SPATIAL CHARACTERIZATION OF SWIMMER'S LOCOMOTIVE MOVEMENT

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Movement technique is one of the factors which determines sport result. The achievement of good results in swimming depends largely on the correct movement technique. The swimmer who wants to achieve best results must not only be very well prepared in the physical sense but also must master the movement technique.

In contemporary swimming the intensity and the range of training load reaches (almost) the maximum of man's abilities. Yet, there are still some reserves from which we search for the possibilities of movement perfection.

The experiments which have been conducted on swimming technique for many years indicated that there is a need for a more precise examination of the phases of movement which are most significant for the locomotion in the water by using new and most modern investigative methods.

Though there is a wide range of experiments on swimming technique, the spatial characterization of a swimmer's movements is still an open problem. Swimmer's movements show great spatial complexity which, though there are many scientific publications dealing with it still requires investigation. It is also because of technical reasons that this complex movement is examined and analysed as plane motion. So far only a few scientists (Barthels and Adrian, 1975, Counsilman 1971, Issurin, Kostiuk 1984, Hay, 1985) have dealt with spatial analysis of the swimmer's motion.

From the biomechanical point of view it is important to determine the relationship between movement of the upper extremity and the locomotive velocity of a swimmer. The analyses of the course of movement of the upper extremity (the pulling one) made against a background of changes of velocity taking place in the movement cycle may have a significant meaning for the examination and determination of the necessity to examine spatial kinematic movement parameters of the swimmer's upper extremity against a background of his locomotive velocity.

PURPOSE

The aim of the paper is to determine the relationships between selected spatial movement parameters of the swimmer's upper extremity and his locomotive velocity (velocity of his body).

Spatial analysis of the swimmer's movements allows one to calculate the spatial kinematic movement parameters of the swimmer's body moving in time and space, thus, achieving the new value in biomechanical experiments on the swimming technique.

METHODS AND PROCEDURE

The investigations concerning the swimming technique conducted in water require the adaptation of the apparatus and methods used on land. Photogrammetric measuring methods based on binocular observation which made it possible to register the phenomena taking place and to carry out the spatial analysis were used. In order to register the swimmer's motions in water the photography of lights pulsating with the constant frequency (LED - light emitting diodes) was used.

The investigation stand consisted of the stereophotogrametric camera which was placed under the surface of the water, electonic tester placed in the photography field and the electronic recorder of movement fixed to the swimmer's back. The tester consisted of two independent gates hung on the lines of the lane in which the swimmer swam.

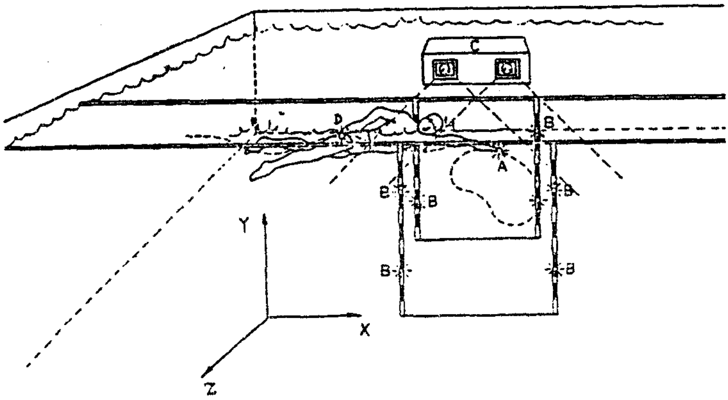


Figure 1: Underwater stereophotogrametric photography
A,D - Light point (LED)
B - Control point
C - Stereophotogrametric camera

A competitor equipped with the recorder for movement covered the distance of anywhere from ten to twenty meters with maximum velocity. Stereocamera registered only one cycle of movement, the one that got into the gates of the tester.

The electronic recorder of the movement (fixed to the swimmer's back) consisted of the rectangular container with three wires ending in LEDS. The diodes registered movement of the upper extremity and swimmer's locomotive movement. The construction of the recorder of the movement enables one to identify the light signals registered on the photographic plate. The time of the light impulse amounted to 12.5ms for the upper extremity, 25ms for the leg and 50ms for the body. The diode fixed to the arm lit when the swimmer's hand immersed in the water and it went out when the arm left the water. It contained information about the time of the extremity's movement in water.

A cyclic character of movements is typical for swimming, which means that a competitor covering a distance constantly repeats a definite cycle of movement. That is why one selected movement has been analysed (the phase of movement which took place under the surface of the water).

Upper extremities are the main driving mechanism in sport swimming, thus, the swimmer's locomotive velocity depends largely on the proper direction and the movement velocity of the upper extremities.

Swimmers representing a high level of sport mastery have been examined. The basic anthropometric measurements which were conducted excluded the influence of the body build on the results of the investigation.

RESULTS AND DISCUSSION

Stereograms including the recording of the trace of the extremities' movement and the trace of the movement of the swimmer's body (the path along which he moved) were the result of the investigation. Photogrametric analysis of the film material resulted in numerical values of XYZ coordinates of the succeeding points of the discrete recording of the swimmer's movement.

Selected kinematic parameters of the swimmer's movements were calculated on the basis of results of the photogrametric elaboration and the information refering to the time of the particular light impulses. In order to calculate the velocities of the movement the following formula was used:

$$v_{i,j} = \frac{\sqrt{\Delta x^2_{i,j} + \Delta y^2_{i,j} + \Delta z^2_{i,j}}}{t_{i,j}}$$

where : i,j - succeeding number of point,
x,y,z - cartesian coordinates,
t - time of impulse

The following kinematic parameters for the upper extremity and the swimmer's body have been obtained:

- velocities between the succeeding points of the discrete recording
- maximum, minimum and mean velocities for the upper extremity
- maximum, minimum and mean velocities for the body motion
- the length of the distance for the upper extremity
- the length of the distance covered by the swimmer's body

The calculation of values of the XYZ coordinates allowed one to draw the path of the upper extremity's movement in three planes: XY - from one side, ZY - in front, ZX - from below.

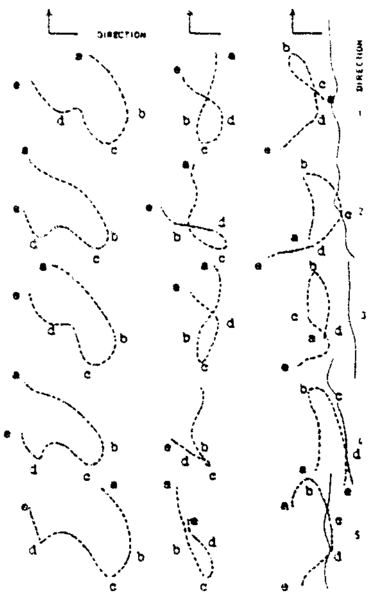


Figure 2: Swimming stroke pattern: side - XY, front - ZY and below - XZ view.

Points a and e are the beginning and the end of the movement respectively, points b,c,d, are the places where the shift of movement took place. These points were marked on the basis of stereocopies observation of the photographs forming the stereogram.

The analysis of parameters presented in the table shows that there is positive relationship between the main velocity of swimming.

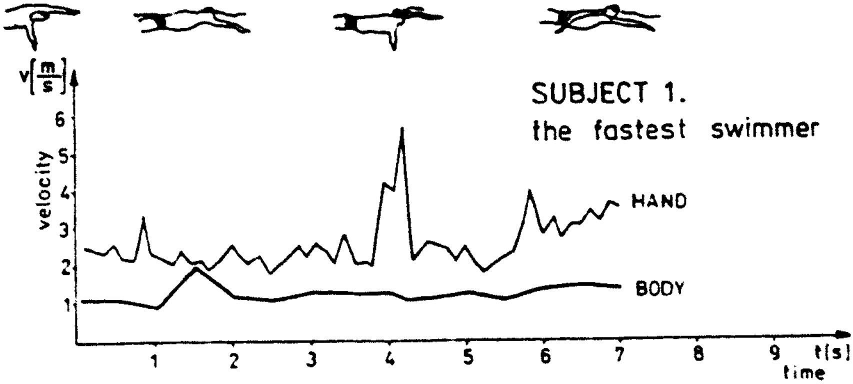
TABLE 1. KINEMATIC PARAMETERS CHARACTERIZING SWIMMING VELOCITY (CRAWL)

SUBJECT	HAND						BODY				
	speed 100 m crawl	time (t)	distance (m)	V mean (m/s)	V max (m/s)	V min (m/s)	time (t)	distance (m)	V mean (m/s)	V max (m/s)	V min (m/s)
1. W.P.	53.73	0.95	2.50	2.57	5.70	1.62	0.85	1.90	1.82	2.10	1.64
2. B.M.	52.38	0.85	2.30	2.38	5.44	1.60	0.95	1.83	1.80	2.07	1.42
3. K.M.	53.12	0.85	2.24	2.30	5.35	1.54	0.70	1.77	1.74	1.99	1.32
4. K.R.	53.25	0.72	2.18	2.28	5.28	1.02	0.70	1.70	1.68	1.92	1.17
5. S.J.	53.88	0.60	2.10	2.15	5.20	0.77	0.64	1.65	1.60	1.87	1.05

Summing up, it can be stated that the obtained results include much more information about the kinematic characteristics of movement than were found in the previous investigations because the course of movement gives us information about the path along which the upper extremity moves, whereas movement velocity of the upper extremity informs us indirectly about the force with which this extremity works.

CONCLUSIONS

1. Time spatial characteristics allowed to differentiate swimmers and proved that the character of the movement (its direction) influences swimming velocity.
2. It was found that there is a positive relationship between the movement velocity of the upper extremity and the length of the distance, and between the mean velocity of the upper extremity's movement and the mean swimming velocity.
3. Stereophotogrammetry analysis of the swimming technique gives the possibility for one to watch the effects of the technical training process in a more objective manner than in two dimensional analysis.



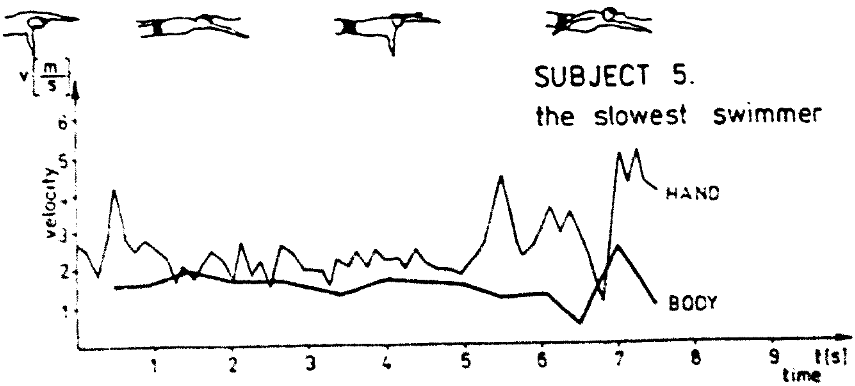


Figure 3: Resultant hand and body speed.

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