SCUBA DIVING FIN TYPES AND CHARACTERISTICS OF DIVER'S PROPULSIVE MOTION

Jaebum Park and Insik Shin
Department of Physical Education, Seoul National University, Seoul, Korea

The purpose of this study was to analyze quantitative evaluation of propulsive motion as different fin types and degree of skill that affected motion. Three skilled dive masters and three unskilled subjects participated in the study. The types of fin are paddle style and propller style which have different functional systems for propulsion each other. Two video cameras (Panasonic D-5100, frame rate: 60 Hz) are used for motion analysis, and two load cells are used for measuring propulsion force. The measuring system for propulsion force was designed to acquire the pulling force. Matlab (Mathwork, Inc.) was used for separating each direction force and calculate the impulse. Kwon3D (Visol, Inc) was used to analyze the fin kick motion. Digitizing points were hip, knee and ankle joint. The subjects were tied with a rope but they could move on all direction a litte bit. Three-way ANOVA was used for analyzing significance of difference between groups, stroke rates (30-60-maximun stroke/min) and fin-types. The results of this work indicate that stroke rate was controlled by the range of knee angle, and the adequate fin style was different according to the diving skill.

KEY WORDS: Scuba diving, impulse, Fin type

INTRODUCTION: The human being cannot breathe under water and human body is fit for life on land. Therefore, human motion cannot help being restricted when we dive. To overcome this point, many scientists have developed the equipment which could help people with underwater motion. So, to access the analysis of aquatic motions in sports biomechanics, both the aspects of motions and equipments which could influence the performance should be considered. Motions and equipments would have interaction so that the characteristics of equipments could have an influence on the characteristics of motions. Skin and scuba diving needs delicate and scientific equipment to be active under water. Of the various equipments, the fin is the most important one to move on rapidly. The good fin could make it possible to exert great propulsion force as less exerted human power. Many manufacturing companies make fins which have special functional factors and these factors could affect diver's fin-kick motion. The quantitative analysis of fin-kick motions due to the functional factor of fins, which is the main purpose of this study, could make possible to grasp the essential factor of effective fin-kick motion.

METHODS: This study observed three skilled dive masters who had more than 10 times of diving experience and three unskilled divers. It was impossible to manufacture individualized fins based on its propulsion characteristics alone, we chose to use two types of fins available on the market, namely paddle and propeller style (Figure1). Stroke rates were categorized into 30, 60, and the maximum stroke (stroke/min) by a sound generator. Each subject conducted kicks with three different stroke frequencies. The frequencies were set randomly to prevent learning effect. Swimming method was tethered swimming (Craig A.B. et al, 1980; Magel J.R., 1970), but the subjects could move on all direction a litte bit. The propulsion force was measured by load cell (maximum load was set at 50 kgf). The experiment was designed to prevent any distortion in measurement due to movements of the participants

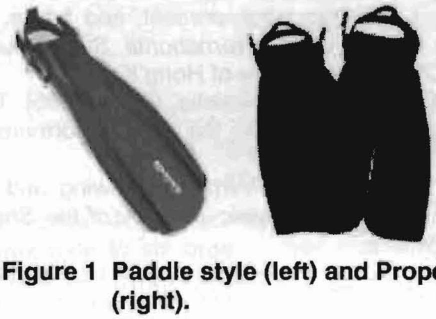

Figure 1 Paddle style (left) and Propeller style (right).

(Figure2 & 3). With the minor axis load cell, the separation of ingredient for forces towards x, y and z directions was carried out by calculating A's value in the three-dimensional coordinates.

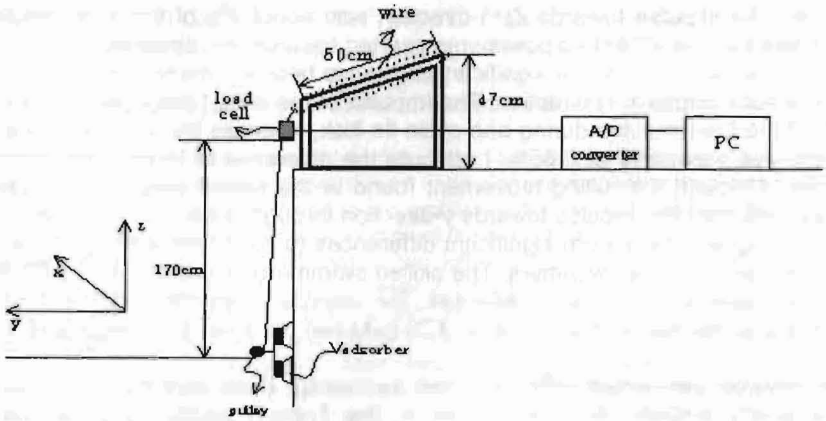

Figure 2 The side view of the measuring system for propulsive force. The Load cell acquires data through pulley which could divert the force direction, and the data is stored to PC.

This study recorded the central points of joints found on the lower limbs to find out the characteristics of propelled motion. After tethered swimming, the three dive masters swum without force measuring system to analyze the distance per stroke. Three-way ANOVA was applied to measure changes in human body movements due to the swimming skill, stroke frequency, and fin type as well as the fin movement. Tukey was performed to check the statistical significance of the finding.

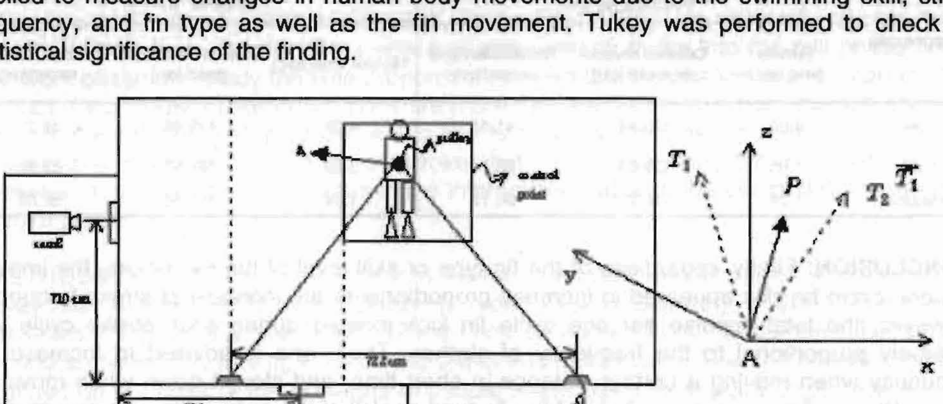

Figure 3 The upside view of the measuring system for propulsive force. Two load-cell are used for measuring force data and two camera are used for motion capture. Point 'A' is digitized to separate each direction force. 'P' represents resultant force of T_1 and T_2.

RESULTS AND DISCUSSION:

The range of knee angle: There was a significant difference ($p < .05$) in the range of knee angle during one cycle fin-kick between the skilled divers and unskilled divers. That is, the skilled swimmers had the angle of 64.50 ± 19.4 degree, whereas the unskilled swimmers had 42.82 ± 16.73 degree. However, there was no effect due to interactions among the swimming skill, fin type, and stroke frequency.

Each direction impulse: Each direction force was calculated to impulse (N·sec) per one cycle fin kick.

Z-direction impulse: There was no statistical difference between the skilled and unskilled participants. The impulse towards Z(+) direction was about 4% of the total impulse during one cycle fin-kick, and almost no power was exerted towards Z(-) direction.

X-direction impulse: There was a significant difference between the two groups regarding the impulse exerted towards x(+) direction. The impulse of the skilled participants was measured at 6.35% of the total impulse during one cycle fin-kick, whereas the impulse of the unskilled participants was measured at 5.86%. I attribute the difference to kicking movements of the participants. Although the rolling movement found in the skilled participants dispersed the force, it also affected the impulse towards y-direction through creating a screw effect.

Y-direction impulse: There were significant differences ($p < .05$) depending on the skill level and stork frequency of the swimmers. The skilled swimmers recorded 5.47 ± 2.72 (N·sec) as the impulse towards Y direction, whereas the unskilled recorded 3.01 ± 1.43 (N·sec). Moreover, the correlation coefficient was .429 between the knee joint angle and Y-direction impulse.

Distance traveled per stroke: After tethered swimming, three dive-masters swum without force measuring system. As it is shown in the Table1, paddle style fin allowed the participants to travel longer distance per stroke and per second than propeller style fin did. The distance traveled due to each stroke was longer when the corresponding stroke frequency was lower. However, the distance traveled per second was longer when the corresponding stroke frequency was higher.

Table 1 The result of the analysis of distance traveled per stroke. Each value is mean value of three dive maters.

Stroke rate	Paddle style fin			Propeller style fin		
	1stroke time(sec)	Distance traveled per stroke (cm)	Traveled Ditance per second (cm)	1stroke time(sec)	Distance traveled per stroke (cm)	Traveled Ditance per second (cm)
30	4.09	170.47	41.87	4.26	149.85	35.22
60	1.95	126.88	65.14	2.09	129.08	62.96
maximal	1.26	110.70	90.12	1.24	107.56	86.55

CONCLUSION: Firstly, regardless of the fin type or skill level of the swimmers, the impulse per one cycle fin kick appeared to increase proportional to the increase of stroke frequency. However, the total impulse per one cycle fin kick exerted during each stroke cycle was inversely proportional to the frequency of strokes. Thus, one is advised to increase the frequency when moving a certain distance in short time, and slow it down when moving a long distance. Secondly, regardless of the fin type or skill of the swimmers, one can create a high impulse per one cycle fin kick by maintaining the increase of knee angle range while increasing the stroke frequency. Thirdly, this study recommends propeller type for unskilled swimmers, and paddle type for skilled swimmers for the best result.

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