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SIMULTANEOUS RECORDINGS OF VELOCITY AND VIDEO DURING SWIMMING

Albert B. Craig [1], Budd Termin[2], and David R. Pendergast [2]

[1]University of Rochester, Rochester, New York and [2]State University of New York at Buffalo, New York, USA

A method is described for the recording a swimmer's velocity and synchronizing these records with the underwater video. Examples of these records during pushing off from the side of the pool, breaststroke, butterflystroke, backstroke, and crawlstroke are presented. These records demonstrate to swimmers and coach the biomechanics of swimming, and they are useful for immediate feedback.

Keywords: *swimming, biomechanics, breaststroke, butterflystroke, backstroke, crawlstroke*

Introduction There have been many pictures of swimmers from above or below the surface of the water (1,4). Patterns of motion have been analyzed in detail, and many coaches form definite opinions about the best stroke techniques. As the arms and legs are moving about the center of mass of the body, it is difficult to judge the velocity, and incorrect conclusions about stroke mechanics are often made. Recordings of swimmers' velocities have also been reported (2). The current work involves underwater videos of swimmers synchronized with recordings of instantaneous velocity displayed on the computer screen. The videos and the recordings are stored, and the data are available for detailed analysis immediately or at a later time.

Methods: Velocity is measured by attaching a fine (0.2 mm diameter) non-stretchable line to the back of a belt around the swimmer's waist. The line passes through a series of pulleys and over the wheel of a DC generator positioned at the side of the pool. The voltage output of the generator is converted to digital format at a sampling rate of 400/s. Underwater video cameras are spaced along the side and one at the end of the pool. The cameras along the side are spaced so that as the swimmer moves out of view from one camera the image appears in the next one. The videos are recorded sequentially, and the pictures are synchronized with the tracings of the velocity. The computer screen showing the velocity and the underwater picture can be viewed during the swim and is available for immediate review and analysis.

Results and Discussion: **Pushoffs** The simplest recording is obtained by asking the swimmer to push off from the side of the pool in a streamlined position and to remain motionless in a horizontal position for the rest of the glide. As shown in Figure 1, the velocity during this gliding motion decreases exponentially due to the swimmer's drag. The computer program calculates the characteristics of the velocity curve (Figure 2). From the point of view of competitive swimming, these curves reveal important considerations. First, it is noted that due to drag the swimmer's velocity immediately decreases upon loss of contact with the side of the pool. In addition the time spent gliding underwater after a start or turn is specific to the swimmer's mean swimming speed on the surface. (5). For example, if the swimmer's mean velocity on the surface is 1.8 m/s, swimming must be resumed by 0.8s after leaving the wall. It is possible to calculate that at this time the swimmer's waist would be 3.3 m from the side of the pool. The coach can know if the swimmer is making the optimal transition from the pushoff to swimming.

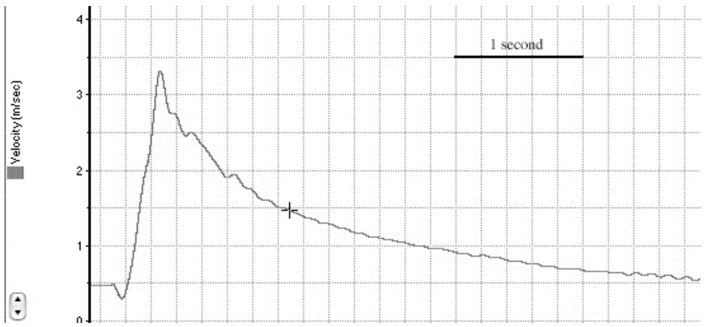

Figure 1. Tracing of velocity after pushoff

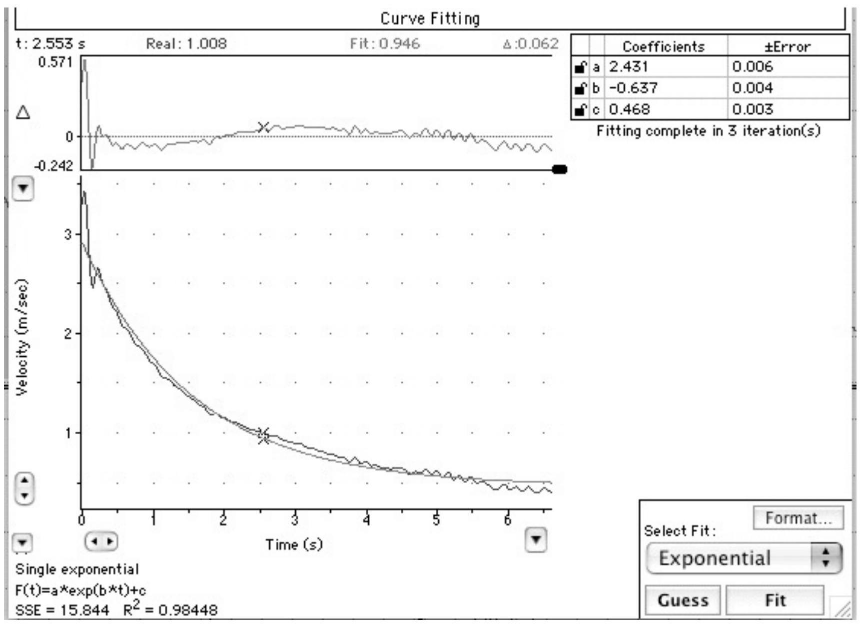

Figure 2. Analysis of velocity after pushoff

In breaststroke races the swimmers are allowed one arm stroke and one leg stroke before coming to the surface and resuming swimming (Figure 3). It has been found that the mean velocity of this underwater swimming may be slower than swimming on the surface (5).

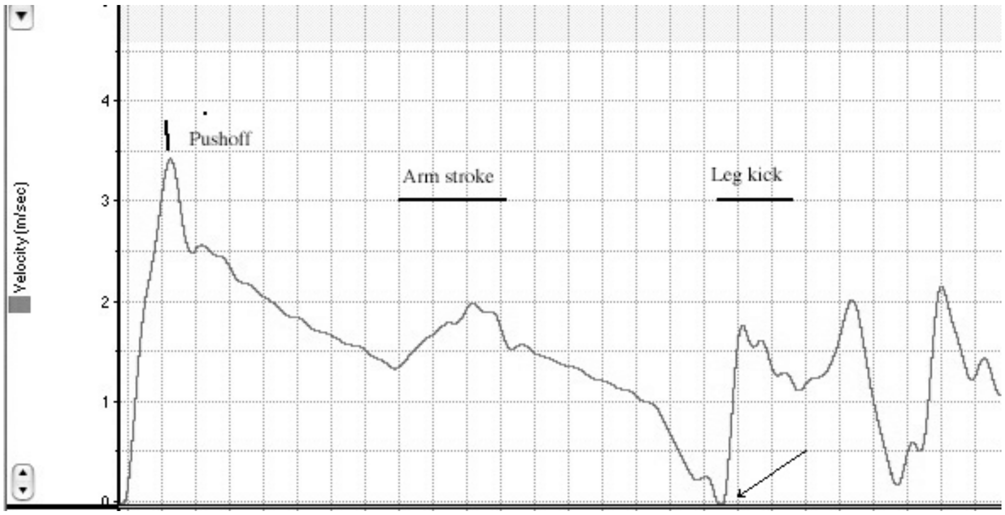

Figure 3. Recording of velocity after pushoff in breaststroke

In Figure 3 the swimmers average velocity from pushing off the wall to surfacing just before the first complete stroke cycle on the surface was 1.52 m/s, and he traveled 7.0 m. His average velocity during the remainder of the lap was 1.58 m/s. This difference indicated a need to complete the underwater phase in a shorter time so the average velocity would be greater or at least equal to his surface velocity. Figure 3 also shows that after the arm stroke the velocity decreased to zero as the swimmer brought the arms under the thorax and the legs were flexed in preparation of the kick (see arrow). Although this preparation for returning to the surface increases drag, zero velocity can be avoided by abbreviating the time underwater (5).

Breaststroke: This style of competitive swimming is the most definable of the four stroke patterns, and the one that is most amenable to analysis. It has the greatest oscillations of velocity. Figures 4 and 5 show stroke cycles of two breaststroke swimmers.

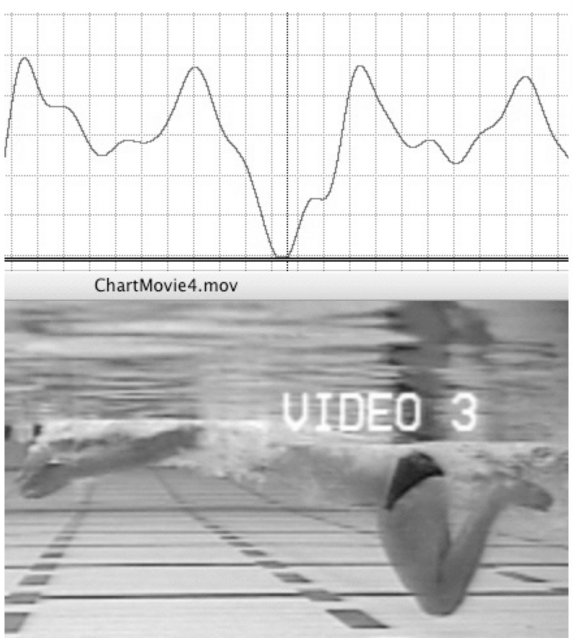

Fig 4. Breaststroke. Picture at minimal velocity

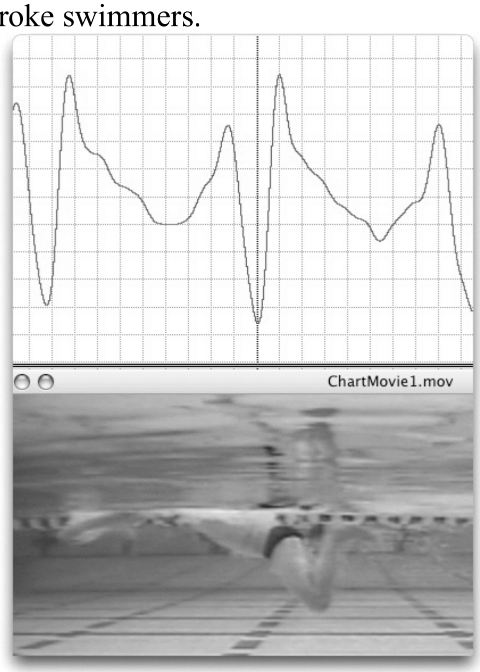

Fig 5. Breaststroke. Picture at minimal velocity

Note: in all of the pictures of swimmers, the vertical dashed lines on the velocity recordings indicate the speed at the time of the video frame and are part of the computer program.

Although these recordings were made at slightly different swimming speeds, it is apparent that the swimmer in Figure 4 has a period of zero velocity when the legs are flexed in preparation for the propulsive kicking action. During the same part of the stroke cycle the velocity for the swimmer in Figure 5 is significantly greater than zero. The cause of this difference can be explained by the differences in the angles of the thighs to the torso. The resistance to forward movement or drag is much greater for the subject in figure 4 than in figure 5. This increase of drag is related to the frontal surface caused by the position of the swimmer's thighs.

The pattern of breaststroke swimming can be characterized by defined phases.

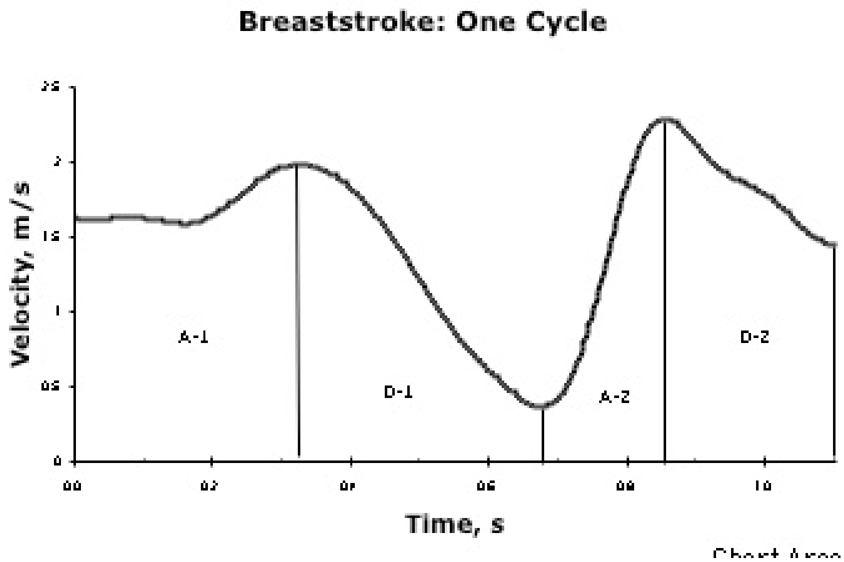

Figure 6.Phases of the breaststroke stroke cycle.

At the beginning of the stroke cycle the action of the arms produces an initial acceleration, A-1.This followed by a period of deceleration, D-1, as the legs are flexed in preparation for the kick. The acceleration due to the legs, A-2 is much greater than A-1. The glide after the kick is associated with the second period of deceleration, D-2.

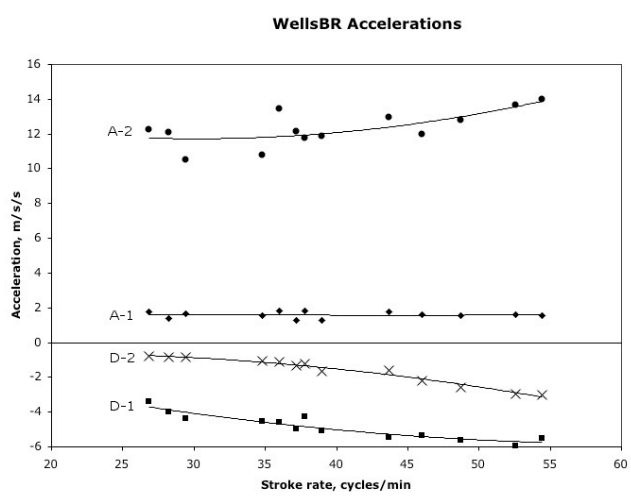

Figure 7 Accelerations during stroke cycle

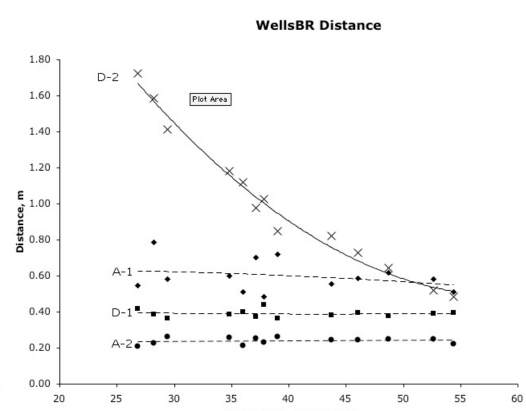

Figure 8 Distances of stroke phases

Figures 7& 8 show the results of the analysis of 13 one-length swims of a swimmer doing the breaststroke and going from slow to fast speeds. The accelerations of the kick phase (A-2) increased slightly, but the accelerations of the arm stroke (A-1) were independent of stroke rate and velocity. In the non-propulsive phases the decelerations were greater when the swimmer was going faster. These patterns were probably related to the increased body drag with increased velocity. As reported before (3), the distance traveled each stroke during the breaststroke is dependent on the time spent in the glide after the leg action (D-2) During all the other phases the distance traveled is independent of stroke rate. Another way of looking at breaststroke swimming is to say, "it's all about timing." These observation suggest that the breaststroke swimmer can practice the skills related to arm and leg action at slow stroke rates. Improvements should transfer to faster stroke rates. Practice at the faster speeds should focus on minimizing drag during the glide after the kick (D-2).

Butterflystroke: The butterflystroke is swum with greater variation of the pattern than the breaststroke. Figure 9 shows the velocity profile of three swimmers who were using the same stroke rate and were going at about the same speed.

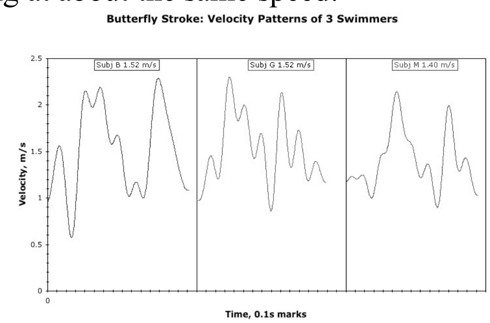

Figure 9. Butterflystroke velocity profile 3 different swimmers

The first peak in each panel is the result of the arm and leg action. There is then a decrease of the velocity until the second leg action. Variations in the pattern can also be observed in the same swimmer.

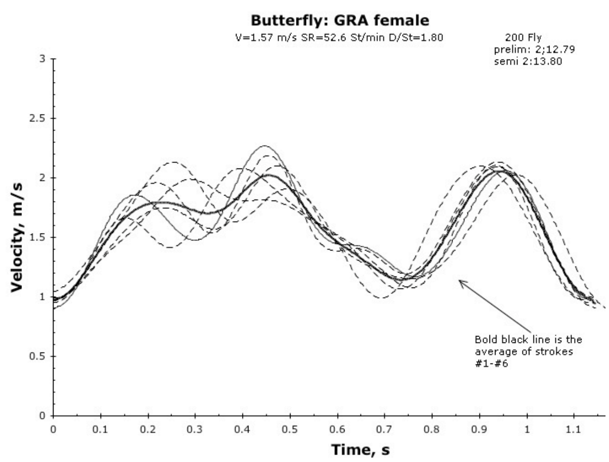

Figure 10. The velocity profiles of six sequential strokes are
Indicated by the dotted lines. The solid line is the average of the six stroke cycles.

In Figure 10 the variations occur in the timing of the arm and leg actions at the first part of the stroke. In some instances the arm flexion occurs before the leg flexion, and there is a decrease of the velocity between the two motions. At the other extreme the initial leg and arm actions are so closely related that the velocity shows just one maximal peak. The second peak of velocity is due to the legs acting alone, and is very reproducible.

Backstroke: Although fluctuations of the velocity during the stroke cycle may be apparent at slow stroke rates, they become very small at greater stroke rates swimming the backstroke.

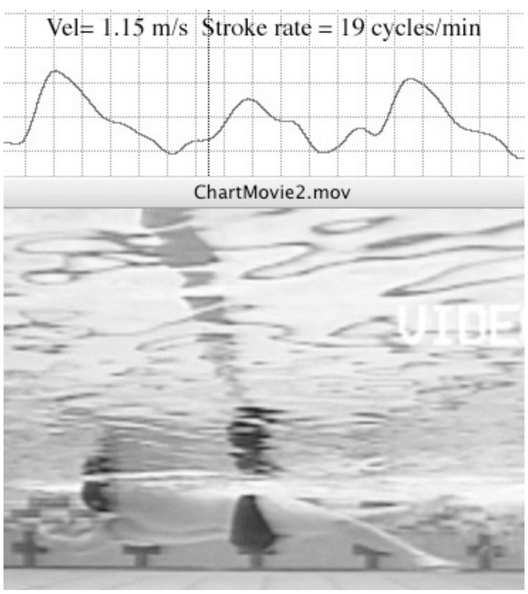

Figure 11.Backstroke at slow speed

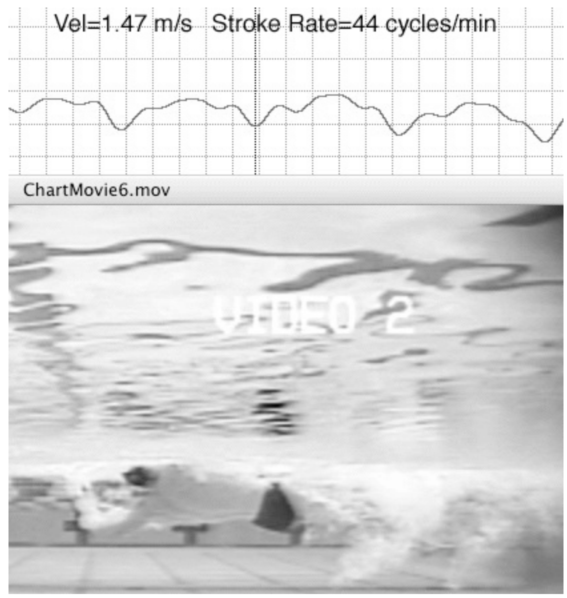

Figure 12. Backstroke at greater speed

As shown in Figure 11 the velocity increases with each arm action and at this slow stroke rate there is a non-propulsive or glide phase. At greater stroke rates the glide phase almost disappears. The recovery of arm after its propulsive motion is fast, and on it's next entry is immediately used for propulsion without a gliding phase. The decelerations noted in Figure 12 are quite common for this stroke style. Although we initially attributed this to the increased flexion of the leg, other views suggested that it might be related to the swimmer's poor alignment at this phase in the stroke cycle.

Crawlstroke:

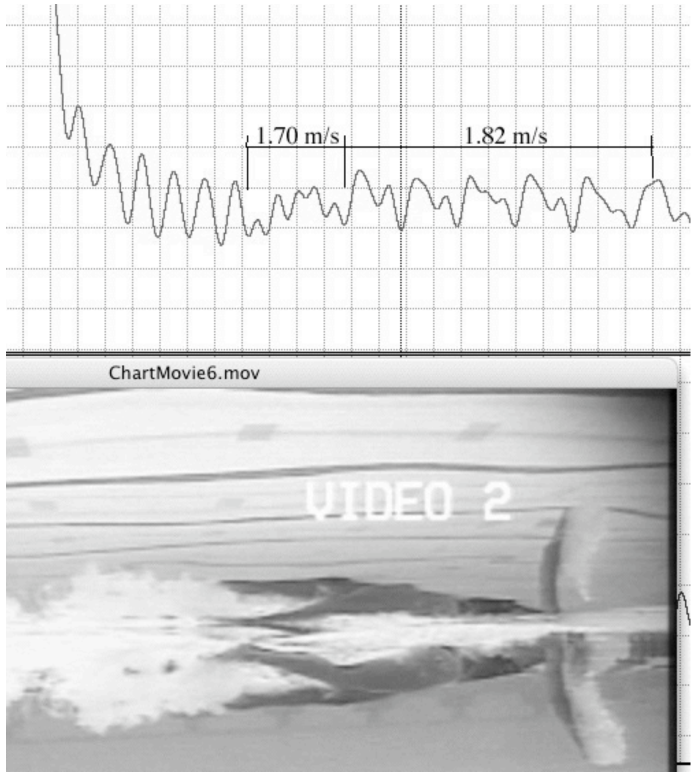

Figure 13.Female-swimming crawlstroke (freestyle).

After the swimmer entered the water from a diving start the velocity decreased rapidly and then showed fluctuations related to the repeated leg flexions and extensions known as dolphining (Figure 13). In this section the mean velocity of was 1.70 m/s. During swimming the crawlstroke the velocity was 1.82 m/s. It is apparent that this swimmer should limit dolphining to three cycles and then begin swimming. It is important for swimmers to learn when to begin and when to stop dolphining after a start or after a push-off from a turn. Such decisions can only be made from recorded data.

Conclusion: Swimming in all competitive stroke styles involves accelerations and decelerations. The simultaneous recording of the swimmer's velocity and the synchronized underwater video enables the viewer to see the effects of motion in different parts of the stroke. Additional calculations such as mean, maximal, and minimal velocities, time of a chosen segment, distance traveled are incorporated into the program and are useful in understanding the effects of different stroke patterns. Swimming involves major accelerations and decelerations. The patterns of movement and the resulting velocities are very different in the competitive stroke styles. In each there are variations among swimmers, and even during a single swim the patterns may change. Starts and turns can also be analyzed. These approaches are limited only by the imaginations of the swimmers and their coaches.

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References:

1. Councilman, JE (1968) The Science of Swimming. Prentice Hall, Inc. Englewood, NJ.

2. Craig, AB, (1979) Relationships of stroke rate, distance per stroke, and velocity in competitive swimming. Med Sci Sports, 278-282.

3. Craig, AB, WL Boomer, PL Skehan (1988) Patterns of velocity in competitive breaststroke swimming. In: Ungerechts, BE, K Wilke, K Reischle (ed) Swimming Science V. Human Kinetics Books, Champaign, Ill.

4. Maglisco, EW (2003) Swimming Fastest, Human Kinetics Books, Champaign, Illinois

5. Termin, B and DR Pendergast (1998) How to optimize performance. Swim Technique 34(4): 41-46