Journal of Theoretical and Applied Mechanics, Sofia, Vol.54 (2024) pp. 511-524
INTERDISCIPLINARY TOPICS

SPECIFICITY OF INTERMUSCULAR COORDINATION IN THE BASEBALL HIT IN RELATION TO THE ANGULAR VELOCITY OF THE BAT SEGMENT

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[Received: 30 November 2023. Accepted: 14 December 2024]

doi: https://doi.org/10.55787/jtams.24.54.4.511

ABSTRACT: The aim of this study was to estimates the relation between the kinematic structure of the baseball strike movement in adolescent baseball players and the applied muscles electromyographic activity. The research was carried out during the movement of the bat in thirteen-year-old baseball players ($n = 5$). The used video recording with two cameras from different points of view was synchronized with conducted surface electromyography. The obtained results are of essential importance for the coaches in a developing and using correct methods in the training process to improve the technical skills of the athletes. Our results relate the muscle activity with the trajectory and speed of the bat during the stroke, which benefits in improving the efficiency in hitting.

KEY WORDS: baseball, hitting, electromyographic and kinematic analysis.

1 INTRODUCTION

The popularization and development of the sport of baseball in Bulgaria is related to initial training and the subsequent inclusion of children in systematic baseball activities in the clubs. Their training is a long-term and consistent process that includes physical, technical, tactical, psychological preparation, which is accompanied by the changes in the child's organism. In thirteen-year-old children, we observe rapidly occurring changes in biological development and psychological attitude, which leads to changes in attitude towards activities, motivation to achieve success. The development of different muscle groups and their importance in the sport of baseball is important for planning and implementing the training process of young athletes. The first study was conducted by Kitzman in 1964 [1]. He followed the bilateral function of the pectoralismajor, tricepsbrachii and latissimusdorsi muscles in two professional

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players versus two non-professional players. The limited results indicate qualitatively that precisely these muscles are involved in the initial part of the rotation. While other muscle groups determine the stroke in the later phase of the swing and movement of the bat. Another qualitative analysis of a non-professional player [2] noted the importance of the abdominal muscles in stabilizing the trunk during the turn [1]. Shaffer and colleagues (1993) provided the first most comprehensive and quantitative look at muscle activity during swing [3]. Using surface electrodes, they recorded EMG signals from 12 muscles in 18 professional batters. These electrodes were simultaneously placed on the erectorspinae and abdominalobliques, and on the vastusmedialisobliques (VMOs), semimembranosus, and bicepsfemoris, as well as the lower part of the gluteusmaximus of the hind leg and on the supraspinatus, triceps, posterior deltoid, and middle part of the serratusanterior of the leading arm during the rotation. As with many kinematic and kinetic studies, researchers divide batting into the following four phases: “preparatory”, “pre-swing”, “swing”, and “follow-through”. The results show that batting is a coordinated muscle activity starting at the hip, followed by the trunk and ending in the upper limbs. The rotational force is initiated at the hip, and the high activity of trunk muscles indicates that they are required for dorsal and abdominal stabilization during rotation. It is concluded that the hamstrings and gluteal muscles contribute to a stable base and provide a power pull that propels the torso during the swing, while the high activity in trunk muscles suggests that they should be the focus of exercise and conditioning programs in batsmen. professionals. Contrary to expectations, upper limb muscles are important more for positioning the upper limb and arms than for generating force with them. Works by Nakata et al., 2012, 2013 tracked changes in lower extremity muscle activity while participants performed a full swing with the bat by examining the RectusFemoris (RF), Biceps-Femoris (BF), TibialisAnterior (TA) and MedialGastrocnemius (MG) of the lead leg and the back leg in 10 professionals and 10 amateurs [4, 5]. The characteristics of EMG activity clearly differed between pitching and pitching, and between baseball professionals and amateurs, indicating that assessing EMG activity in batting allows for technical evaluation of performance.

Consistent and systematic instruction in the proper mastery of the technical elements of the baseball game is especially important in beginning youth baseball players. The use of electromyographic and kinematic analysis allows detailed information to be obtained on the different muscle groups used in the hitting swing technique. In connection with the upper words the aim in this investigation was to estimates the relation between the kinematic structure of the baseball strike movement in adolescent baseball players and the applied muscles electromyographic activity.

2 Materials and Methods

We set out to determine the electromyographic activity of selected muscles of the baseball player's kinematic chain during the realization of the bat motion for a baseball strike in relation to the angular velocity of the bat segment. Conducting the research made it necessary to solve the following tasks: Survey of publications on similar studies in world literature. Carrying out a combined study of kinematic and myographic indicators for the given group of muscles from upper and lower limbs. Expert selection of quality baseball shots. Practical shooting was done in two mutually perpendicular planes at the scale of the athlete “general plan”, which means that all parts of the body are within the frame. The calibration of the measuring field is realized independently for both planes. The video camera for recording the vertical plane is placed stationary on a tripod at the required distance and height around the general center of gravity of the athlete in a standing position. A second vertically positioned video camera is placed directed at the horizontal plane in which the rotational movements of the baseball player's upper body are performed. Its point of view is at the necessary distance providing the conditions for observing the movements of the upper limbs including the trajectory of the bat and is directed vertically downwards. Thus, the two video cameras shoot separately and calibrate independently. The cameras used in the research are CASIOZR400. The selected video recording rate is 120 fps (time magnification) in automatic setting. The speedshutter function is set to 1/2000.

For the realized surface electromyography, the BTSFREEEMG 300 equipment was used, which through the 8 sensors placed on the tested athletes allowed to measure the activity of the tested muscles. In the conducted research, the used equipment and video cameras were synchronized to determine the intermuscular coordination and determine the absolute values of muscle tension in each examined muscle when performing the movement. Five athletes aged 13 with different physical capabilities and developed technical skills from the children's team of the Lions - NSA were studied. All have one year of experience, have been playing baseball regularly since the beginning of 2022 and are right-handed batters. The research was carried out on 23.05.2023, and we examined five successful attempts. Using 8 electrodes, we monitor the activity of the following eight muscles: Right deltoid muscle front part – Deltoideus Anterior Right (DAR), right deltoid muscle back part – Deltoideus Posterior Right (DPR), left biceps axillary muscle Biceps Barchii Left (BBL), left triceps armpit muscle - Triceps Barchii Left (TBL), right gluteus maximus Right (GMR), right biceps femoris Biceps Femoris Right (BFR), left vastus lateralis Left (VLL), left pectoralis major – Pectoralis Major Left (PML). The task was to determine their importance in the movement of the bat to hit the baseball.

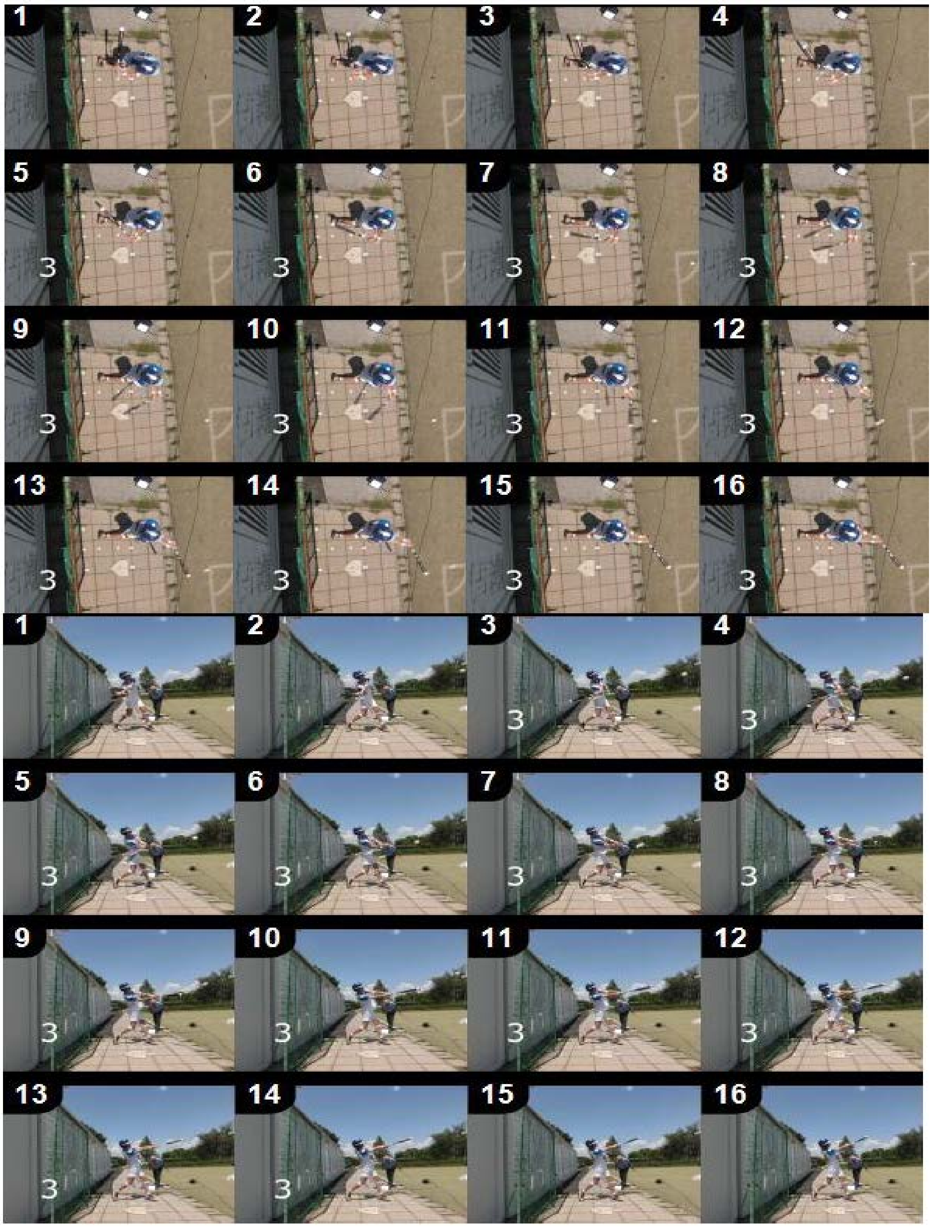

Fig. 1. Movement of the bata in the horizontal and vertical planes.

3 Results and Discussion

The specific research interest is focused on the activity of the studied muscles in individual players during the realized movement with the bat for an effective hit on the ball. Recording the electromyographic activity of selected muscles from the baseball player's kinematic chain when swinging a baseball hit in relation to the angular velocity of the bat segment gives information about their activity at each moment of the movement. The recorded muscle activity is different for everyone, as well as the effectiveness of the hit expressed in power and the ability to hit the ball farther, as Fig. 2 presents the study of the most successful player.

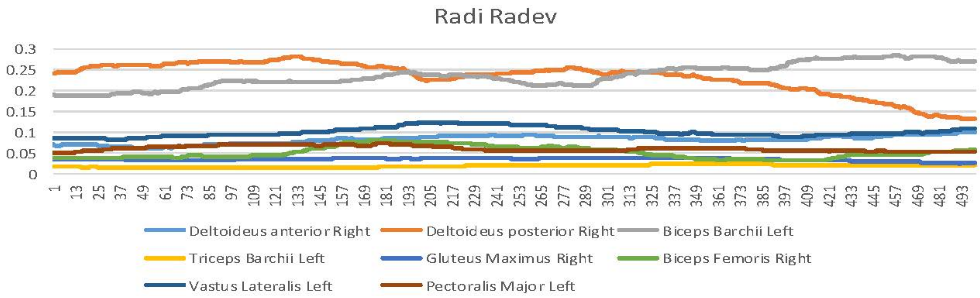

Fig. 2. The electromyographic activity of the examined muscles in Participant 1 (P1).

The DPR, BBL, GMR action prevails with a uniform development of their dynamics along the trajectory. In VLL, activity also increases. A substantial increase in myographic signal was observed in DPR and BBL. The value of the angular velocity logically increases significantly during the trajectory of the bat, and its maximum precedes for a short time interval the moment of hitting the ball. The angular velocity increases to a value of Vmax-1939.42 deg/s. The muscle activity of DAR and TBL overlap each other, and if at the beginning the electrical activity is higher for DAR and lower for TBL, at the end of the motor action they are exchanged. During the execution of the shot, we observe the maximum linear speed of the bat (Vmax) of 36 m/sec. and a maximum angular velocity (Vygl.max) of 2121 deg/sec. At the actual impact of the ball, the linear velocity at the impact (Vlin) has a value of 24 m/sec., and the angular velocity at the impact (Vygl) is 1611 deg/sec.

The use of the above-described figure indicator (angular velocity – Fig. 3) is suitable for participants with upper and lower limbs with significant differences in their lengths. Although, according to statistical theory, the DAR, DPR muscles are mutually opposed, they are involved in the development of instantaneous speed. A similar conclusion is also available for the TBL–PML muscles, but the two muscles are positioned in the lower and upper limbs. Indicators of myographic activity can be grouped

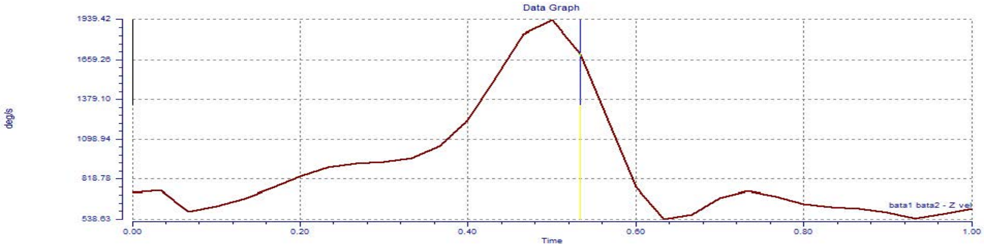

Fig. 3. Angular velocity of the rod segment at P1.

into two different groups – upper and lower limbs.

In this baseball player more involved muscles DPR, BBL, TBL, GMR, BFR, VLL are present. Activity for DPR and BBL is strongly highlighted. VLL joins this group.

Under the influence of muscle activity during the execution of the kick by this competitor, we observe reaching a maximum linear speed of the bat (Vmax) of 17 m/sec. and a maximum angular velocity (Vygl.max) of 1313deg/sec. At the actual impact of the ball, the linear velocity at impact (Vlin) has a value of 13 m/sec., and the angular velocity at impact (Vygl) is 1084 deg/sec.

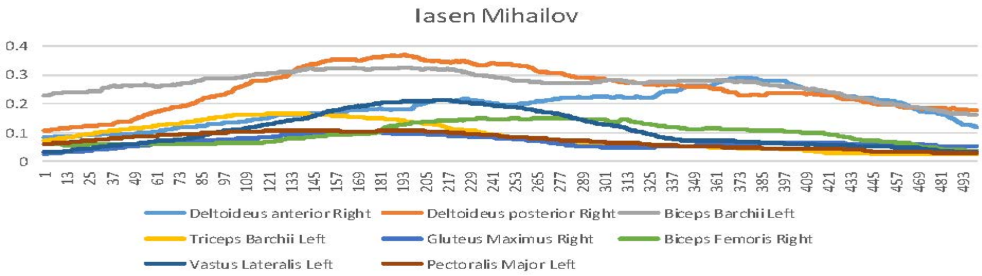

Fig. 4. The electromyographic activity of selected muscles in Participant 2 (P2).

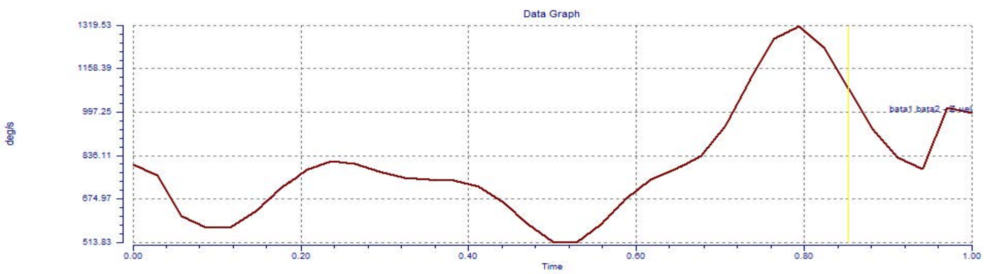

Fig. 5. Angular velocity of the bat segment at P2.

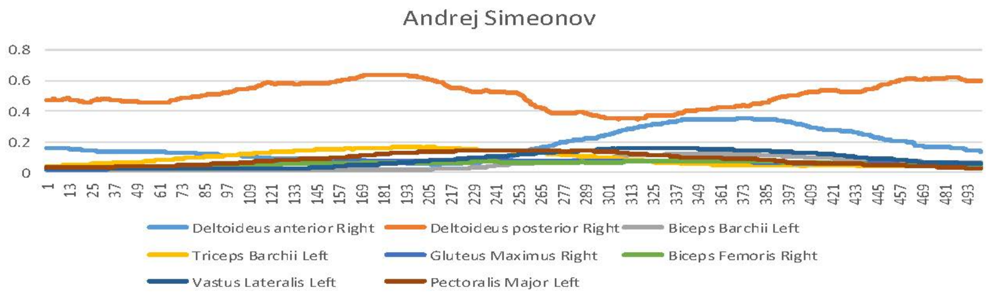

Fig. 6. Electromyographic activity in Participant 3.

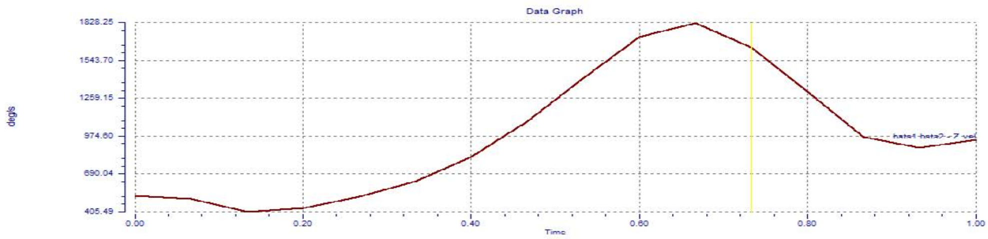

Fig. 7. Angular velocity of the drum segment at P3.

DAR and DPR predominate in this competitor. Dominance of DPR activity was observed compared to the rest of the examined muscles. At the time of the decrease in the activity of the DPR, the influence of the DAR is increasing.

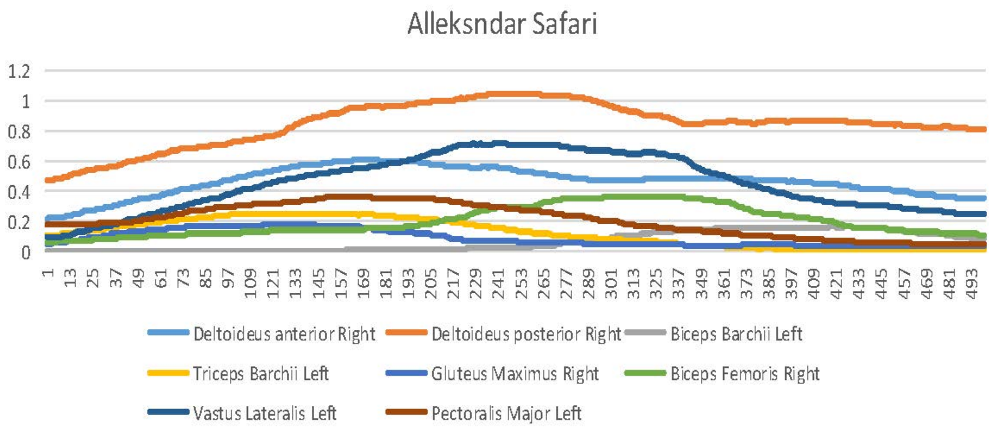

Fig. 8. Electromyographic activity for Participant 4.

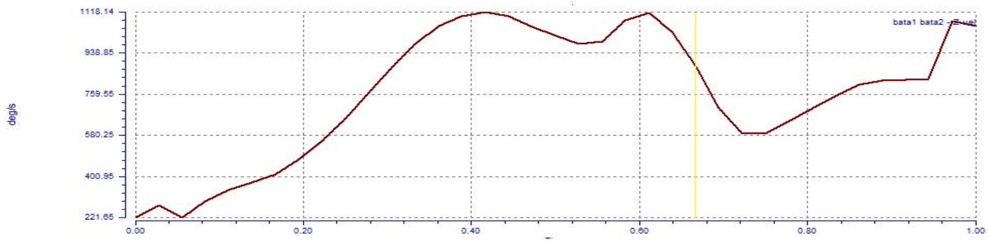

Fig. 9. P4 bat segment angular velocity.

During his execution of the shot, we observe reaching a maximum linear speed of the bat (Vmax) of 20 m/sec. and a maximum angular velocity (Vygl.max) of 1825 deg/sec. At the impact of the ball itself, the linear velocity (Vlin) has a value of 17 m/sec., and the angular velocity at the impact (Vygl) is 1730 deg/sec.

The following muscles are relatively evenly involved with good synchronization between them in the order of electrical activity – DeltoideusanteriorRight, DeltoideusposteriorRight, BicepsBarchiiLeft, TricepsBarchiiLeft, GluteusMaximusRight, BicepsFemorisRight, VastusLateralisLeft, PectoralisMajorLeft with a clear maximum in the middle of the trajectory of the motor activity performed. Vmax –1828.25 deg/s Vmax/Vlin. – 19/9 m/sec. Vygl. – 1113/873 deg/sec.

When performing the stroke, we observe a maximum linear speed of the bat (Vmax) of 36 m/sec. and a maximum angular velocity (Vygl.max) of 2121 deg/sec. At the impact of the ball itself, the linear velocity at impact (Vlin) has a value of 24 m/sec., and the angular velocity at impact (Vygl) is 1611 deg/sec.

DAR and BFR predominate, and Fig. 10 shows the integrated myographic signal for the participant under study. The electrical activity for DAR is predominant and

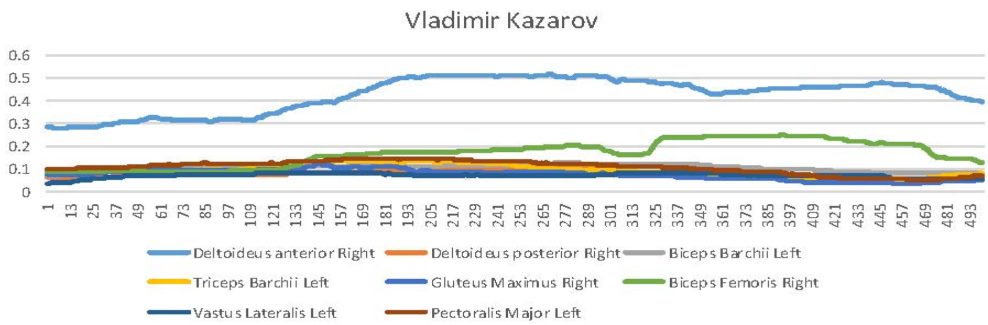

Fig. 10. Myographic structure for participant 5.

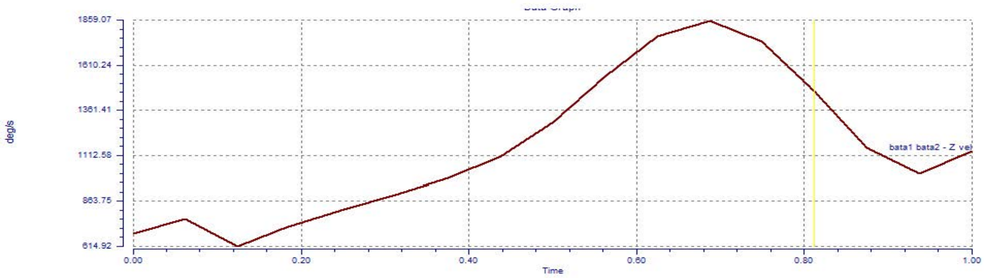

Fig. 11. Angular velocity of the segment of the bata for P5.

BFR is next in the series. The rest of the muscles have low values. DAR also has a distinct feature containing changes over time. Muscles should be divided according to their belonging to the upper limbs DAR, DPR, BBL, TBL, BMR, and to the lower limbs GMR, VLL, PML.

Under the influence of muscle activity during the execution of the kick by this athlete, we observe reaching a maximum linear speed of the bat (Vmax) of 22 m/sec. and a maximum angular velocity (Vygl.max) of 1851 deg/sec. At the actual impact of the ball, the linear velocity at impact (Vlin) has a value of 16 m/sec., and the angular velocity at impact (Vygl) is 1470 deg/sec. The speed realized by the individual competitors is of important importance for their efficiency when performing the shot, as the summarized values of Vmax, Vlin, Vygl.max, Vygl are presented in Table 1.

Table 1. Values of Vmax, Vlin, Vygl.max, Vygl for individual athletes' indicator Unit of measurement with name initials – R.R. Y.M. An.S. Al.S. V.K.

Parameter	Units	R.R.	Y.M.	An.S.	Al.S.	V.K.
Vmax	m/sec	36	17	20	19	22
Vlin	m/sec	24	13	17	9	16
Vygl.max	deg/sec	2121	1313	1825	1113	1851
Vygl	deg/sec	1611	1084	1730	873	1470

The values of one of the participants R.R. stand out. which reaches a maximum angular velocity (Vygl.max) of 2121 deg/sec. when performing the baseball bat motion and at a maximum linear bat velocity (Vmax) of 36 m/sec.

Table 2 shows the significant correlation coefficients of the angular velocity of the bat segment in relation to the myographic activity of the studied muscles in individual participants. The bata segment is the segment connecting its two ends. Angular velocity testing is convenient for all participants as it eliminates the varying length of the upper limbs. The presence of DAR containing significant values in all

Table 2. Correlation dependencies of the electromyographic activity of the studied muscles in individual participants

Participants	DAR	DPR	BBL	TBL	GML	BFR	VLL	PML
1	.523*	-.915**	.891**	.711**	-.573*	-.261	-.101	-.524*
2	.800**	-.131	-.404	-.861**	-.360	.236	-.429	-.827**
3	.617*	-.569*	.815**	-.063	.689**	.820**	.948**	.674**
4	.804**	.479	-.092	.429	.432	.381	.623**	.565*
5	.672**	.081	.067	-.662**	-.798**	.904**	.290	-.601*

participants is evident. In second place is PML, where the action of the muscle is ambiguous, positive values are obtained for some and negative values for others. The electromyographic activity of the studied athletes is different for each of them, this can be seen in more detail in the summary data. The general dependencies of DAR for all studied participants are presented in Fig. 13.

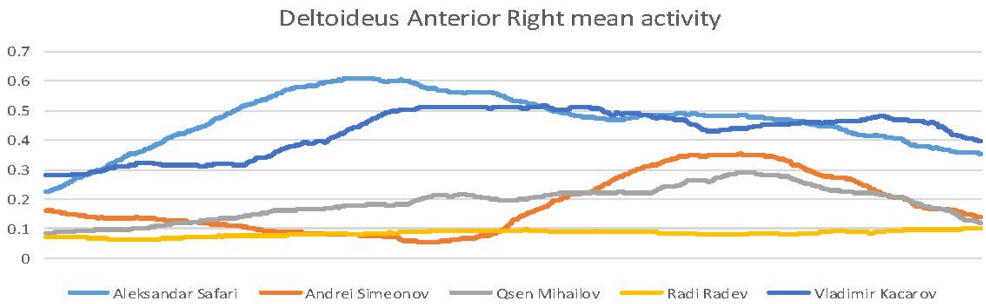

Fig. 12. The electromyographic activity of Deltoideus anterior Right.

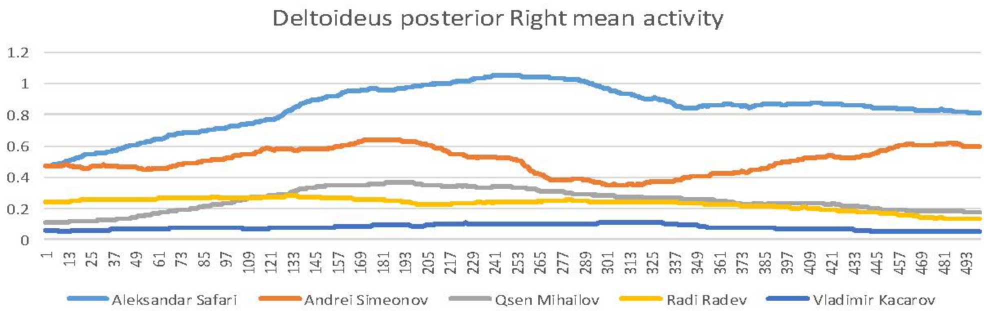

Fig. 13. The electromyographic activity of Deltoideus posterior Right

The DAR-integrated electromyographic signal predominates. Electrical activity for DAR is predominant – 214 units of total signal. The remaining muscles have low total values. DAR also has a distinct feature containing changes over time. Muscles should be divided according to their belonging to the upper limbs DAR, DPR, BBL, TBL, BMR, and to the lower limbs GMR, VLL, PML. These characteristics individualized for the DAR muscle show what they mean to the participants. High electrical activity is present for A.S. and for V.K. Al. S. and An. S. were underlined when using DPR.

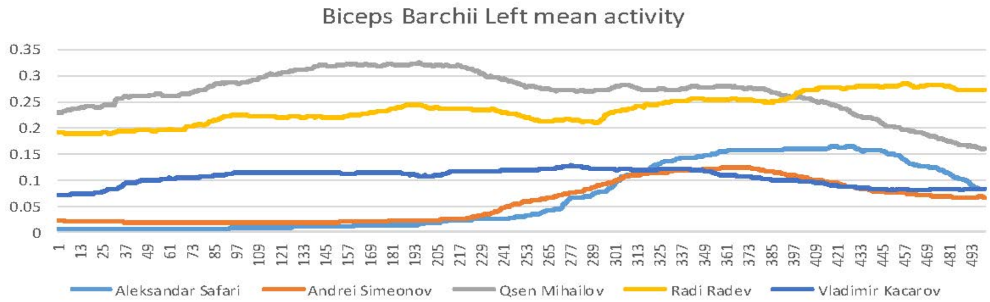

Fig. 14. Electromyographic activity of Biceps Barchii Left.

A preference for this BBL muscle is shown by A.S., R.R.

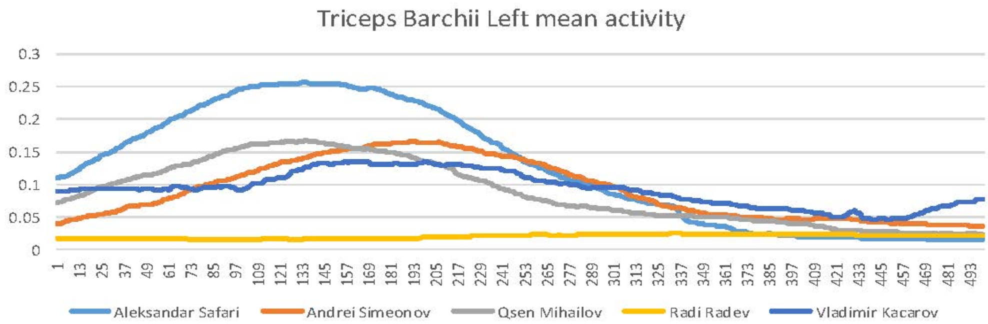

Fig. 15. Electromyographic activity of Triceps Barchii Left.

The involvement of the TricepsBarchiiLeftTBL is expressed in the extension of the arm and preparation for the acceleration of the bat relatively early in its trajectory.

GluteusMaximusRight is the most involved muscle because it initiates action at the beginning of the swing and during the trunk rotation, it reaches its maximum of the cycle, before the impact of the club.

BFR is most active in with two competitors. BFR has a pulling effect.

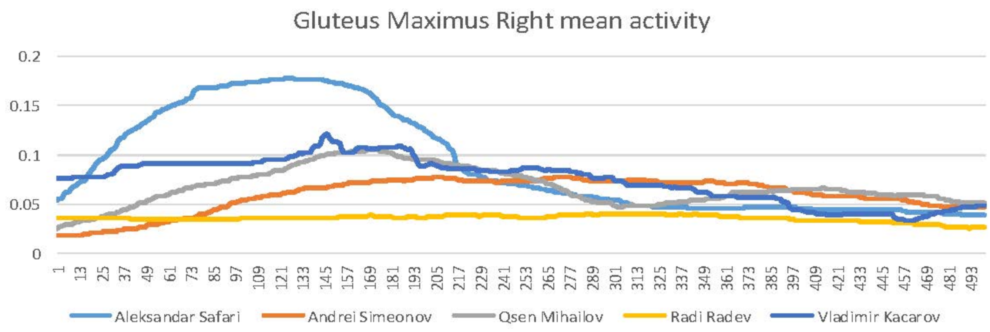

Fig. 16. Electromyographic activity of GluteusMaximusRight.

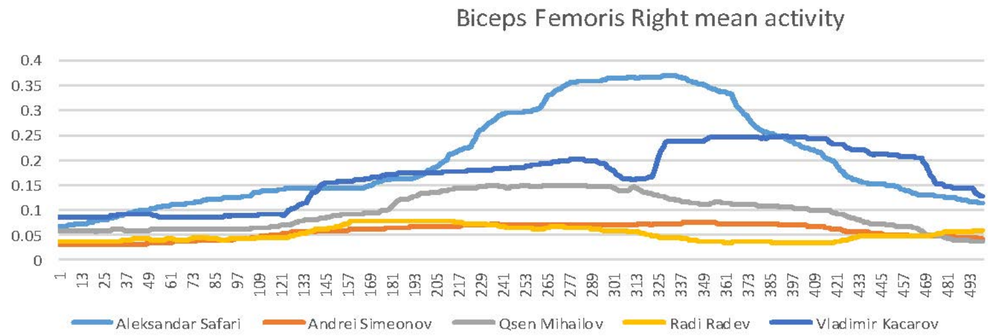

Fig. 17. BFR electromyographic activity.

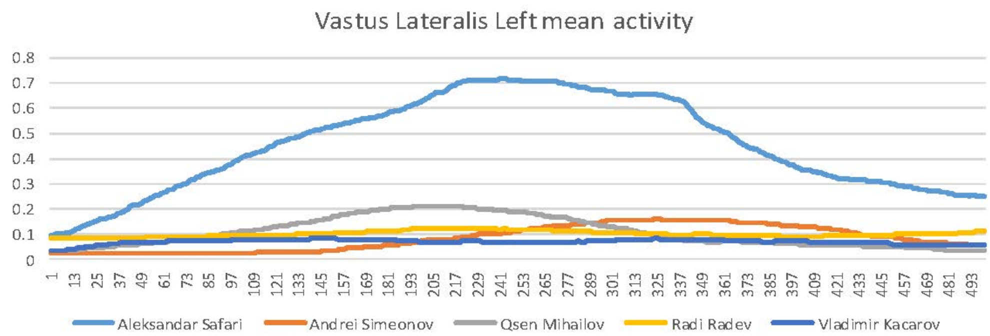

Fig. 18. The electromyographic activity of Vastus LateralisLeft.

At A.S. predominantly involved VastusLateralisLeft is observed, being almost similar in the other participants.

Electromyographic activity shows that in A.S. a predominant involvement of PML is observed.

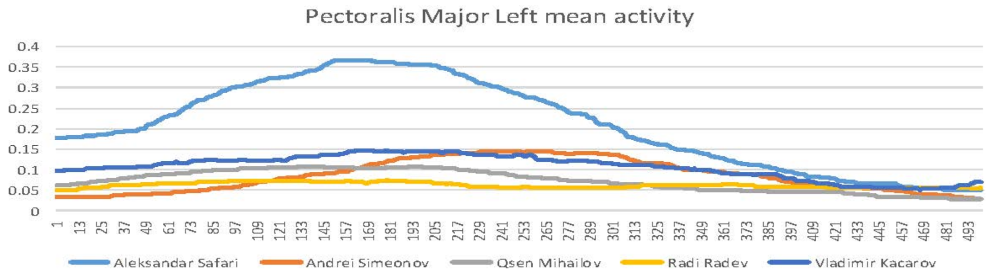

Fig. 19. The electromyographic activity of PectoralisMajorLeft.

4 Conclusions

Preparation at this age is complex for developing all physical qualities and mastering correctly the basic technical elements of the baseball game. Proper preparation is a prerequisite for preventing trauma and contusions, as well as incorrect movements that can lead to permanent disabilities. Authors such as Monti Ryan, 2015 point out that an injury to any area can affect a player's ability to swing the club [6]. Assuming that batting requires the synchronous engagement of different muscle groups of the body, the activity of selected muscles from the baseball player's kinematic chain in realizing the movement of the bat for a baseball strike in relation to the angular velocity of the baseball player's bat segment in each of the studied.

In the athletes studied, there were proportional significant correlations between the instantaneous angular velocity Vyg and Deltoideus anterior Right. We accept that for the conducted research, the competitor Radi Radev executes his shots most successfully, we can assume that this is due to the predominant action of Biceps Barchii Left, due to which the highest instantaneous angular velocity is reached.

Taking into account the small sports experience of the studied athletes and poor technique when performing the swing with the bat, we can assume as normal that the different activity of the studied muscles is due to mistakes made in the approach to the shot.

The conducted research allows us to conclude that the studied muscles have an influence on the performance of the baseball hit, represented by the values of the angular velocity of the segment of the baseball player's bat.

As the main acting muscle to achieve good Vmax and Vygl.max, we can point to the high muscle activity of the BBL during R.R.

The training methodology for young players, along with the recommended exercises to improve the baseball swing, must include exercises for the development of the studied muscles and muscle groups.

Tracking the movement of the baseball strike in adolescent baseball players, through the use of video recording and kinematic and electromyographic analysis of muscle activity, can serve to improve the training process by coaches in clubs in the Republic of Bulgaria.

It's important to note that the batting technique and strategy involve a combination of factors, including footwork, stroke mechanics, timing, and coordination [7, 8]. As a future task it must be done mathematical modelling of basic anthropometric and mass inertial characteristics of young baseball players which will help to understand the principles of rotational motions in batting and how moments of inertia influence movement can help athletes execute complex maneuvers with greater efficiency and control.

ACKNOWLEDGEMENTS

This work was supported by the National Sports Academy "Vassil Levski"— grants CRAS 14/01.03.2023 and CRAS 7/15.02.2024.

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