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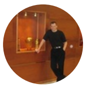

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EFFECT OF MUSCLE EXHAUSTION ON KINEMATICS OF KAYAK ROWING

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Abstract. Changes in kinematic structure of stroke movements caused by exhaustion are investigated in the paper. Young oarsmen at the age of 15–16 years having qualification of the first sports category and the candidate for the master of sports took part in the experiment. At passage of a distance of 1000 m on rowing ergometer, a registration of dynamic parameters of every stroke with continuous videorecording has been made. Using obtained videodata, the analysis of stroke movements in various phases of stroke for a number of kinematic pairs has been carried out: oar–water, trunk–vertical, rotation of trunk around vertical axis, trunk–shoulder, shoulder–forearm. Possibility of determination of stroke movements parameters and estimations of change of stroke kinematic characteristics under the influence of exhaustion are shown.

Key words: stroke phases, kinematic pairs, flexion angles, skeletal muscles, exhaustion.

INTRODUCTION

Sometimes, at the highest level competitions, the tenth or frequently the 100-th shares of second separate the sportsmen from a gold medal. Among the reserves enabling reduction of passage duration, the increase of technical qualification of the oarsman is marked. The majority of the authors investigating the rowing technique pay the basic attention to features of kinematic structure of sportsmen movements [1, 2–5, 7].

The aim of the present work is to research the features of kinematic structure of stroke movements, to compare the model kinematic characteristics of stroke with stroke parameters, appeared with exhaustion, and to define of the reasons of their occurrence.

RESEARCH TECHNIQUE

Young oarsmen at the age of 15–16 years having sports qualification of the first sports category and the candidate for the master of sports took part in research. Testing was done in the Research Laboratory of Physical Training and Sports of F. Skorina Gomel State University on rowing ergometer «Brancha» (Hungary), shown in Fig. 1.

The dosed loading depending on weight of the sportsman was set and the passage of a distance of 1000 m with continuous videorecording was modeled. Comparison of kinematic parameters of rowing with range of 100 m was made by videorecording.

Rowing on a kayak consists of a number of the cyclic movements interconnected among them and creating complete impellent action. The full cycle consists of two serial

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Fig. 1. Exercise performance on rowing ergometer

strokes by each blade of an oar from two sides of a boat and a pause between strokes. Every stroke from the one side consists of several phases. The question about the phase structure of movements is one of the most contradictory one in the rowing theory since in literary data, there is no common opinion on decomposition of phase structure of a stroke by components. So, G.M. Krasnopevtsev divides a basic phase into the beginning of conducting, conducting, and the end of conducting [6]. In works of German biomechanicians [9, 10], the decomposition of a motion cycle into the main and intermediate phases is suggested, but smaller components are distinguished in the main phase: oar dipping, drawing, extraction. Yu.A. Gagin in [1] considers separately phase structure of stroke (conducting, extraction) and phase structure of conducting. T.V. Mikhailova divides phase structure of stroke into capture, conducting (first half and second half), the conducting end, rise of an oar [2].

Authors suggest the following structure of a stroke. One cycle of the stroke from the one side of the boat shares on the basic phase corresponding to a staying of the blade of an oar in water, and a support-free phase of a staying of the oar in the air. The basic phase is conditionally divided into phases of water capture, stroke, and the stroke completion. The support-free phase is characterized by the period of preparation to a new stroke. For the more detailed description of changes in kinematic structure of stroke, we divide the phase of water capture into the beginning of capture and directly water capture, the stroke phase on 1st half and 2nd half of conducting, the completion phase of the stroke on the beginning of a pulling-out of the blade from the water and the completing the pulling-out of the blade from the water. The borders of the divided phases were defined by position of the oar relatively the vertical axis of the oarsman and the horizontal axis of the boat. Position of the oarsman when the shoulders line is perpendicular to line of the boat is selected to be reference one for measure of the trunk rotation around the vertical axis and corresponds to angle 0º. The rotation angle of the oarsman's trunk to the left (counterclockwise) is accepted to be negative (–1°, –2°, –3°, etc.), and to the right (clockwise) is selected to be positive (1º, 2º, 3º, etc.).

In order to obtain the information on kinematic characteristics of rowing technique at the various instants of stroke, the videoanalysis of stroke movements is performed.

Results for biomechanical parameters obtained after passage of the first 200 m were accepted as model ones (without the expressed exhaustion) and listed in the Table.

Modelling structure of the movements in various phases of the stroke

No.	Biokinematic pairs		Stroke phases (angles in biokinematic pairs), degrees						
			Basic						Support-free
			Phase of water capture		Stroke phase		Stroke completion phase		Phase of preparation to a new stroke
			The beginning of water capture, $x \pm \sigma$	Water capture, $x \pm \sigma$	1st half of conducting, $x \pm \sigma$	2nd half of conducting, $x \pm \sigma$	The beginning of oar blade pulling out from water, $x \pm \sigma$	Completing of oar blade pulling out from water, $x \pm \sigma$	Raise of an oar for the next stroke, $x \pm \sigma$
1	Oar–water		48± 3.21°	62± 3.52°	79± 3.44°	110± 3.35°	131± 3.17°	145± 3.62°	163± 3.27°
2	Trunk–vertical		12± 2.12°	12± 2.23°	11± 2.35°	11± 2.45°	8± 2.21°	7± 2.32°	7± 2.29°
3	Rotation of trunk around vertical axis (γ)		–56± 3.45°	–35± 3.32°	–4± 3.65°	25± 3.23°	43± 3.72°	48± 3.34°	56± 3.64°
4	Pulling hand	Trunk–shoulder	67± 3.22°	54± 3.27°	43± 3.12°	26± 3.34°	–1± 3.57°	–11± 3.68°	–21± 3.36°
		Shoulder–forearm (α)	176± 3.75°	172± 3.89°	166± 3.48°	153± 3.89°	98± 3.78°	88± 3.68°	69± 3.47°
5	Pushing hand	Trunk–shoulder (β)	163± 3.78°	191± 3.85°	250± 3.56°	263± 3.67°	264± 3.25°	270± 3.59°	258± 3.78°
		Shoulder–forearm	106± 3.43°	114± 3.67°	125± 3.55°	146± 3.58°	176± 3.49°	177± 3.68°	177± 3.4°

Results and discussion

As a result of the videorecording analysis, model parameters (after passage of the first 200 m of a distance) were compared with the characteristics which have changed by the influence of exhaustion. It is revealed, that four most typical indicators of a deviation in kinematic structure of the stroke movements arise by exhaustion in comparison with model parameters. In particular, the most strongly pronounced deviation in the technique of stroke in second half of the distance is excessive bending of a pulling hand in the elbow joint in the 1st half of conducting (decreasing of α, Fig. 2).

The first part of conducting is performed at more favorable position of the oar blade in the water since the optimum attack angle is realized by the oar and the maximum effort

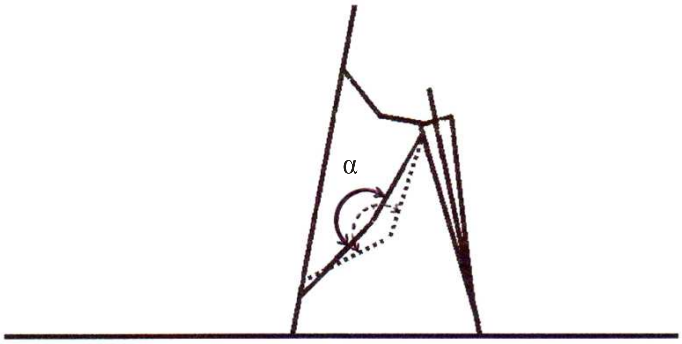

Fig. 2. Excessive bending of a pulling hand in the elbow joint in the first half of conducting of an oar (decreasing of α): side view

created by the oar is reached. It defines the importance of the given phase for increasing the kayak speed.

Feature of the oar conducting is the fastest increase of the oar blade pressure on the water and holding of the reached value before the conducting completion. It is reached by the coordinated work of certain muscles group of the back, the shoulder-girdle, and the hands. In this phase, the basic work is carried out by the abdominal external oblique muscles and the muscles of the shoulder-girdle. Hands perform auxiliary function. However, the pulling hand transferring effort of the trunk to the oar blade at unbending of the pushing hand in the elbow joint also creates the effort which is the total force moving the boat forward and includes force of the hands, the shoulder-girdle, and the trunk.

The oarsman trunk actively turns around the vertical axis. During turn, it is necessary to achieve that the effort is directed parallel to boat movement but not aside. Hands move simultaneously with the trunk.

The pushing hand pushes the oar’s rod forward by unbending in the elbow joint creating more rigid support of the blade on the water. The pulling hand in the 1st half of conducting remains nearly straight and transfers the effort developed by trunk rotation to the oar.

In order that supporting force of the oar blade on the water became driving force of the boat, it is necessary to transfer it from the oar blade to the oarsman support. The effort from the oar blade is transferred successively through its rod, oarsman’s hands, thoracic spine, trunk, and pelvis of the oarsman to the ergometer platform, footboard, and boat.

As in this phase the maximum effort to blades concentrates, it on a chain is transferred to pulling hand which should be straightened for increase of length blade conducting in the water. Due to the collected exhaustion, it becomes difficult to transfer the high efforts through the straight hand, and all loading passes to the shoulder-girdle where the basic work is performed by the *m. deltoideus* and *m. trapezius*. As a result of exhaustion, these muscles cannot perform the optimum work of the pulling hand and it induces the flexion in the elbow joint. Flexion of the hand decreases the arm of the force acting on the hand and creating moment with respect to the shoulder joint. It decreases the efforts action on the mentioned muscles. Model angle between the shoulder and the forearm α (the solid line) amounts 166° ± 3.48°, and due to exhaustion (dashed line) this angle is less 163°. In this case, the shoulder muscles are more actively involved in movement performance (biceps and triceps). They carry the part of the effort increasing thereby hand flexion in the elbow joint. As a result, holding the hand in the set position is facilitated. Early inclusion of shoulder muscles leads to their fast fatigue as they carry the basic loading in the second half of conducting and in the phase of the beginning of oar blade pulling out from water. Beside that, due to

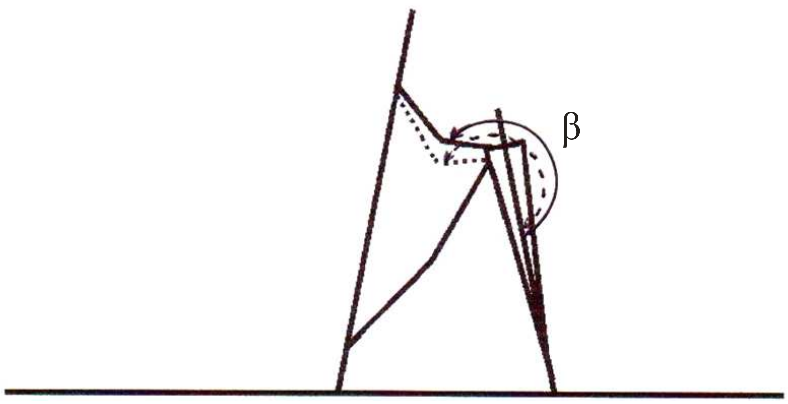

Fig. 3. Lowering of the elbow of a pushing hand in the first half of conducting of an oar (β). (increasing of β): side view

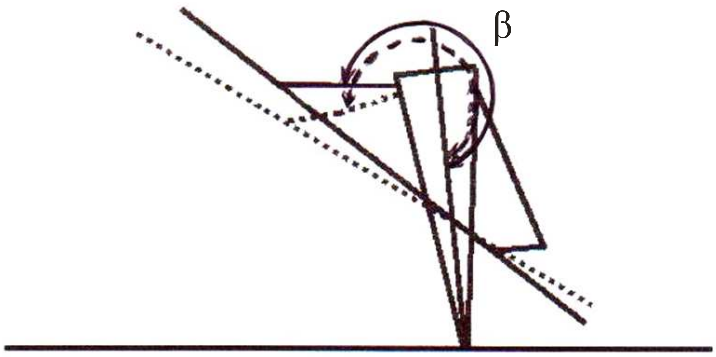

Fig. 4. Lowering of a pushing hand in the phase of a full pulling out of the blade of an oar from water (β): side view

the flexion of the pulling hand in the elbow joint, the length of the oar blade conduction is decreased at the same rotation of the trunk and usage of the trunk muscles is diminished.

The second indicator of change in the stroke technique due to exhaustion is the lowering of the pushing hand elbow in the 1st half of conducting and increase of angle β (Fig. 3).

In the first part of conducting, the greatest acceleration is given to the boat since the maximum effort on the oar is created. The effort is transferred through the oar, arms (the hand, the forearm, and the shoulder), the trunk, and the pelvis of the oarsman to seat and the boat footboard. If in this path, the transfer efficiency of one segment decreases by the influence of constant physical activity and occurrence of inevitable exhaustion, the structure of movement is deviated. Namely, as a result of the collected exhaustion in weak links of the biokinematic chain, there is a disturbance of efficiency of stroke techniques. We reveal lowering of the elbow of a pushing hand (angle β more than 253°) while model indicators of the angle between the trunk axis and the shoulder (β) are 250 ± 3.56°. Due to structure deviation of the stroke from the model one, the support of the pushing hand on the oar is diminished that leads to reduction of effort on the blade.

The third change in the stroke movements is characterized by lowering of a pushing hand in the phase of the oar blade pulling out from the water (Fig. 4).

The oar blade pulling out from the water is performed by the sharp elevation of the forearm and hand of the pulling arm. Before the hand of the pulling arm together with the forearm comes to the trunk, they sharply raise upwards and aside. The top edge of the oar

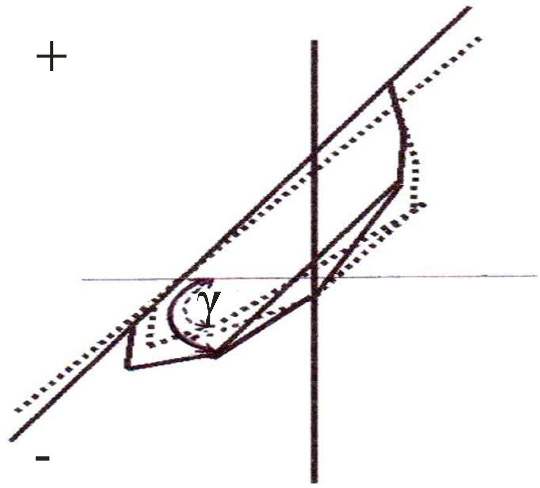

Fig. 5. The absence of «total turn» of the trunks around the vertical axis in a drift phase for the following stroke (decreasing of γ): top view

blade leaves water. The pushing hand remains practically straight and motionless at the chin level. The trunk performs the turn around the vertical axis. At the correct motion of the blade, the splashes are not observed.

Under the influence of exhaustion, there is a lowering of the pushing hand. The angle β between the trunk and the shoulder of the pushing hand becomes more than 273°. It reduces efficiency of use of the phase of preparation for the new stroke for setting the oar blade in the most favourable position before the input in the water at the subsequent stroke since lowering of the pushing hand reduces the vertical speed of the oar at water capture. As a result, the time of water capture increases. The length of conducting, hence, decreases and capacity of stroke diminishes.

The fourth change in the rowing techniques, worsening quality of stroke, is the absence of the total turn of the trunk around the vertical axis in a preparation phase before the subsequent stroke (Fig. 5).

At performance of stroke from the left side of the boat, the left hand straightened forward is at chin level, the hand and the forearm of the right hand leave behind the elbow, rise upwards to the level of eyes. All movements of preparation are carried out by the right hand. The trunk of the oarsman released from the traction of the oar turnes completely to the right that provides preliminary preparation of skeletal muscles for effective performance following stroke movement. It has a crucial importance for the greatest efficiency of the stroke. The preliminary stretching of the muscles before the stroke increases the magnitude and the speed of the developed effort in the main movement since the muscle having stored up elastic energy at the preliminary stretching returns it at the subsequent work. The increase of nervous impulse speed, decrease of the threshold of excitation, and involving in the work the large number of impellent units are marked. In addition, the preliminary stretching of the muscles promotes their subsequent reflex contraction. Therefore, stroke will be automatically started.

Later on, the left hand actively lowers downwards – to the left, and the hand of the right arm continuously moves upwards – forward. Stroke begins with the left side and all movements repeat.

In our case, as a result of the collected exhaustion, there is a reduction of the trunk turn around the vertical axis (the angle γ is less than –53°, Fig. 5) due to the absence of total turn in the preparation phase. The preliminary stretching of muscles decreases, that as a whole leads to decreasing stroke capacity.

Distortion of the stroke technique due to the collected exhaustion is occur since the certain skeletal muscles do not perform the direct functions in keeping the necessary trajectory of movement or holding the parts of the body in correct positions.

In our opinion, excessive flexion of the pulling arm in the elbow joint at the 1st half of conducting, elbow lowering of the pushing hand at the 1st half of conducting, and lowering of the pushing hand in the phase of completing of the oar blade pulling out from water are connected with weak development (or low functionality) of the deltoid muscles (*m. deltoideus*). Since the main functions of deltoid muscles (*m. deltoideus*) are abduction, flexion, and unbending of the shoulder, its turn inside or outside, and also lowering of the lifted hand, then according to its anatomic-functional features, this muscle should keep the shoulder in the given position. It does not occur at developing exhaustion in the 1st half of conducting and at the phase of completing of the oar blade pulling out from water. First half of conducting and the phase of the completing of the oar blade pulling out from water are very important for effective use of the support stroke phase since the first half of conducting gives the greatest acceleration to the boat and any deviation in the technique leads to speed reduction. In a phase of the completing of the oar blade pulling out from water, the preconditions for optimum use of the main phase of the subsequent stroke are created.

The absence of total turn of the trunk in the preparation phase is connected with functioning of abdominal external oblique muscle (*m. obliquus externus abdominis*). External oblique muscles perform the trunk rotation, thorax lowering, bending of the spine. Hence, these muscles due to exhaustion do not perform the necessary movements.

Conclusions

1. Efficiency of stroke movement performance in the kayak rowing directly depends on the character of interaction of the body parts in biokinematic pairs and degree of transfer of the effort developed by the groups of muscles.

2. Change in the sportsman stroke technique due to the accumulated exhaustion is caused by the fact that certain skeletal muscles do not provide necessary movement or holding of the concrete segment of the body.

3. As a result of the biomechanical analysis, it is established that even little change of the kinematic structure of the stroke leads to significant changes of stroke movements and to decrease the efficiency of their interaction.

4. It is established that the technique errors caused by exhaustion can be a consequence of weak development of the concrete muscle or group of muscles. Results of research allow us to suggest the correction in the training program for timely removal of disadvantages that is the key point to improve the sport result.

References

1. Гагин Ю.А. Гребной спорт. – М.: ФиС, 1976. – С. 30–65 (*in Russian*).
2. Жмарев Н.В. Тренировка гребцов. – Киев: Здоровье, 1976. – 124 с. (*in Russian*).
3. Иссурин В.Б., Шарабайко И.В., Шубин К.Ю. Динамика спортивно-технического мастерства в процессе многолетней подготовки гребцов высокого класса // Программирование тренировки квалифицированных гребцов: Сб. науч. трудов. – Л., 1987. – С. 37–43 (*in Russian*).
4. Иссурин В.Б., Бегак В.М., Краснов Е.А., Разумов Г.Г. Сравнительная эффективность различных вариантов техники гребли на байдарках и каноэ // Теория и практика физической культуры. – 1983. – № 9. – С. 11–13 (*in Russian*).
5. Краснов Е.А., Химич О.К. Некоторые вопросы техники гребли на байдарках и каноэ // Гребной спорт. Ежегодник. – 1986. – С. 31–34 (*in Russian*).
6. Краснопевцев Г.М., Силаева А.П., Фомин С.К. Гребной спорт. – М.: ФиС, 1966. – С. 100–127 (*in Russian*).

7. Михайлова Т.В., Комаров А.Ф., Долгова Е.В. Гребной спорт: Учебник для студентов высших педагогических учебных заведений. – М.: Издательский центр «Академия», 2006. – 400 с. (*in Russian*).
8. Никоноров А.Н. Фазовая структура движений в гребле на байдарках // Гребной спорт. Ежегодник. – 1983. – С. 44–48 (*in Russian*).
9. Schnabel G. Bewegungslehre. – Berlin: Volksingener Verlag, 1976. – P. 59–220.
10. Wozniak K.H. Kanusport: Ein Lehrbuch für Trainer, Übungsleiter und Aktive. – Berlin: Sportverlag, 1972. – P. 77–94.

ВЛИЯНИЕ УТОМЛЕНИЯ МЫШЦ НА КИНЕМАТИКУ ДВИЖЕНИЙ ПРИ ГРЕБЛЕ НА БАЙДАРКЕ

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В работе исследованы изменения кинематической структуры гребкового движения вследствие утомления. В эксперименте принимали участие юные гребцы в возрасте 15–16 лет, имеющие квалификацию первого спортивного разряда и кандидата в мастера спорта. При прохождении дистанции 1000 м на гребном эргометре происходила регистрация динамических параметров каждого гребка с непрерывной видеозаписью. С использованием полученных видеоматериалов проводился анализ гребковых движений в различные фазы гребка по ряду кинематических пар: весло–вода, туловище–вертикаль, вращение туловища вокруг вертикальной оси, туловище–плечо, плечо–предплечье. Показана возможность определения параметров гребкового движения и оценки изменения кинематических характеристик гребка под воздействием утомления.

Ключевые слова: фазы гребка, кинематические пары, углы сгибания, скелетные мышцы, утомление.

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