deltoideus and the right biceps is interesting. This finding may point to associations regarding contralateral patterns and muscle imbalances and would be worthy of further observation.

Table 3. Correlation results

	m deltoideus		**biceps femoris**		**semitendinosus**	
	right	**left**	**right**	**left**	**right**	**left**
deltoideus right		0.69	***0.83***	0.54	0.61	0.59
deltoideus left	0.69		***0.79***	***0.81***	0.47	0.34
biceps femoris right	***0.83***	***0.79***		0.52	0.56	0.41
biceps femoris left	0.54	***0.81***	0.52		0.48	0.55
semitendinosus right	0.61	0.47	0.56	0.48		***0.75***
semitendinosus left	0.59	0.34	0.41	0.55	***0.75***	

We chose the phases of the spike run that we evaluated on the basis of the involvement of the muscles of the right and left side. Both in the adjustment phase and in the wind-up phase, the muscles of the right and left sides should be engaged symmetrically. The assessment proceeded similarly to the MVC evaluation. First, the normality of the data was assessed using the Shapiro-Wilk test. The values of individual measurements in the pre-jump phase and wind-up are alternately distributed, some are normally distributed, some are not. If the data were parametric, a T-test was applied; for non-parametric data, the Mann-Whitney U test was used. If one side was normally distributed and the other was not, the T-test was applied based on the central limit theorem.

Table 4. Statistical tests results between right and left side of body

phase	muscles	test	p- value	difference between sides
Pre- jump	deltoideus	Man- Whitney U test	0.04	sides are different
Pre- jump	biceps femoris	Man- Whitney U test	0.03	sides are different
Pre- jump	semitendinosus	T-test	0.25	sides are the same
Wind-up	deltoideus	Man- Whitney U test	0.03	sides are different
Wind-up	biceps femoris	T-test	0.87	sides are the same
Wind-up	semitendinosus	T-test	0.04	sides are different

The test criteria can be seen in table 4. In evaluating the individual attempts of the group, the following conclusions were made. In the pre- jump phase, the deltoids and biceps are involved differently, so there is a difference in the involvement of the right and left sides. Semitendinosus are involved equally. In the wind-up phase, the biceps are involved in the same way and the deltoid and semitendinosus are involved differently.

In the final phase of the results, the effectiveness of muscle involvement in the movement task during the assessed phases is evaluated. Based on the MVC, the involvement of individual muscles in the movement task was calculated in percentages. Tables 5 and 6 contain the average values of the assessed movement tasks of individual probands.

Table 5. Average percentage of muscle involvement from trials assessed in the pre- jump phase.

Pre- jump	deltoideus		biceps femoris		semitendinosus	
	right	left	right	left	right	left
1	5.48%	22.51%	48.01%	22.54%	21.58%	34.80%
2	3.76%	58.28%	31.27%	31.18%	39.45%	45.89%
3	11.87%	39.75%	25.42%	6.92%	22.70%	15.33%
4	1.72%	3.70%	55.23%	32.79%	35.95%	20.97%
5	43.42%	28.54%	18.29%	7.74%	26.27%	13.14%
6	*15.23%*	*32.52%*	*32.61%*	*35.63%*	*35.09%*	*37.34%*
7	19.24%	14.88%	39.93%	15.18%	27.37%	12.92%
8	5.91%	14.71%	31.75%	10.62%	19.84%	16.89%
9	95.00%	93.30%	59.45%	31.35%	94.20%	51.00%
10	7.33%	32.04%	32.85%	40.79%	18.75%	17.77%
11	11.17%	11.59%	18.04%	6.38%	22.31%	10.04%
12	13.05%	2.89%	33.14%	11.05%	20.20%	27.59%
Average	19.43%	29.56%	35.50%	21.01%	31.98%	25.31%

The following tendencies can be seen in the adjustment jump phase: On average, the left deltoid muscle is more active in the wind-up phase, in three players the activity is low and symmetrical. One player's deltoid activity is high. If muscle activity is low in the adjustment phase, a relaxed hand swing occurs, and it is therefore an advantageous position for the subsequent jump. In the group, the left deltoid muscles are more active in this phase. The biceps of two players are involved symmetrically, otherwise the right side is much more active. In the semitendinosus, the muscles are symmetrically involved in three probands, otherwise the right side is also more active, as in the biceps femoris. In the adjustment pre-jump phase, the contralateral involvement of the left deltoid muscle with the hamstrings of the right leg can be observed. The effectiveness of the involvement in the pre-jump phase in the deltoid muscle fluctuates, in a few probands it is more efficient, but in the majority the involvement is rather lower, which should be related to the relaxed swing of the arms before the jump. For higher values, there is a possibility of incoordination with the last step and swing, the arms are already moving forward at this moment. In this phase, symmetrical and balanced muscle activity is observed in proband no. 6.

Table 6. Average percentage of muscle involvement from the assessed trials in the wind-up phase

Wind-up	**deltoideus**		**biceps femoris**		**semitendinosus**	
	right	**left**	**right**	**left**	**right**	**left**
1	*69.21%*	*74.11%*	*59.69%*	*50.22%*	*24.60%*	*21.91%*
2	52.50%	38.44%	36.10%	69.41%	33.52%	28.88%
3	*40.23%*	*33.93%*	*46.38%*	*45.70%*	*45.06%*	*43.37%*
4	12.65%	13.53%	46.20%	46.40%	41.87%	31.67%
5	54.06%	51.60%	50.19%	63.22%	56.01%	46.87%
6	23.31%	12.37%	25.11%	32.34%	59.30%	51.37%
7	49.66%	21.47%	59.45%	36.22%	45.31%	10.84%
8	9.87%	8.20%	40.23%	35.22%	44.96%	27.35%
9	*97.00%*	*96.08%*	*96.43%*	*93.39%*	*96.12%*	*53.49%*
10	20.64%	18.47%	30.99%	46.05%	19.96%	16.06%
11	26.37%	17.79%	25.10%	33.33%	45.93%	29.06%
12	72.73%	47.59%	57.56%	21.26%	57.58%	8.61%
Average	44.02%	36.13%	47.79%	47.73%	47.52%	30.79%

In the wind-up phase, the involvement of the right and left deltoid muscles is much more symmetrical.

In this phase, half of the probands symmetrically engage the right and left deltoid muscles, in the other half, higher activity of the right side prevails. The activity of the biceps femoris is equally distributed on the right side, left side and symmetrical involvement. In the semitendinosus, there is a symmetrical involvement in three cases, and in the rest of the group, the right side is more heavily loaded. In the wind-up phase, the right side is more involved in all the monitored muscles.

The efficiency of deltoid muscle involvement is higher in this phase than in the pre-jump phase. In only two cases is the efficiency of the deltoid muscle work low, the efficiency value was also reduced in the pre-jump phase in these probands. Both probands in the video did not have a relaxed hand swing in the full range of motion, so the values may be lower. The effectiveness of the involvement of the biceps femoris and semitendinosus is higher and relatively symmetrical.

When assessing the effectiveness of the involvement of individual muscles in the movement task, the probands 1, 3, 5 and 9 effectively engage muscles when performing the movement task.

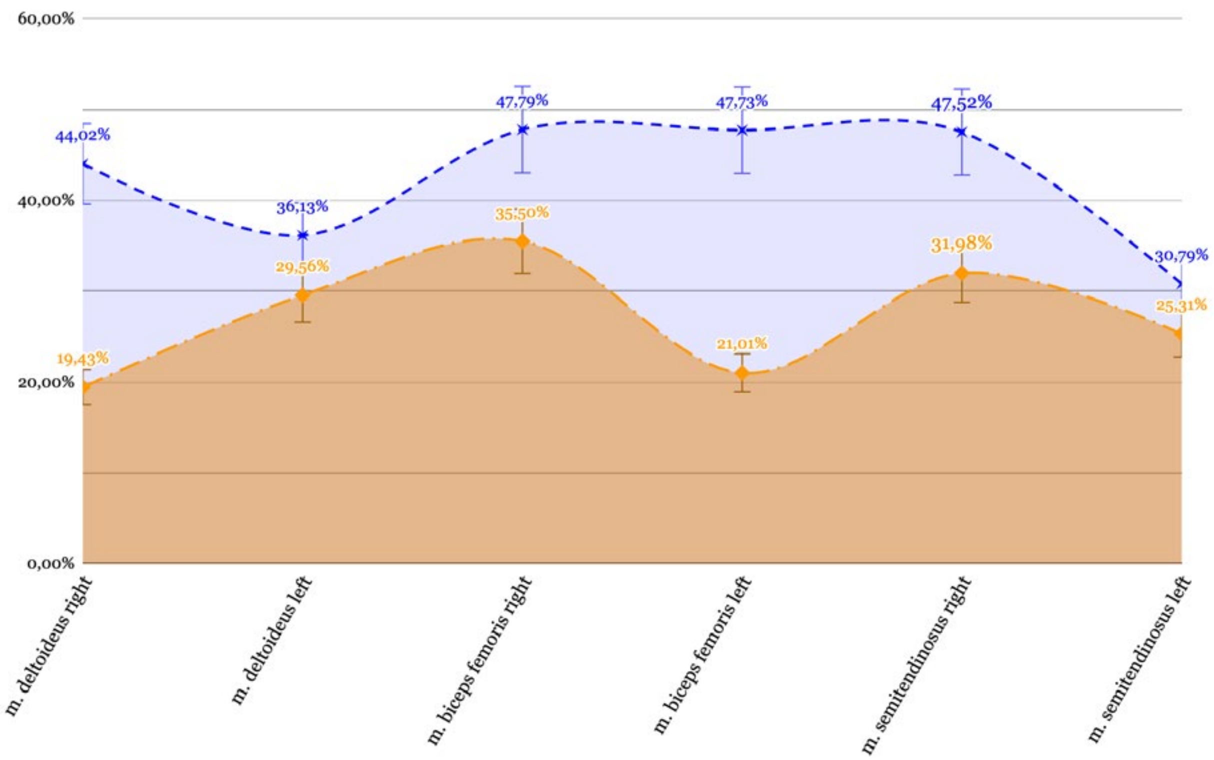

Figure 1. Average percentage of muscle involvement between right and left side

In conclusion, a comparison of the effectiveness of the average involvement of individual muscles in the assessed phases is presented. As can be seen in figure 1, the efficiency is higher in the wind-up phase for all the assessed muscles. The highest difference in efficiency is in the biceps femoris on the left leg, where the difference in the efficiency of involvement in the individual phases is over 25%. Conversely, the lowest difference is for the left semitendinosus (5.5%).

DISCUSSION

The aim of the study was to assess the involvement of the right and left sides during selected phases of the offensive strike. The involvement and effectiveness of the deltoideus, biceps femoris, and semitendinosus were assessed.

When assessing the selected muscle activity, based on the evaluation of maximum voluntary contractions, it was statistically demonstrated that there is no statistically significant difference between the MVC values of the right and left biceps femoris, semitendinosus, and deltoideus in the research group. In the evaluated muscle groups, there are no demonstrable imbalances in the work of the left and right sides.

In the pre-take-off phase, the right side is much more active, and in the wind-up phase, the muscles of the right lower limb are more involved, or the limbs are symmetrically involved. During the movement, statistical analysis showed that the biceps femoris and the semitendinosus work differently in the pre-jump phase. In the wind-up phase, the biceps femoris works symmetrically and the semitendinosus works differently. In the MVC correlation, the high correlation between the left deltoid muscle and the right biceps femoris is interesting. This correlation may point to associations regarding contralateral patterns and muscle imbalances and would be worth further research.

In this study, the deltoid muscles are used much more during the wind-up phase, in this phase they are also more symmetrically involved laterally compared to the phase before the rebound, in which the left deltoid muscle is much more active. In both phases, a statistically different involvement of the right and left sides was also found. These tendencies in the involvement of the deltoid muscle may be the beginning of chronic health problems.

As part of the assessment of the involvement of individual muscles effectiveness during the movement task, more right hamstrings are involved in both evaluated phases. In the pre-jump phase, the left deltoid muscle is more active, in the wind-up phase, the right deltoid muscle is more active. The effectiveness of the involvement in the pre-jump phase in the deltoid muscle fluctuates, in a few probands it is more efficient, but in the majority the involvement is rather lower, which should be related to the relaxed swing of the arms before the jump. For higher values, there is a possibility of incoordination with the last step and swing, the arms are already moving forward at this moment. In this phase, symmetrical and balanced muscle activity is observed in proband No. 6.

When assessing the effectiveness of the involvement of individual muscles in the wind-up phase, according to the results, the muscles of probands 1, 3, 5 and 9 are effectively involved. In conclusion, it is confirmed that the effectiveness of muscle activity is greater in the wind-up phase. Additionally, it is noted that in this phase, the muscles work more symmetrically.

In the study of disorders of the motor system in female volleyball players by Vorálek (2007) confirms the theory of the presence of muscle imbalance, with a predominance of the upper fixators of the shoulder blades and insufficiency of the serratus anterior muscle, as well as shortening of the pectoralis major, minor, and sternocleidomastoid muscles. This leads to poor posture with shoulder protraction, forward head posture, increased cervical lordosis and thoracic kyphosis. These muscle imbalances, in the sense of upper crossed syndrome according to Janda, are also confirmed by Page in his study from (2011) in volleyball players. According to Reeser (2010), the shoulder joint is listed as the third most frequently caused injury. It even ranks second among chronic problems. In this study, deltoid muscle activity alternates in observed phases so these claims cannot be supported (Jadhav, 2010; Page, 2011; Reeser, 2010; Verhagen, 2004; Vorálek, 2007; Zetou, 2006).

The most exposed joints in beach volleyball are the shoulder, hip, and knee joints. During the game, not only the joints themselves are stressed, but also the entire joint capsules. In the shoulder joint, proper function depends on the corresponding functioning of static (shoulder joint ligaments and labrum glenoidale) and dynamic (rotator cuff muscles and deltoid muscle) stabilizers. The shoulder girdle is the most mobile segment of the human body, which is why it is prone to instability and, consequently, susceptibility to many injuries. During the training process, micro-traumas can occur, and based on them, imbalances and pain syndromes arise in this area In this study, no statistically significant difference was found between the activity of the right and left deltoids, so the results of these studies cannot be supported (Dylevský, 2009; Martínková, 2013).

According to Frisch (2017), shoulder pain and injuries in overhead sports are caused by overtraining and overload. In beach volleyball, Contemori (2017) deals with the health condition of the shoulder. In his study, he evaluates professional players using surface EMG. He uses this method to evaluate external rotation and elevation, especially in the infraspinatus and supraspinatus muscles. 12 players have infraspinatus atrophy. EMG shows a higher activation pattern of the infraspinatus muscle of the hitting arm in players who do not suffer from atrophy of this muscle (Contemori, 2017; Frisch, 2017).

Currently, one of the very common problems is impingement syndrome, which is caused by internal rotation with simultaneous abduction in the shoulder joint and is therefore often associated with damage to the rotator cuff (Burkhart, 2003). A typical symptom is pain between 60° and 120° of abduction or flexion (Hamill & Knutzen, 2009). At the same time as the muscles of the shoulder joint, the long head of the biceps brachii muscle is also affected, in abduction with rotation, the bicipital groove is damaged. During the overhead throw, the shoulder joint rotates extremely externally during the thrust and at the same time flexion occurs in the elbow joint. biceps brachii slows the movement of the elbow joint into extension during the throw and is therefore maximally loaded. Oliveira (2011) analyzes shoulder girdle muscle activity using surface EMG during delivery in players with impingement syndrome compared to healthy volleyball players. Probands with impingement syndrome have increased activity in the trapezius and infraspinatus muscles, reduced muscle activity in the rectus abdominis and obliquus abdominis externus muscles. According to Skolimowski (2009), there is a big difference in the work of the infraspinatus muscle and the deltoideus (Hamill & Knutzen, 2009; Oliveira, 2011; Skolimowski, 2009).

CONCLUSION

It can be concluded that there is no difference between the right and left sides in the evaluated muscle groups. The high correlation between the left deltoideus and the right biceps is interesting. This finding may point to associations regarding contralateral patterns and muscle imbalances and would be worthy of further observation.

In the pre-take-off phase, the left side is more active, while in the wind-up phase, the right side is more active. Different activity in the observed phases does not indicate overloading of one party during this activity. Compensation in beachvolleyball focuses on lateral imbalance and shortened hamstrings. In this study, no statistically significant difference was demonstrated between the activity of the right and left muscle groups. In the hamstrings, increased compensation between the dominant and non-dominant limbs does not need to be considered. The same statement cannot be made for the deltoid muscles, as the shoulder joint consists of many muscle groups, many of which are in deeper layers. Therefore, the activity of the deltoid muscle is not sufficient evidence to change the view on this issue. It would be interesting to use the method of deep electromyography to gain a deeper understanding of muscle activity in the shoulder joint.

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