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Kinematic characteristics of the backstroke swimming technique of the qualified swimmers with the effects of cerebral palsy

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Purpose: *to determine kinematic characteristics of backstroke swimming technique of athletes with spastic cerebral palsy (CP).*

Material & Methods: *12 swimmers with effects of cerebral palsy were involved in the experiment (level of sports qualification – master of sports and candidate of master of sports); Video shooting and computer video analysis of their technique of backstroke swimming; The obtained data were analyzed and generalized using the methods of mathematical statistics.*

Results: *kinematic characteristics of the technique of backstroke swimming of disabled athletes with spastic diplegia and a hemiparetic form of CP, such as the body position of swimmer in water (angle of attack, angle of rotation of the trunk around the longitudinal axis), position and work the hands and feet of the swimmer (the angles of flexion the main joints and their movement), integral characteristics (cycle time, step, rate and ratio of these characteristics at a constant swimmer speed).*

Conclusions: *determined biomechanical characteristics motions skilled swimmers with spastic CP forms, which indicate the specificity of their technique of backstroke swimming, so we recommend that you take into account the findings in the search for effective means and methods of sports training.*

Keywords: *kinematic characteristics, swimming technique, backstroke swimming, cerebral palsy.*

Introduction

Modern level of achievements in sport swimming is characterized by high technical skill. Several scientists [2; 3; 6] argue that the rationality and productivity of the technician's swimming skills depends on the biomechanical characteristics, namely the kinematics movements. Therefore, in sports practice, an important direction is to determine and analyse the athlete's kinematic characteristics in order to find effective means and methods for training him. Today there are a large number of both foreign [10; 11; 12; 23; 24], and domestic research [1; 4; 8; 9], devoted to the kinematics of movements of swimmers.

Preparation of athletes with disabilities has the specificity associated with the means at their physical and psychological characteristics [6; 16; 17]. Only some scientists in their studies [13; 14; 15; 20] highlight some aspects of the problem of the influence of kinematic characteristics on the technique of swimming such swimmers. Determination of the kinematic characteristics of the technique of sporting methods of swimming for such a special group of people as athletes with effects of CP was found in foreign publications [18; 19; 21; 22]. However, in the domestic literature available to us, scientific substantiation of such data in accordance with the methods of swimming, in particular backstroke swimming, is not represented.

In view of the foregoing, this problem becomes extremely relevant in the sports training of swimmers with effects of CP. All this was the impetus for our research in this area.

Communication of the research with scientific programs, plans, subjects

The research is carried out in accordance with the plan of research work of the Sumy State Pedagogical University named after A S Makarenko for 2011–2015 . Under the theme "Raising the level of health and physical fitness of the various groups of the population by means of physical culture" (state registration number 0111U005736); for 2016–2020 under the theme "Optimizing the training process of athletes in long-term training system" (state registration number 0116U000898).

The purpose of the research

To determine kinematic characteristics of backstroke swimming technique of athletes with spastic cerebral palsy (CP).

Material and Methods of the research

The study involved 12 athletes with effects of CP the level of sports qualification master of sports and candidate masters of sports, which belong to the class of S6–S8 in accordance with the classification code of the International Paralympic Committee. All athletes agreed to conduct the study. At the beginning of the study, we analyzed and summarized the data of the scientific and methodological literature, which allowed us to determine the state of the study of the problem. To quantify the performance of athletes, we used video in the frontal and sagittal planes with the help of two video cameras (GoPro HERO 3 + Silver Edition). The results were processed and analyzed by a computer program Kinovea®. Statistical processing of materials research was carried out using the

software package Microsoft Excel 2010 using common methods of mathematical statistics.

Results of the research and their discussion

The results of the video analysis obtained were summarized and presented in tables 1–4, where the following kinematic characteristics were determined: the position of the body of the swimmer in the water (angle of attack, angle of rotation of the trunk around the longitudinal axis), the position and work of the swimmer's arms and legs (angles of flexion of the main joints and their movement), integral characteristics (cycle time, step, rate and ratio of these characteristics at a constant swimmer speed). These indicators characterize the main features of the backstroke swimming technique of athletes with effects of CP, depending on its forms.

According to the data of table 1, in swimmers with SD, the angle of attack is more by 11% compared to the parameters of swimmers from the HF, it averages 11,3±0,82°. For swimmers from the HF this indicator ranges from 5° до 14°. In some swimmers with effects of CP, the angle of attack reaches a minimum – 5°, but the athlete's body is stored in a streamlined position, the body's midsection is increased because of the low immersion in the water limbs and the stable angle of the hip joints.

It is important to note that in swimmers with GF CP, the angle of attack increases in the repulsion phase of the affected arm when this phase coincides with the preparatory phase of the affected leg.

For the technique of swimming athletes with both SD and HF CP is characterized by a violation of the balance of the body in all planes, most pronounced in the horizontal and sagittal. Because of this, the body torsional oscillations around the longitudinal axis occur, at this moment the roll of the trunk in swimmers with SD 33,2±1,22° and 35,9±0,96° in swimmers with HF, which is a consequence of the lesion of one side of the body. Therefore, the greatest angle of rotation of the trunk around the longitudinal axis is observed in swimmers with HF at the beginning of the repulsion phase of the working movement by hand and is 40°. A swimmer with SD there is an increase of the angle when the athletes overcame a distance, using straight arms traffic.

Since during the movement of the hand the main moving planes of the swimmer are the hands and forearms [5], we measured the angle of attack of the hand and the angle of flexion of the elbow joint (table 2).

A characteristic feature of the work of the hands of athletes with spastic diplegia is the proximity of its characteristics to the work of the hands of healthy athletes, therefore the effectiveness of the hands of swimmers with SD is higher than HF. The angle of flexion of the elbow joint of swimmers with SD is greater on average by 19% of the corresponding indexes of the affected extremity of swimmers from the HF, and the exponent of the stroke – approximately 21%.

For swimmers from the hemiparetic form of CP such features is characterized: 1) length of the stroke of an affected limb is

Table 1

Kinematic characteristics of the body position in water during the backstroke swim of the swimmers with effects of CP (n=12)

Characteristic	CP form	Meanings		$\bar{X}$±Sx
		min	max	
Angle of attack (deg.)	SD	6	14	11,3±0,82
	HF	5	14	10,1±0,79
Angle of rotation of the trunk around the longitudinal axis (deg.)	SD	24	38	33,2±1,22
	HF	28	40	35,9±0,96

Note. *SD – spastic diplegia; HF – hemiparetic form.*

Table 2

Kinematic characteristics of the position and work of hands during the backstroke swim of the swimmers with effects of CP (n=12)

Characteristic	CP form		Meanings		$\bar{X}$±Sx
			min	max	
Elbow flexion angle (deg.)	SD	R	130	178	150,3±3,81
		L	134	176	152,1±3,96
	HF	affected limb	98	136	121,5±3,77
		healthy limb	125	154	141,2±3,03
Angle of attack brush (deg.)	SD	R	21	44	29,8±2,32
		L	20	42	29,2±2,24
	HF	affected limb	28	45	38,1±1,39
		healthy limb	24	44	33,5±1,68
Length of the stroke (m)	SD	R	1,46	1,92	1,76±0,32
		L	1,42	1,86	1,68±0,54
	HF	affected limb	1,01	1,49	1,38±0,84
		healthy limb	1,24	1,65	1,56±0,02

Note. *SD – spastic diplegia; HF – hemiparetic form; R – right hand; L – right hand.*

less than the length of the stroke of a healthy limb due to contracture of the joints; 2) angles in the joints of the affected limb are almost constant due to the impossibility of full extension of the arm, therefore the arm enters the water with the elbow rather than the brush, and outruns the brush in the working movement phase, the expressed position of the elbow below the wrist is observed, which adversely affects the efficiency of the swimming technique; 3 healthy limb performs an *S*-shaped stroke, so it is more effective, and the affected limb performs a more straightforward stroking, which is not rational; 4) there is a large load on the legs, if the hands are more affected, and vice versa.

Swimmers with effects of CP HF, limited use of the affected part of the body is observed, which leads to asymmetry in the technique of performing swimming movements with hands and kicking. For athletes with effects of CP is characterized by constant spasticity of the muscles of the affected side, therefore a number of motor limitations arise. The angles of flexion of the elbow and wrist joints affected limbs close to constant, so the angle of attack of the hand of the affected limb more than 12% of the angle of attack brush healthy limb swimmers with GF CP (table 2). Angles of flexion in the elbow joint of the affected limb through spasticity and contractures are constant almost throughout the entire movement. As a result, athletes can not perform a full stroke by hand. The repulsion phase, as a rule, is not completed, which leads to a shorter stroke. Therefore, these athletes have a small step, but they try to compensate for the swimming speed, increasing the pace of movements (table 1). For a healthy limb, characteristic movements with a large amplitude. Some swimmers have a prolonged delay of the injured arm at the thigh in the repulsion phase at the end of the working movement, there are difficulties holding the arm in a static position and carrying it over the water.

Since the main moving planes when moving the swimmer's legs, first of all, are the foot and the shin [5], we measured the angles in the ankle, knee and hip joints (table 3).

Video analysis of the position and work of the legs during the backstroke swim of the swimmers with the effects of CP showed that a healthy leg or less affected performs continuous movements that move forward, striking with the injured legs almost does not give the driving force to the swimmer, so there is a violation of the horizontal and lateral balance.

The features of the foot injury of swimmers with SD (angles of flexion of the hip and knee joints are actually permanent) lead to the lack of effective foot movements, so athletes keep the limbs in the most streamlined position. When characterizing the work of the feet during the backstroke swim of the swimmers with the effects of CP is appropriate to talk only about the effectiveness of the legs of swimmers from the HF.

The greatest angles of flexion of the hip and knee joints in athletes of the HF CP are observed during the performance of the working phase (table 3). Some athletes in the phase of the hand grip there is a pronounced hip flexion up to 133°, which results in an increase in the angle of attack to 10°. Some athletes also have a knee joint out of the water. This is the reason for the increase in the body's midsection, and accordingly the force of the drag.

The angle of flexion of the ankle through spasticity of muscles and contracture retains an almost constant value. The greatest angle of flexion of the ankle is observed in the limiting phase of the transition from the working to the preparatory phase and is on the average 129,2±3,47° for athletes with SD and 131,2±4,64° for the affected limb swimmers from the HF, respectively. At the same time, a healthy limb works more actively with a large amplitude, the bending angle on average is 140±3,27°. In some athletes with the effects of CP in the ankle, the fixed value of the flexion angle is 106°, which is a consequence of excessive spasticity of flexor muscles and low joint mobility.

For the swimming technique of athletes with both SD and HF CP, the following characteristics are typical: the stricken limb these athletes try to keep in a more streamlined position, almost without moving it; through the spasticity of the extensor muscles, the legs retain near-angled corners during movement; a healthy limb performs movements with large amplitude and powerful strokes.

To integral biokinematic characteristics of swimming, the backstroke swimmers with the effects of CP refer to the rate, step and speed of movement (table 4). It should be noted that the higher the athlete's class, the more individual are these indicators. Swimmers with SD step is not significantly higher than the corresponding figure at the swimmers with the HF (by 10,5%), but the rate is lower by 6,8%. Figure 1 shows the relationship between the step and the rate of athletes with HF and SD. Athletes with SD observed average step of 1,8 m, while the rate is 31 cycles min^{-1}. Athletes with HF have a step of 1,6 m, however, the rate of these athletes 33 cycles min^{-1}.

Table 3

Kinematic characteristics of the position and work of legs during the backstroke swim of the swimmers with effects of CP (n=12)

Characteristic	CP form		Meanings		$\bar{X}$±Sx
			min	max	
Angle of flexion of the hip joint (deg.)	HF	SD	165	176	171±1,15
		affected limb	152	170	161,8±1,37
		healthy limb	133	148	140,9±1,58
Angle of knee flexion (deg.)	HF	SD	154	170	164,1±1,48
		affected limb	148	168	160,1±1,58
		healthy limb	108	144	131,1±3,06
Angle of ankle flexion (deg.)	HF	SD	106	144	129,2±3,47
		affected limb	110	162	131,2±4,64
		healthy limb	124	158	140±3,27

Note. *SD – spastic diplegia; HF – hemiparetic form.*

Table 4

Integrated kinematic characteristics of backstroke swimming of the swimmers with effects of CP (n=12)

Characteristic	CP form	Meanings		$\bar{X}\pm Sx$
		min	max	
Step (m)	SD	1,5	2,2	1,80±0,07
	HF	1,2	2,1	1,61±0,08
Rare (cycles min^{-1})	SD	28	37	31,3±0,81
	HF	32	39	33,6±0,69
Cycle time (s)	SD	1,7	2,3	1,93±0,05
	HF	1,5	2,2	1,80±0,05
Relationship betweenthe step and rate	SD	0,041	0,076	0,058±0,003
	HF	0,027	0,064	0,049±0,002

Note. *SD – spastic diplegia; HF – hemiparetic form.*

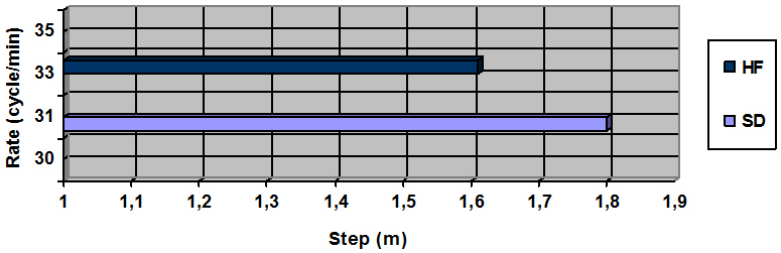

Fig. 1. Step and pace during the backstroke swim of the swimmers with effects of CP

That is, an inverse proportion is observed, and a smaller step is compensated for by a higher rate. This is because the upper limbs of athletes with a hemiparetic form are more affected. As a consequence, the ratio of the step to the rate for swimmers with SD and for swimmers with GF HF is, on average 0,058 and 0,049 respectively. At the same time, the cycle time of athletes with spastic diplegia is 6.7% higher than that of swimmers from the hemiparetic form of CP.

The results of the research show that swimmers with effects of CP have a number of physiological characteristics (impaired motor function, contracture, increased muscle tone, decreased muscle strength and performance, impaired coordination of movements, etc.) that actively influence the training process and determine the specifics techniques of various styles of swimming, including backstroke swimming.

Conclusions

1. Analysis of scientific and methodological literature testifies to the lack of scientifically grounded research on the kinematic characteristics of the technique of backstroke swimming of athletes with spastic forms of CP.

2. The kinematic characteristics of the technique of backstroke swimming of disabled athletes with spastic diplegia and hemiparetic form of CP are determined: the body position of the swimmer in the water (the angle of attack, the angle of rotation of the trunk around the longitudinal axis), the position and work of the swimmer's arms and legs (angles of flexion of the main joints and their displacement), integral characteristics (cycle time, step, rate and ratio of these characteristics at a constant swimmer speed).

3. It is established that for the technique of swimming of athletes both with SD and HF CP, the balance of the body in all planes and the asymmetry of the movements. The effectiveness of the hands of swimmers with SD is higher than that of swimmers with HF, but the low efficiency of leg movements. Swimmers with SD, the step is higher than the corresponding index of swimmers with HF (by 10,5%), but the rate is lower by 6,8%. An inverse proportion is observed, and a smaller step is compensated by a higher rate.

4. The received data testify that the technique of backstroke swimming of athletes with spastic forms of CP has its own specifics.

Prospects for further research in this direction

In further research, it is necessary to take into account the obtained kinematic characteristics as a theoretical foundation for the justification of new techniques backstroke swimming for teaching children with effects of CP.

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