THE POWER INITIATING POINT AND TAIL VORTEX IN SCUBA SWIMMING

Shuping Li, Youlian Hong[1] and Tze-Chung Luk[1]
Hubei University, Wuhan, Hubei, The People' s Republic of China
[1]The Chinese University of Hong Kong, Hong Kong

The purpose of this paper was to explore the position of the power initiating point and the function of tail vortex in scuba swimming. According to the kinematics, human structure and fluid dynamics analysis, it is apparent that the waist serves as the power initiating point. Unlike the traditional concept of swimming, the tail vortex does not always provide resistance in scuba swimming. In this instance, it is necessary to avoid production of intensive vortex action, in order to reduce energy waste, which is a result of the loss of energy being positive to the square of the quantity of vortex. On the other hand, the thrust is positive to the quantity of vortex. Attention should be paid to the quantity of vortex to facilitate producing thrust necessary to overcome resistance found in scuba swimming.

KEY WORDS: scuba swimming, thrust

INTRODUCTION: Scuba swimming, along with other competitive swimming events, was accepted as a sport in the Olympic games in 1986. Scuba swimming is a competitive sport in which the swimmer uses a single fin, like a dolphin, under-water. It is performed under water using the similar conditions as regular swimming. With the help of a strong fin and an underwater respirator, the fin swimmer can be submerged in water longer and can swim faster, covering approximately 50 meters in about 15 seconds. In scuba swimming, an air cylinder is employed so that competitor can stay submerged for longer periods of time.
There is no action required with the arms in scuba swimming. The thrust depends on the oscillation of the trunk and lower extremities as well as fin. Different views persist on which body part, shoulder or waist, serves as the power initiating point. However, it appears that confirmation of power initiating point is important for the techniques and the training in this sport. It is a well-known fact that a streamlined body can reduce tail vortex and therefore reduce the consumption of energy. For the self-thrust body, such as is used in scuba swimming, vortex action is not a complete waste of energy. This study will describe the method used to identify the power initiating point in scuba swimming and the use of tail vortex by means of theoretical and experimental biomechanical analysis.

METHODS: Six male and five female elite short distance fin swimmers were selected as subjects for this study. Four long distance athletes provided the reference group. The selection of the subjects was based on the fact that he/she at least won once in international and national competitions.
An ARRIFLEX 16 SR underwater high-speed camera set at a speed of 100 fps was used to record the performances. The camera was placed under the water with its optical axis perpendicular to the motion plane at the height of 1.08 meters from the bottom of the swimming pool and distance of 10 meters from the track. (FIGURE 1). A total of four tests were made during the yearlong experimental period. Subjects were asked to perform three trials in each test with his/her maximum effort for 100 meters. The athletes' actions at the section among 25-35 meters from the start line were recorded. Filming materials were then analyzed on the JTK-2 Motion Analysis System. The Zatsorsky human body model was employed in motion analysis.
The tail vortex were observed and analyzed by means of Two Dimensional Thrust Method of fluid mechanics.

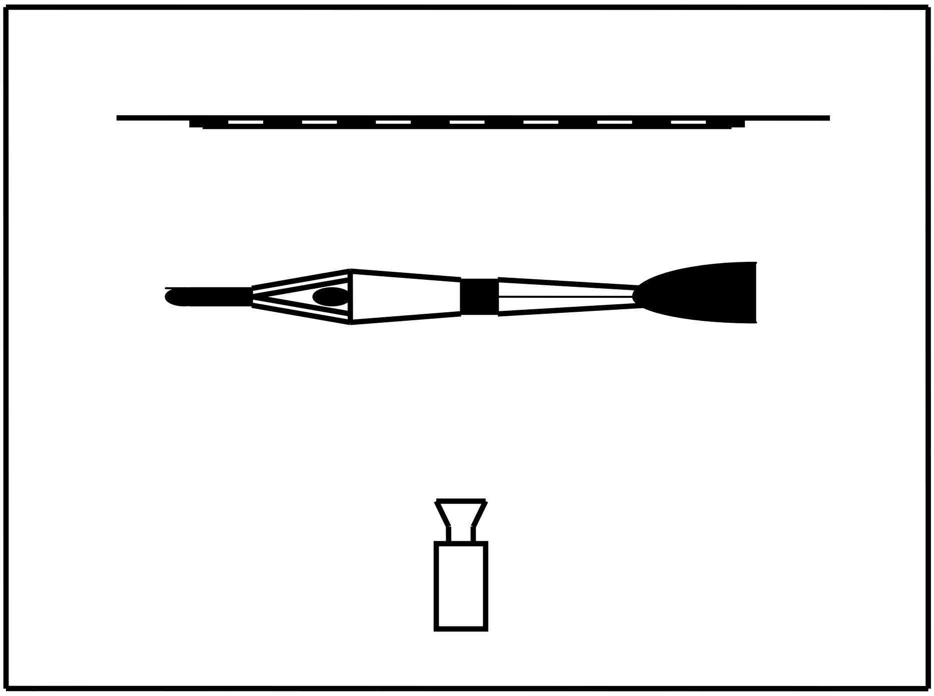

Figure 1- Camera position in the experiment

RESULTS AND DISCUSSION: The kinematics data collected include linear displacement and velocity of the joint centers at wrist, elbow, shoulder, hip, knee, ankle; the center of mass of the body; as well as angular displacement and velocity of the joints at elbow, shoulder, trunk, hip, knee, ankle, and the cylinder.

1. The power initiating point

There existed different views on which serves as the power initiating point, whether shoulder, representing higher frequency oscillation model, or waist, representing lower oscillation model, According to the obtained data, the above views will be examined from three angles:

First, it can be seen that the angular velocities of arm for all four groups were the smallest measurements. The angular velocity of upper trunk and thigh were larger than that of the arm (TABLE 1). In the first column, M and F represent male and female scuba swimming athletes. S and L indicate the short and long distance respectively. When scuba swimming in water, there is no fulcrum to the body. If the shoulder served as the power initiating point, then in order to maintain the balance of angular momentum of the whole body, the angular velocities of the arm would be considerably higher than they appeared to be. This is because that there exists a considerable difference in the mass between the part containing the upper extremities, head and neck and the part containing the trunk and lower extremities. The rate of the mass of these two parts is about 1:4.6. On the other hand, if the waist were considered to be the demarcation, the mass ratio between the upper and lower parts of the body would be 1: 0.9. Therefore, the waist serving as power initiating point should be a logical conclusion from the kinematics data.

TABLE 1 Angular Velocities of Some Specific Body Sections (rad/s) [Mean(SD)]

	upper trunk	arm	thigh
MS	1.96 (1.06)	0.63 (0.49)	1.19 (1.09)
FS	1.57 (0.77)	0.39 (0.34)	2.06 (1.54)
ML	1.20 (0.66)	0.67 (0.36)	1.45 (1.29)
FL	1.49 (0.61)	0.57 (0.27)	1.21 (0.78)

Second, the human body performed “ contrary movement” in the water. The musculature of the abdomen and rear, around the waist, has no fulcrum and therefore will make concentric contractions in this case. However, the muscles around shoulder do not function like the waist, linking together two different parts of body.

Finally, from the viewpoint of efficiency, when a swimmer oscillates his body to produce propulsion, part of the kinetic energy will be transferred into the tail trace and wasted. Under conditions where the propulsion produced is equal, the whole body oscillation would produce more eddies, resulting in greater waste of energy, and therefore the performance would become less efficient. A strong fin provides the main thrust component in scuba swimming. Like dolphin, it is not necessary to oscillate with the whole body. Therefore, more attention should be placed in training on strengthening the muscles around the waist.

2. The tail vortex in scuba swimming

In the traditional view of swimming it is felt that tail vortex does not contribute to movement in the water. Vortex action results from disturbance of the streamline in movement. As a result, it will consume energy and normally is thought of as resistance to movement. However, in the case of self-propulsion of the body, this is not always the situation.

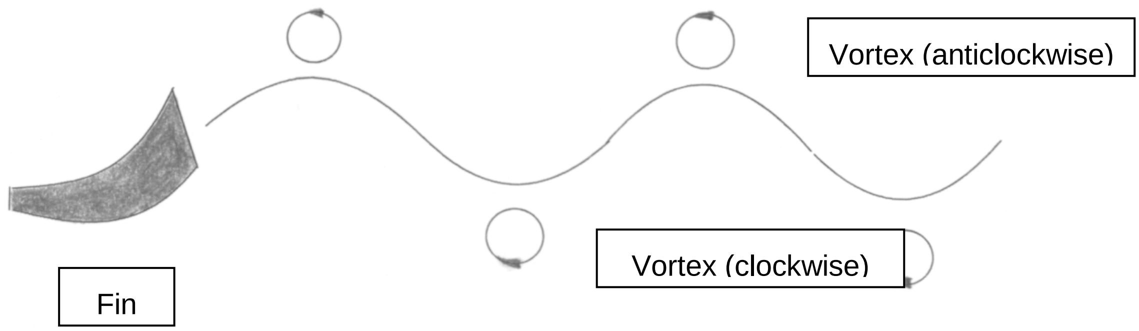

Figure 2

The main thrust in scuba swimming comes from the reaction force of water through the oscillating of the fin. According to the Elongated-Body Theory conducted by Lighthill, M.J., the value of the average thrust of the fin that can be obtained in one movement cycle at the swimming rate of 2.37 m/s was 259 N. The Re is high to 10^6. The production of tail vortex is inevitable. Observation of the tail vortex (Figure 2), showed that when the fin is at the highest position and kicks in the water, there is an anti-clockwise vortex action which produces a backward impulse to the water beneath the fin. Therefore the water provides a reaction to the human body (fin). When the fin is at the lowest position and kicks upwards in the water, there is a clockwise vortex action and that also produces a backward impulse to the water above the fin. Therefore the water give a reaction to the human body again. It is interesting to note that the directions and the upper and lower column position of tail vortex are opposite to the Kaman Vortex Column produced when fluid flows through cylinder body. The function of Kaman Vortex Column is to provide resistance to the cylinder body. In scuba swimming, there is an " anti-Kaman Vortex Column" . Thus the thrust is produced.

CONCLUSION: From the data that has been collected for this study, it is evident that the waist serves as the power initiating point, supported by the kinematics, human structure and fluid dynamics analysis. Regarding the tail vortex, attention should be paid to the fact that some quantity of vortex is needed so that enough thrust is produced to overcome the resistance in scuba swimming. The thrust is positive to the quantity of vortex. On the other hand, the energy waste is positive to the square of the quantity of vortex. It is necessary to avoid production of intensive vortex action in order to reduce the waste of energy and increase efficiency.

REFERENCES:

Landau, L.D. & Lifshitz, E.M.(1959). *Fluid Mechanics* (Translated from the Russian by Sykes, J. B. & Reid, W. H.), London: Pergamon Press; Reading, Mass: Addison-Wesley Pub. Co.

Li, S.P.(1990). Mechanical analysis of elite female fin swimmer technique. *Sports Science*, **10**(2), 57-61.

Lighthill, M.J. (1971). Large-Amplitude Elongated-body Theory of Fish locomotion, *Proc.R.Soc. Lond.B,* **12,**179-198.

Tao Z.L. (1984). *Biological Fluid Mechanics*, Beijing: Science Publishing House.