BIOMECHANICS OF SWIMMING

BIOMECHANICS AS PRECONDITION FOR THE UNDERSTANDING OF SWIMMING

DR. Bodo Ungerects

The importance of mechanical laws for the explanation of swimming techniques is often in contrast with its consideration in the literature of swimming. This is especially true for the "biomechanics of Swimming," as evolved after 1970 since the first International Symposium of Biomechanics in Swimming. General biomechanics, as far as documented in textbooks, does not consider this new approach sufficiently. There exists different ways of explaining swimming techniques, which are contradictory.

The specific meaning of biomechanics in swimming for the understanding of this sport partly results from the fact that the motorical and physical movements take place in a medium, which influences the rise of forces by its material properties. Drag forces, which always have an effect on swimming and which make steady swimming velocity impossible, belong to them. Measurements with gliding swimmers showed that velocity within a distance of one body-length decreases by 50% (Klauck 1982). In the air, e.g. in long jump, there is no decrease even if velocity is three times higher. In the biomechanics of swimming it is therefore important to approach kinetic phenomenons from "the water's view." This view leads to an appropriate explanation of swimming techniques, which goes beyond a morphological view of movement.

Based on the breast-stroke, it is described using the methods of biomechanics of swimming which work and by which results are achieved. Moreover, it will be demonstrated how questions at issue can be solved with the help of these results or how decisions in introducing swimming strokes can be influenced. The breast stroke is a challenge for biomechanical research because of its fluctuation in velocity, for it is essential to minimize it.

Sample of pattern and methods

Skilled competitive swimmers (17 female and 22 male swimmers) took part in this study. All participants had the task to swim a distance of 15 m two times. First they had "to swim properly" and then "to swim fast." In all trials, the swimmers were filmed with a 16 mm camera with 54 fps from a 5 m platform.

First the pathway of the hands at the level of the water surface was determined. During slow reproduction, the path of the middle finger was painted on a foil. The advantage of this method is for didactical reasons the spectator is able to follow the process, what is not possible when digitating single points.

In the kinematic analysis, the way of one point of the body on the level of the tuber ischiadicum was digitated. The range of evaluation enclosed 2, 24 s, nearly two cycles. At the same time, those movements were recorded, in which the extremities reached specific positions.

Results

The presentation of the pathway of the hands is restricted to the projection on the level of the water surface, depending on the camera position (Figure 1). In all swimmers, this pathway had an ellipsoid form and its axis was (more or less) perpendicular to the swimming direction. A movement footward cannot be determined. This result corresponds with findings, which were found with other techniques.

Schleihauf (1974) proved that in the crawl stroke the hands are not moved footward but rather remain on place and that the point, where the hand leaves the water is in front of the entry (Figure 2). This is only possible if the hand is moved in cycloid shape. The following explanation lies behind this form: the pathway is the result of the superimposition of two separate movements—movement of the body and movement of the hands.

The velocities of both movements depend on place and time and vary intracyclic. In order to produce a vertical pathway, the hands must be moved outward rather quickly.

In the breast stroke, the extended arms start spreading at nearly the same level. After the transitional movements they are moved to the middle of the body in the third dimension, which is not shown here. Thus, a "sculling" movement is carried out, in which forces according to the 'principle of hydrodynamic lift' was established for the phases of movement. Corresponding to the theory, propulsion is produced by the resultant of both forces—drag and hydrodynamical lift. Counsilman shows that the production of forces by the hands is similar to the thrust production by ships' propellers. The thrust production here depends on the relative velocity of flow and the angle of attack under which the flow encounters the hands.

The movement of the extremities serve the locomotion of the body. Flow forces are generated with the hands and feet and thus the body is propelled. One result of the acceleration of water masses is the body velocity. The intracyclic distribution of velocity estimated by film data is shown in Figure 3. This velocity curve may represent the average curve of all participants and is similar to those described by Reischle (1982). The figure shows the fast run of a good male breast stroker. In Table 1, the average data and standard deviation of selected biomechanical parameters of movement are listed.

The curve should be explained briefly in connection with the phases of movement. When the knee flexion is at maximum, velocity is at minimum. The whip action of the legs begins without retardation of time. Thus, the body is accelerated and after a certain time +(s), the velocity curve reaches its first peak v (leg). Although the legs have not yet finished their movement at that movement, the body retards, though. In the period of retarding velocity, the opening of the arms begins. The length of time between recovery and for gliding begins here.

Velocity does not increase before the inward phase of the arms. At the end of the inward phase a clear second peak v (arm) is reached. Immediately after reaching the second peak of velocity, which is usually higher than the first, a remarkable decrease of velocity appears during the leg recovery. After t (zyk) one cycle is finished.

The statistical review did not show any significant differences between the data of women and men according to t (zyk), t($\mathcal{G}$) and v (leg). The maxima of the peaks of course differed accordingly to competition time.

Chronological synchronization of the movement of arms and legs, comparison between a fast and slow run.

When looking at the difference between a slow and fast run, a clear decrease of the time for gliding is remarkable. The difference of the time for gliding t (G) is highly significant. According to the intention to swim faster, the swimmers shorten the time, at which the arms remain extended considerably. Furthermore, the data of the first peak according to the movements of the legs, differ significantly. In fast swimming, higher coefficients are attained. The difference of the velocity of the arms is only of low significance. The result is in contradiction to experts' conviction according to which the arms have to perform more in fast swimming.

This study can be used for answering a controversy, that often appears in experts' discussion on breast stroke swimming. The question is, whether the beginning of the arm movements should infer with the finish of the leg action. Therefore, this part is pointed out in Figure 4.

Whereas in slow swimming the begin of the opening of the arms takes place after closing the legs on the average, the arms are already opened during the movement of the legs in fast swimming. The standard deviation, which is much smaller, leads to the conclusion that all swimmers shorten this phase in fast swimming. This results is a surprise, when taking into account that the swimmers come from different clubs, in which divergent opinions concerning breast stroke exist. The study shows that swimmers according to the tasks swim in different rhythms. In modern, fast breast stroke, the arms are opened during the movement of the legs. Thus, the length of a cycle is shortened and the rhythm is changed.

Conclusion

What kind of conclusion can be drawn from the results for practice? First of all, the results help to clarify points of controversy and thus, they bring more certainty to the acting of coaches and athletes. The statements concerning the pathway of the hands will affect the instructions on positions of the hands and velocity of the arms. Furthermore, the elucidation of the causality between movement of the arms and propulsion is of an importance, which must not be underestimated. As Barthels (1979) claims: "It is important to remember that the purpose of arm movements is to move the swimmer's whole body forward, not merely to feel a great amount of pressure on his hands."

The data concerning the intracyclic course of velocity serve the feedback to the athletes. With the help of a group comparison, the individual curve can be evaluated. For movements are the origin of the body's velocity, the athletes should know about their data concerning this relationship. It appeared that the swimmer gets an impression of the result of his movements in the water by his curves, and by interindividual comparisons, comes to insights on form and quality of his curve, which can be recalled during the training of techniques and can influence his acting to the point of heightened motivation to stabilize the technique.

All coaches and athletes know about the importance of rhythm for performance in breast stroke. The present study does not allow the calculation of forces underlying swimming, nor does it give information about the application of specific theories of movement. Its meaning for practice lies more in showing trends in synchronization over the comparison of means and in the demonstration of solving tasks in movement over the deviation. Obviously, a principle is applied, according to which movement is interpreted as a "dynamical unity" in context with style and surrounding and important factors (pattern of movement, forces or movements) are influenced by biomechanical conditions.

Experience has shown that active participants changed their attitude after the presentation of the results. They realized that a change of coordination produces different flow situations, that means different stimuli on the surrounding and that each cycle is a trial of solution under biomechanical 'pressure' (Ungerechts 1983). A swimmer, who succeeds in that, is said to have a perception of the water to a high degree.

The knowledge of biomechanical conditions is helpful for the training of the perception of the water. By them, the responsible coach is able to select and impart the decisive perceptions. For a body in the water is a large field of receptors for flow conditions, a well-founded selection is necessary. Knowledge of hydrodynamics can abbreviate the process of understanding decisively.