Patterns Of Forward Velocity in the Four Competitive Swimming Strokes

Ernest W. Maglischo
California State University
Bakersfield California

Cheryl W. Maglischo and T.R. Santos
California State University
Chico, California

INTRODUCTION

It has been repeatedly demonstrated that there are marked periods of acceleration and deceleration within each cycle of the various competitive strokes (Craig et al, 1988; Hanavan, 1964; Kent and Atha, 1975; McElroy and Blanksby, 1976; Persyn et al, 1975; Reischle, 1979; Van Tilborgh, et al, 1988). These intra-cycle variations in velocity have generally been plotted in two ways: (1) by measuring the forward velocity of the swimmer's hips, and (2) by measuring the forward velocity of their centers of gravity. Of the two, measuring the velocity of the center of gravity is the more accurate method.

Measures of forward velocity are valuable because the indicate when and to what extent certain phases of the stroke cycle are propulsive For this reason, investigating intra-cyclic variations in the strokes of world-class swimmers should provide valuable models of propulsive efficiency. These models could help in the diagnosis and correction of strokes for swimmers at any level.

PURPOSE

Therefore, the purpose of this study was to evaluate intra-cyclic variations of forward velocity among selected world-class forward velocity among selected world-class swimmers in the four competitive strokes. Forward movements of the swimmers' centers of gravity were used to measure forward velocity.

METHODS

The subjects were 18 males and female members of the 1984 United States Olympic Swimming Team. They ranged in age from 17 to 24 years. All testing took place at the Mission Viejo Swimming Center on June 12, 1984, two weeks prior to the 1984 Olympic Games. The project was supported by funds from United States Swimming and approved by the U.S. Olympic Coaching Staff.* The forward velocity of the swimmers' centers of gravity were plotted while swimming each of the four competitive strokes.

A Redlake Locam 16mm, DC motor drive movie camera was placed in a plastic underwater housing and secured by weights to the bottom of the pool 12 feet below the surface. In this way, the swimmers could be filmed from underneath as they passed through the field of view. The camera was interfaced to a switch box so it could be started and stopped from the pool deck. The camera was levelled and positioned so that it faced directly upward. The film speed was 64 frames per second.

Each of the subjects swam one length of the pool at their Olympic qualifying speed, passing over the camera in the process. A stopwatch was used to insure the proper speed and the trial was repeated if not completed properly. Each swimmer performed at least three trials using his/her Olympic qualifying stroke or strokes.

Foreach competitive stroke, the trials for 10 swimmers were selected for analysis, a total of 40 trials in all This large number of trials was possible because those swimmers who qualified in the individual medleys tested in all four competitive strokes and because some swimmers qualified in more than one stroke. the trials selected were those that were completed at the proper speeds and where the swimmers' entire bodies were visible during one complete stroke cycle.

An Eiki Motion Analyzer was used to project the selected trials on a smooth white paper fastened to a wall A vertically suspended Numonics digitizer interfaced to the California State University, Chico computer was used to collect data. Every second frame was digitized. The position of 20 segmental endpoints and a reference point were determined in each digitized frame according to the method described by Dempster (1955).

The digitized data were analyzed by the computer program JFILMB which was developed at Indiana University. This program calculated the position and instantaneous velocity of the center of gravity of the swimmers' bodies.

One subject's selected trial was digitized 10 times to determine the reliability of the digitizing process. Reliability was established by correlating the forward velocity of the center of gravity on the first digitized trial with velocity of the center of gravity on the first digitized trial with velocity patterns of the center of gravity for the additional nine digitized trials of that some stroke cycle.

The forward velocity curve of the center of gravity for each selected trial was then graphed so that the pattern of acceleration and deceleration within each stroke cycle could be inspected visually and analyzed quantitatively.

RESULTS AND DISCUSSION

The reliability coefficients determined for digitizing ten trials of one subject's freestyle stroke cycle are presented in Table 1.

Table 1.

Reliability coefficients for digitizing one trial of the front crawl stroke ten times.

TRIALS	CORRELATION
1 vs. 2	.90*
1 vs. 3	.92*
1 vs. 4	.90*
1 vs. 5	.90*
1 vs. 6	.89*
1 vs. 7	.93*
1 vs. 8	.90*
1 vs. 9	.96*
1 vs. 10	.91*

*Significant at the .01 level of confidence.

These correlations ranged from .89 to .% with the average being .91. The reliability coefficients were considered acceptable by the investigators in this study.

Patterns of Forward Velocity in the Front Crawl Stroke.

The graph in Figure 1 shows a typical pattern of forearm velocity during one stroke cycle in the front crawl stroke. The cycle began with the front crawl stroke. The cycle began with the entry of the right arm and included its underwater armstroke. This was followed by the left armstroke. The cycle was completed with the next entry of the right arm. The points of entry and exit of the right and left arms were indicated by the figures of swimmers at the top of the graph. Each armstroke was divided into three phases, a downsweep, **insweep,** and upsweep. These phases were designated at the top of the graph and illustrations by the figures of swimmers.

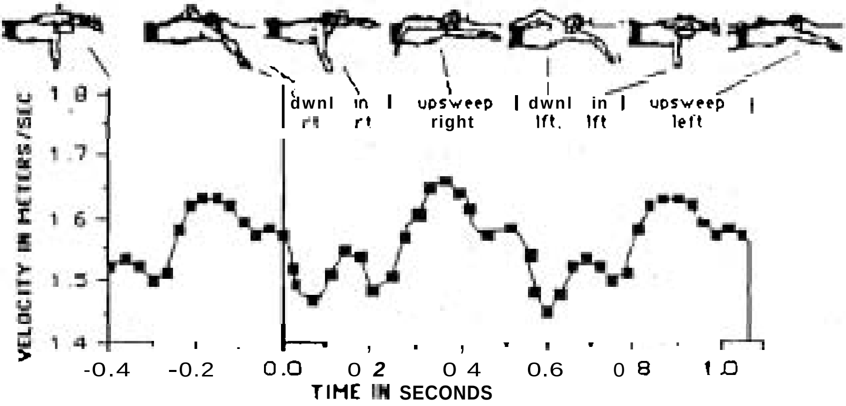

Figure 1: Forward velocity pattern for front crawl stroke

The downsweep began at entry and continued until the **insweep** commended, (a point commonly called the "catch). The **insweep** began at the catch and continued until the swimmer's arm was flexed approximately 90 degrees underneath **his/her** body. The upsweep began at completion of the **insweep** and continued until the propulsive phase of the underwater armstroke was completed, just prior to the swimmer's hand leaving the water. Pressure on the water was then released and the swimmer's hand left the water and completed its recovery over the water.

The armstroke was divided into the following four underwater phases; **first** downsweep, first upsweep, second downsweep, and second upsweep. The first downsweep took place after the entry and continued until the catch was made. The first upsweep began at the catch and continued until the swimmer's arm was flexed approximately 90 degrees. The second downsweep began at the end of the first upsweep and continued until the swimmer's arm was completely extended and below his/her thigh. The second downsweep and continued until the swimmer's arm left the water.

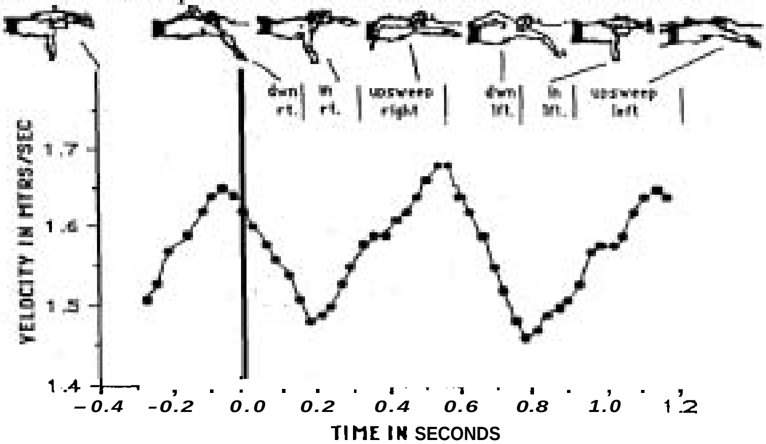

Figure 2: A one-peak velocity pattern for the front crawl stroke

The propulsive peak coinciding with the entry of the right arm in Figure 3 was due to the second downsweep and/or the second upsweep of the lift armstroke. Once the left arm released pressure on the water, the right began to sweep down and out in its first downsweep (point 0 on the graph). The swimmer's forward velocity decelerated during this movement. most swimmers decelerated approximately .2 meters/second and the movement required between .15 and .20 seconds to complete.

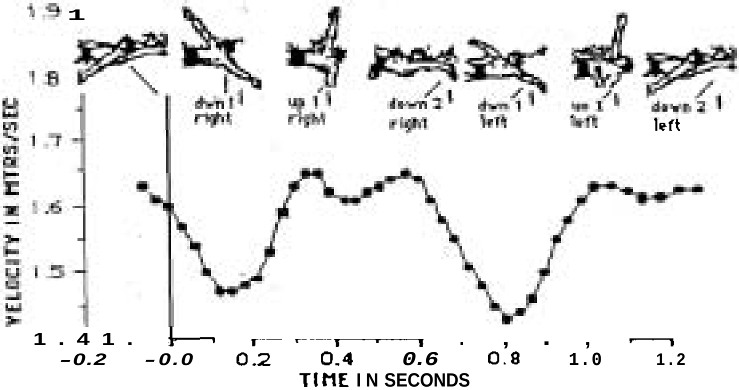

Figure 3: Forward velocity pattern for the back crawl stroke

The first propulsive phase of the armstroke was the first upsweep. It was very propulsive with many swimmers reaching their peak forward velocity during its execution. Others increased their forward velocity markedly during this phase and increased it only slightly more during the second downsweep. The first upsweep generally required .10 to .20 seconds to complete. The range of increase in forward velocity was .10 to .25 meters/second.

There was usually a slight decelerated during the transition from first upsweep to second downsweep. Followed by an acceleration in forward velocity throughout the latter sweep. The effect of this second downsweep on propulsion varied considerably among the subjects in this study. Most increased forward velocity between .05 and .10 meters/second after the transition. Only a few were able to surpass the forward velocity attained during the previous upsweep. Most approached or equalled it, however. The second downsweep was usually completed in .10 to .20 seconds.

The right arm released propulsive pressure on the water at completion of the second downsweep. After that it was brought to the surface in the second upsweep and then out of the water and into recovery.

The left arm of the swimmer entered the water just as the right was completing its second downsweep. Once again, there was a deceleration in forward velocity during the first downsweep of the left arm. This was followed by accelerations in forward velocity during the first upsweep and second downsweep. As was the case in the front crawl, forward velocity was greater during the right armstroke than during its counterpart.

For most of the back crawl swimmers, propulsive force ended with completion of the second downsweep. During the second upsweep. They released pressure on the water and swept their hands to the surface and out of the water into the recovery. A surprising finding was that some swimmers continued to propel their bodies forward during the second upsweep. The graph in Figure 4 shows the velocity pattern of a swimmer who is accelerating his body forward during the second upsweep of each armstroke. Heretofore, this motion was considered non-propulsive and part of the arm recovery. These data indicate that the second upsweep can be used for propulsion. Swimmers who use it for this purpose completed the second upsweep in .10 to .20 seconds and increased their forward velocity approximately .10 meters/second.

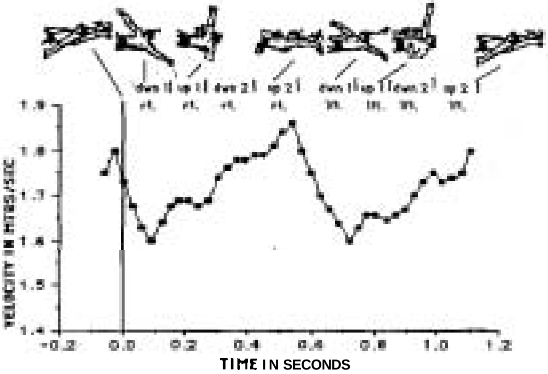

Figure 4: Forward velocity pattern for the back crawl stroke using the second upsweep for propulsion

Forward Velocity During the Butterfly. The graph in Figure 5 illustrates changes in forward velocity during one stroke cycle. The phases of the stroke are listed at the top. They are the outsweep, upsweep, and the recovery. The figures at the top show when the swimmer's hands entered the water in addition to illustrating the stroke phase being completed.

The outsweep began after entry with the arms sliding out to the catch position. At that point the first propulsive phase, the insweep, began. The insweep continued until the swimmer's arms were flexed nearly 90 degrees under his/her body. The second propulsive phase, the upsweep, started near the end of the previous insweep. The swimmer's arms travelled up, out and back until they released propulsive pressure near the surface of the water. The recovery was the phasebetween completion of the upsweep and the entrance of the hands into the water for the next stroke cycle.

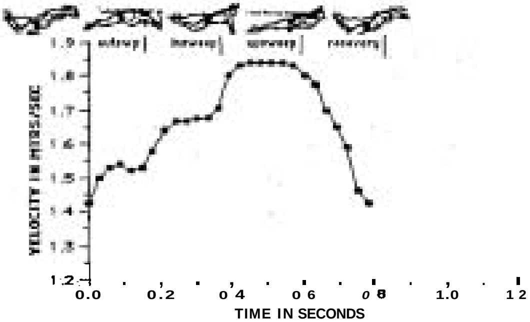

Figure 5: Forward velocity patterrn for a two-peak butterfly

Looking at Figure 5, the acceleration in forward velocity that occurred during the **outsweep** of the arms was probably due to the downbeat of the swimmer's **first** kick. The **outsweep** generally required about **.10** seconds to complete and the swimmer's forward speed accelerated approximately **.10 to .15 meters/second.**

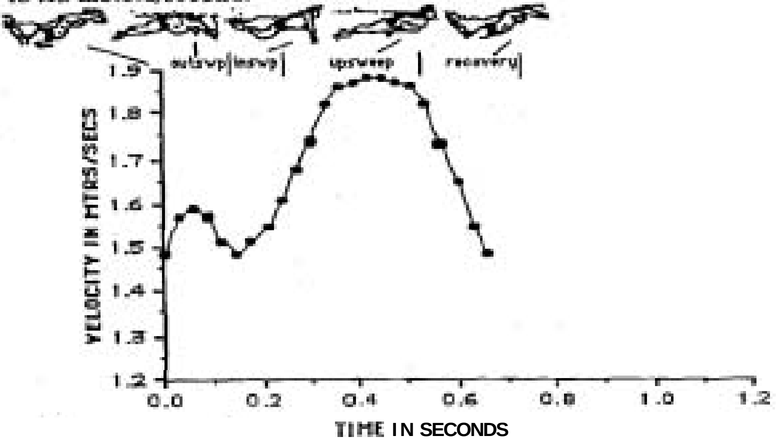

Figure 6: A one-peak velocity pattern for the butterfly

There was usually a slight decelerated in forward velocity after the downbeat of the kick hand been completed and before the **insweep** began. For most swimmers, the **insweep** that followed was a very propulsive phase of the armstroke. Most accelerated forward .20 to .30 **meters/second** in the .20 seconds required to complete this stroke phase. Additionally, they maintained or increased their forward velocity during the following upsweep. It required approximately. 20 seconds to complete this upsweep.

Propulsive pressure was released just before the swimmers' hand left the water. This was followed by a recovery of the arms over the water. The arm recovery required between **.20** and **.30** seconds and forward velocity decreased by **.30** to **.40 meters/second.**

The major variation in patterns of forward velocity seen among **world-**class butterfly swimmers involved the relationship between the **insweep** and upsweep. Some swimmers had two-peak patterns like the one shown in Figure 5. Others exhibited a one-peak pattern like that illustrated in Figure 6. One-peak butterfly swimmers achieved their peak forward velocity during the **insweep** and then maintained it during the upsweep. They tended to use a minimal **insweep** and a lengthened upsweep.

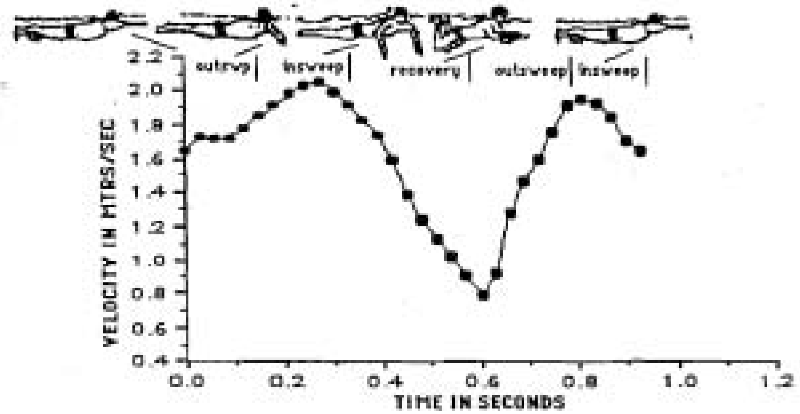

Figure 7: Forward velocity pattern for the breaststroke

Forward Velocity in the Breaststroke.

Intra-cyclic variations in forward velocity were greater during the breaststroke than any of the other competitive strokes. A typical velocity pattern for one stroke cycle is illustrated in Figure 7. The armstroke was divided into an outsweep, insweep and recovery. The recovery of the legs coincided with the arm recovery. The propulsive phase of the kick were the outsweep and insweep.

The outsweep of the arms began as they stretched forward during the recovery and ended when the insweep began at the catch. The insweep was the only propulsive phase of the armstroke and continued until the hands were nearly together under the swimmer's body. The arm recovery was the stretch forward for the next stroke. The recovery of the legs took place during the arm recovery. It ended with the legs flexed. The outsweep of the legs was an extension back and out. The insweep was a squeezing together of the legs. Both the outsweep and insweep of the legs were propulsive.

Most of the world-class breaststrokers we studied began the outsweep of their armstrokes as they completed the insweep of their kicks. Thus, the forward velocity they maintained during the outsweep of their arms was probably due to the kick. The outsweep generally required .10 to .20 seconds to complete.

Forward velocity decelerated slightly once the kick was completed and then increased again during the insweep of the armstroke. Most of the subjects completed the insweep in .20 seconds and increased their forward velocity .15 to .30 meterslsecond.

Forward velocity decelerated markedly during the arm and leg recoveries Although this deceleration was unavoidable, it was observed that world-class breaststrokes spent less time in the recovery phase and decelerated less during that phase then breaststrokes of lower achievement. Most of the breaststrokers were studied decelerated approximatelv 1.0 meters/second during this phase and the recovery required approximately .30 seconds. Based upon the author's observations of less-skilled breaststrokers, it was not uncommon for then to decelerate 1.5 meterslsecond during the recovery phase of the stroke cycle and that phase often required .4 to .5 seconds for them to complete.

Forward velocity accelerated sharply during the outsweep of the kick regaining, or nearly so, the velocity that was lost during the recovery phase. The outsweep generally lasted .10 to .15 a second. Some swimmers maintained their forward velocity during the insweep of the kick. Others decelerated .10 to .30 meters/second during this phase. The insweep of the kick generally lasted .10 to .20 seconds.

Those swimmers who lost speed during the insweep of the kick seemed to do so because they plantar flexed their ankles. On the other hands, swimmers who maintained propulsion during this phase had their ankles dorsi flexed and their feet inverted so that their soles faces inward.

CONCLUSION

Hopefully, these descriptions of the patterns of forwardvelocityin the four competitive strokes may aid swimmers, coaches and researchers in understanding how and where swimmers apply propulsive force during each stroke cycle.

REFERENCES

Craig, A.B., W.L. Boomer, and P.L. Skehan. 1988. Patterns of velocity in competitive breaststroke swimming. B. Ungerechts, K. Wilke, and K. Reischle (Eds.), *Swimming Science V*. Illinois: Human Kinetics Books, pp. 73-78.

Dempster, W.T. 1955. Space requirements of the seated operator. ***Wade Technical Report.*** Wright-Patterson Air Force Base, Ohio, 55-159.

Hanavan, E.P. **1964.** A mathematical model of the human body. ***AMRL Technical Report.*** Wright-Patterson Air Force Base, Ohio, 64-102.

Kent, M. and J. **Atha.** 1975 Intracycle Kinematics and body configuration changes in the breaststroke. In: L. **Lewillie** and J.P. Clarys (Eds.). Swimming **II.** Baltimore: University Park Press. pp. 125.129.

McElroy, K. and B. Blanksby. 1976. Intra-cycle velocity fluctuations in highly skilled breaststroke swimmers. ***Australian Journal of Physical Education, 71:25-37.***

Miyashita, M. 1971. An analysis of fluctuations of swimming speed. In: L. Lewillie and J.P. Clarys (Eds.), ***First International Symposium on Biomechanics in Swimming, Waterpolo and Diving. Belgium: Universities Libre De Bruxxelles, pp. 53-58.***

Persyn, U., J. **DeMaeyer,** and H. Vervaecke. 1975. Investigation of hydrodynamic determinants of competitive swimming strokes. In: L. Lewillied and J.P. Clarys (Eds.). Swimming **II.** pp. 214-222. Baltimore: University Park Press.

Reischle, K. 1979. A kinematic investigation of movement patterns in swimming with photo-optical methods. In: J. Terauds and E.W. Bedingfield (Eds.). Swimming **III.** Baltimore: University Park Press. pp.127-136.

Van Tilborgh, L.V., E.J. Willems, and U. Persyn. 1988. Estimation of breaststroke propulsion and resistance-resultant impulses from film analysis. B. Ungerechts, K. Wilke and K. Reischle (Eds.), ***Swimming Science V,*** Illinois: Human Kinetics Books, pp. 67-72.