EVALUATION OF ARM STROKE TECHNIQUE IN FRONT CRAWL SWIMMING

Hiroshi Suito, Hironari Shinkai*, Hiroyuki Nunome, and Yasuo Ikegami****

Faculty of Psychological and Physical Science, Aichi Gakuin University, Nisshin, Japan
***Graduate School of Education and Human Development, Nagoya University, Nagoya, Japan**
**** Research Centre of Health, Physical Fitness, and Sports, Nagoya University, Nagoya, Japan**

The purpose of the present study was to evaluate the high elbow technique in arm stroke motion, and to investigate the relationship between the technique and the swimming performance in front crawl swimming. Subjects were fourteen skilled male swimmers and five unskilled male swimmers. The arm stroke motions of subjects were captured three-dimensionally (3-D) at 60 Hz during 25 m front crawl swimming. A new index of the high elbow arm stroke technique (high elbow index) was developed. The index was defined by the 3-D coordinates of the three joints (shoulder, elbow and wrist). As the result, the arm stroke technique of the skilled swimmers was different compared with the unskilled swimmers. Moreover, a significant correlation was obtained between the index and the swimming velocity. The results indicated that the index was effective to evaluate the arm stroke technique and the high elbow technique was effective for improvement of the swimming performance in front crawl swimming.

KEY WORDS: high elbow, swimming performance, pull phase

INTRODUCTION:

In swimming, propulsive force is induced by motion of the arms and legs. During the front crawl, the propulsive force is known to be mainly generated by the arm stroke motion (Hollander et al., 1988, Deschodt et al., 1996). In general, there are distinctive differences between skilled and unskilled swimmers for the arm stroke motion. In the early stage of the arm stroke motion (the pull phase), the skilled swimmers try to keep their elbow high in the water while the unskilled swimmers found it difficult to maintain such high elbow position. The high elbow stroke has been accepted as a key feature to effectively engage the water in the pull phase. However, there has been no study that tried to evaluate the state of the high elbow stroke quantitatively. To date, therefore, the quantitative definition of the high elbow stroke is still vague and the relationship between the state of the high elbow stroke and the swimming performance has never been clarified. The present study has two aims: (1) to evaluate the state of high elbow stoke in the pull phase of the front crawl and (2) to investigate the relationship between the high elbow stroke technique and the swimming performance.

METHODS:

Subject: Fourteen skilled male swimmers (age = 19.9 ± 0.8 yr; height = 174.5 ± 7.3 cm; mass = 69.8 ± 5.8 kg; the season's best time of 100 m = 55.37 ± 3.51 s) and five unskilled male swimmers (age = 25.6 ± 3.4 yr; height = 173.6 ± 10.8 cm; mass = 67.8 ± 8.6 kg; the season's best time of 100 m = 120.74 ± 31.00 s) volunteered to participate in this study. All subjects were completely informed about the procedures and demands of the study and signed a written informed consent form.

Data Collection: All subjects performed the full-exertion 25 m front crawl in a 25 m pool (water temperature = 29.0°C). All subjects started from the water, using a push-off start. Before the start of measurement, the swimmers conducted a warm-up with self-selected intensity for 30 min. Before the trials, half-spherical markers (diameter = 15 mm for hand, and 30 mm for wrist, elbow, shoulder and waist) were fixed securely onto the lateral side of bony anatomical landmarks of the right arm, i.e. the 3rd fingertip (hand), 2nd knuckle (hand),

5th knuckle (hand), styloid process of the ulna (wrist), radial head (elbow), acromion (shoulder), and iliac crest (waist).
Two electrically synchronized video cameras (SONY Inc., CCD-IRIS) were used to capture the right upper limb motion from 15 m to 20 m at 60 Hz (exposure time 1/1000 s). Each camera was enclosed in a waterproof cylinder and fixed underwater at a depth of approximately 0.6 m from the surface. The cameras were positioned to the right front and the right rear of the subject. To calibrate the performance area, a calibration frame (1.0 × 3.0 × 1.0 m) with 15 control points was videotaped before the trials.
A digitizing system (DKH Inc., Frame-DIAS) was used to manually digitize the landmarks. Each trial was digitized from the entry of the right hand into the water to the release of the right hand from the water.
The direct linear transformation (DLT) method (Abdel-Aziz & Karara, 1971) was used to obtain the three-dimensional coordinates of each landmark. The three-dimensional coordinates were expressed as a right-handed orthogonal reference frame fixed on the surface of the water (Z was vertical and pointed upward, Y was pointed in the swimming direction, X was perpendicular to Y and Z). The maximum error for the X, Y and Z components in the performance area (X = 1.0, Y = 3.0, Z = 1.0 m) were 11 mm, 14 mm and 13 mm, respectively.

Data Analysis: The swimming velocity was computed as the first derivative of the Y displacement of the waist landmark using central differentiation.
For evaluation of the state of the high elbow in the pull phase, the vector perpendicular to the plane formed by the forearm and upper arm was projected onto the horizontal plane (X-Y plane). The angle θ was computed as the angle between the projected vector and the Y direction vector (Figure 1). The angle θ was defined as high elbow index (HEI). For example, if the angle is a negative and/or small positive angle, the HEI corresponds to the state of the high elbow (Figure 1 (a)). On the other hand, if the angle is a large positive angle, the HEI corresponds to the state of the dropped elbow (Figure 1 (b)).

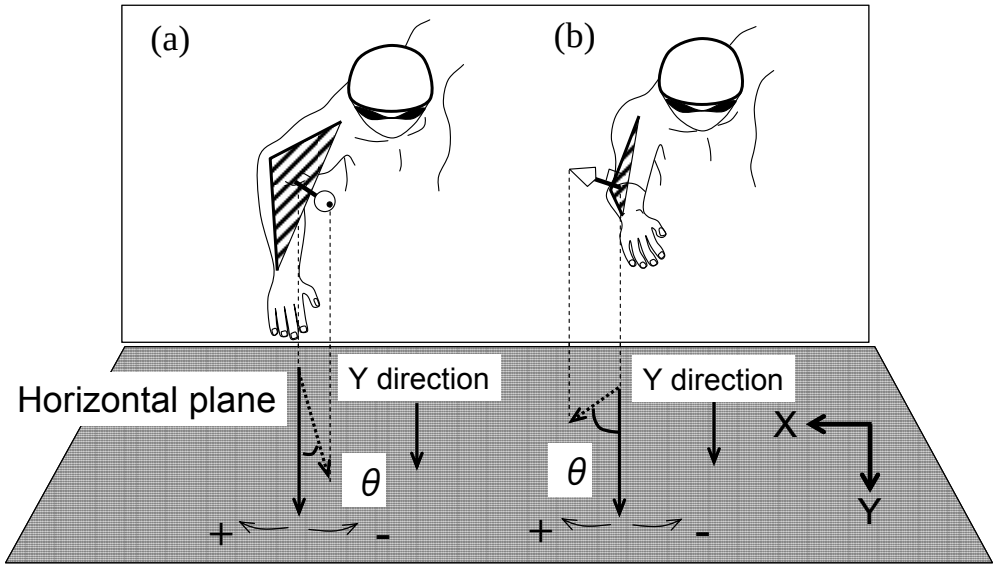

Figure 1: Definition of high elbow index (HEI) in front crawl swimming. Left (a) indicates the state of the high elbow. Right (b) indicates the state of the dropped elbow.

Statistical Analysis: Mean and standard deviations were calculated for the measured parameters. Pearson correlation was also used to estimate the relationship between the averages of HEI and swimming velocity during pull phase.

RESULTS:

Figure 2 shows the average changes of the HEI of the skilled and the unskilled swimmers. The average change of the HEI of skilled swimmers was distinctively smaller than that of the unskilled swimmers. Thus, the difference of the state of the high elbow between the two groups was clearly highlighted by the HEI.

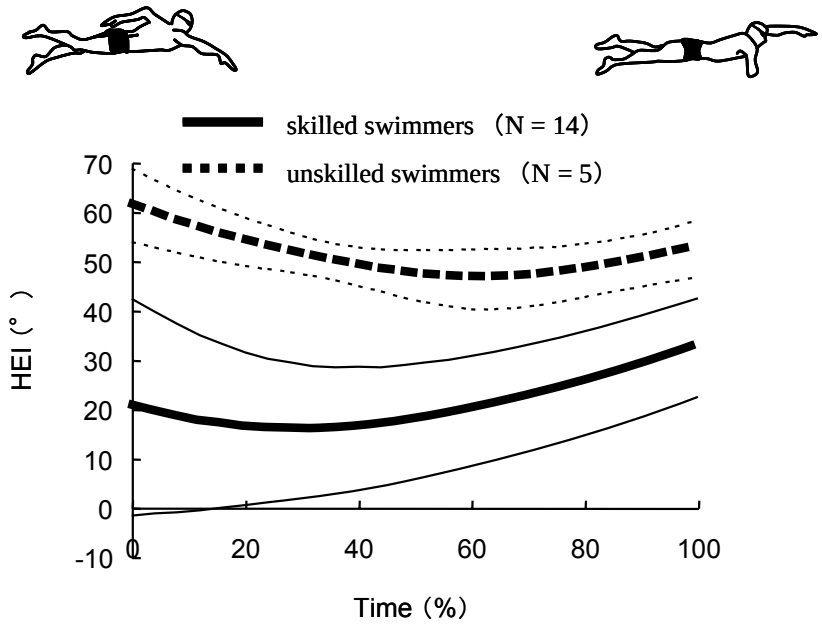

Figure 2: Average changes of the HEI of the skilled swimmers (solid line) and the unskilled swimmers (broken line) in the front crawl swimming.

Figure 3 shows relationship between the HEI and the swimming velocity in pull phase. A high correlation coefficient was obtained for the all swimmers between the HEI and the swimming velocity in pull phase. Moreover, it can be seen a moderate correlation coefficient between the HEI and the swimming velocity in pull phase among the skilled swimmers.

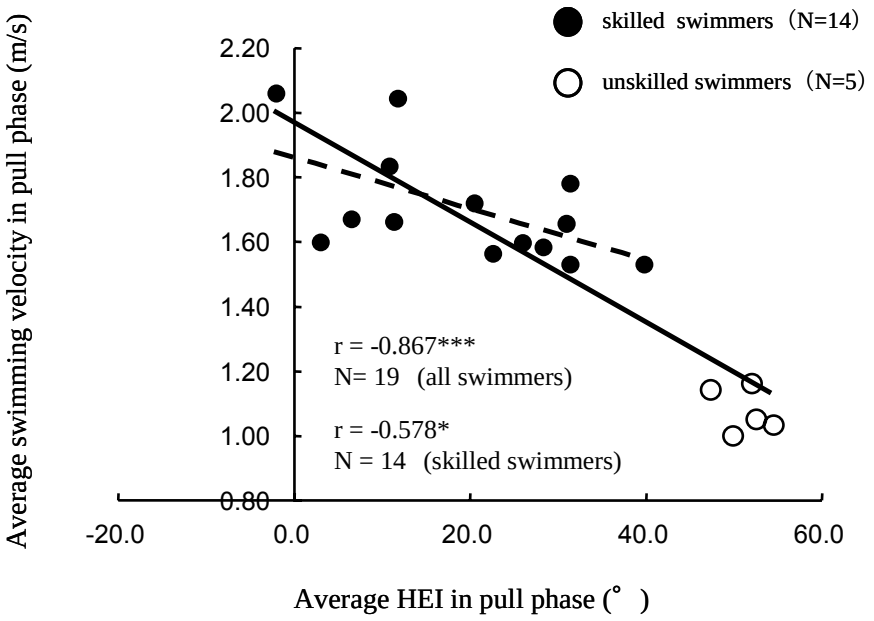

Figure 3: Relationship between the HEI and the swimming velocity in the pull phase. Solid line: all swimmers; broken line: skilled swimmers (*: $p < 0.05$, *** $p < 0.001$).

DISCUSSION:

In the present study, specific arm stroke technique (the high elbow stroke) of skilled swimmers generally seen in the pull phase of the front crawl was evaluated quantitatively and its effect on the resultant swimming velocity was investigated. The high elbow index (HEI) developed in the present study succeeded in clarifying a distinctive difference of the state of the high elbow stroke between the skilled and the unskilled swimmers (Figure 2). Moreover, the HEI was highly correlated with the swimming velocity of all swimmers ($r = -0.867$) and moderately correlated with that of the skilled swimmers($r = -0.578$). These results support that the high elbow stroke would be a key feature to improve the propulsive action of the arms.

It is well known that fluid forces are proportional to the projected area toward the moving direction. From the viewpoint of fluid dynamics, it can be considered that the projected area toward the propulsion direction of the forearm and hand become large by keeping high elbow during the pull phase; therefore, this particular position of the arm most likely allows swimmers to generate the propulsion force more effectively.

From the poolside, coaches often advise, “catch the water with high elbow” to swimmers, although there is no quantitative evidence to supports this type of instruction. The present study is the first to provide evidence that strongly support the above practical instruction by showing the state of high elbow stroke and its relationship to the swimming velocity. As the moderate correlation between the HEI and the swimming velocity was observed among the skilled swimmers, keeping the elbow high in the early stage of the arm stroke is likely effective to improve the swimming performance of those swimmers.

CONCLUSION:

The present study succeeded in evaluating the arm stroke technique during the pull phase of front crawl swimming by the high elbow index (HEI). Moreover, there was a significant correlation between the HEI and the swimming performance. These results emphasized that to keep the elbow high in the water is most likely effective to improve the swimming performance.

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