# VELOCITY PROFILE IN STREAMLINE SWIMMING: DRAG QUANTIFICATION

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## INTRODUCTION

In swimming, as in any sport, any edge an athlete can find to improve his/her time, score, accuracy, efficiency, etc. is key to becoming a champion. The average swimmer trains 60,000 yards per week, which equates to approximately 2400 flip turns in a normal 25-yard competition size pool! After the flip is complete, the push off the wall in a tight streamline position is a crucial part of every race. The goal of studying the biomechanics of the streamline position is to find an optimal position of the arms to produce the least amount of drag and the fastest time possible.

There are two types of drag associated with swimming, passive and active. Passive drag is the resistance the swimmer feels when he/she is not actually moving his/her arms and legs. Active drag is the resistance the swimmer feels when he/she is swimming. Studies on the influence of body posture and orientation in relation to flow on the magnitude of hydrodynamic resistance provide evidence that the form resistance is a major component of total hydrodynamic resistance [1]. It is commonly recognized that total hydrodynamic resistance of the body during passive towing is a sum of the body during passive towing is a sum of its friction, wave-making and form components:

$F_{total} = F_{friction} + F_{wave\text{-}making} + F_{form}$

Experimental results have shown the approximate magnitudes of these values to be [1]: $F_{form}$ = 93.5 N, $F_{friction}$ = 0.05 N, $F_{wave\text{-}making}$ = 5 N

There is a wide range of flows in which full field information is essential for understanding and solving complex fluid dynamics-related problems [3]. Background literature reviews indicate a lack in fluid profiles of freestyle swimming. Fluid flow analysis completed with image processing around solid objects has been performed routinely [3].

The objective of this study is to incorporate the digital particle image velocimetry technique to quantify drag in various streamline positions. Currently, our laboratory is examining fluid flow profiles created by a swimmer, while also looking at passive drag measurements for various streamline positions.

## METHODS

### Velocity Profile Measurement

Rutgers University is home to the Sonny Werblin Recreation Center, which houses an indoor 8-lane Olympic sized pool. A viewing window is located 5 feet below water surface level, which is ideal for capturing digital recordings. Control of the underwater lighting was useful in obtaining optimal recordings. Streams of air bubbles were also available and turned on to assist in particle velocity measurement. Several members of the Rutgers University swim team will be involved in this experiment.

The experimental set up consisted of an elastic tubing tether attached around the waist of the swimmer doing freestyle, to ensure that the swimmer's position stayed within the viewing window. The swimmer was allowed to warm-up for 5 minutes before recording at maximum speed. A Kodak Megaplus 18-108 mm camera with computar zoom lens and video capture boards was used to collect 500 two-dimensional sagital images taken from several trials. During each trial the swimmer completed an average 100 arm cycles. Anthropometic body segment measurements of the swimmers arm were used to scale images. The time between picture frames was set at 0.03 seconds. In this manner, both time and distance were scaled appropriately to insure accurate velocity measurements.

The image processing consisted of using Adobe Photoshop by enhancing images size, and brightness/contrast levels. A high-resolution video-based technique for obtaining two-dimensional fluid velocity field data known as the digital particle image velocimetry (DPIV) technique was utilized [3]. The algorithm uses a combination of cross-correlations and auto correlations on doubly exposed images of particle-seeded flows. Autocorrelations of individual video frames in an image pair yield two instantaneous velocity fields. Tecplot was used to graphically demonstrate velocity vector fields of each successive frame. Dimensional analysis was then used to validate results by converting the velocity into yards per second and then calculating the time it would take the swimmer to complete 50 yards.

## RESULTS AND DISCUSSION

Figure 1 displays three digital image sequences and their corresponding velocity profiles. The velocity in yards per second of the hand position in the second arm position in Figure 1 corresponds to a speed of 1.79 yards per second, which is reasonable for the level of swimmer used in the experiment. The third velocity profile in Figure 1 shows the effects of both arms as the right arm is entering the water as the left is still in the pulling motion. Analysis of several stroke cycles indicated velocity magnitudes of the second arm position to yield consistent velocity magnitudes of 1.79 ± 0.2 yards per second. The swimmer in these images has the ability to swim at maximum speed of 1.9 yards per second.

The next focus of our experiment is to collect data on passive drag measurements associated with different arm positions for the streamline position. It is extremely difficult to determine the frictional, wave-making and/or eddy resistance because the swimmer's propulsion along the water surface is regarded as a collection of numerous traveling pressure points [2]. To measure the passive drag, the following protocol developed by Russell Mark, Biomechanics Coordinator at USA Swimming Inc. will be used:

- Athletes will be fully submerged and hang from a towrope in a streamline position attached to a load cell and tensiometer in the flume.
- Measurements are taken when the athlete reaches a stable streamline position (no lateral movement, body position fully adjusted)
- 5 x 10 seconds of data collection @ 1.5 m/s flume velocity
- 5 x 10 seconds of data collection @ 2.0 m/s flume velocity

## SUMMARY

Velocity profiles of a swimmer in freestyle motion, provides both qualitative and quantitative data summarizing the motion of the fluid particles displaced and surrounding the swimmer. Consequently, DPIV processing can be instrumental in the comparison of different swimmers motions and speeds. The next step in our experiment is to look at several members of the Rutgers University swim team velocity profiles for freestyle motion.

The analysis on different arm postures in the streamline position should provide an optimal arm position resulting in minimal drag and an increase in velocity.

## REFERENCES


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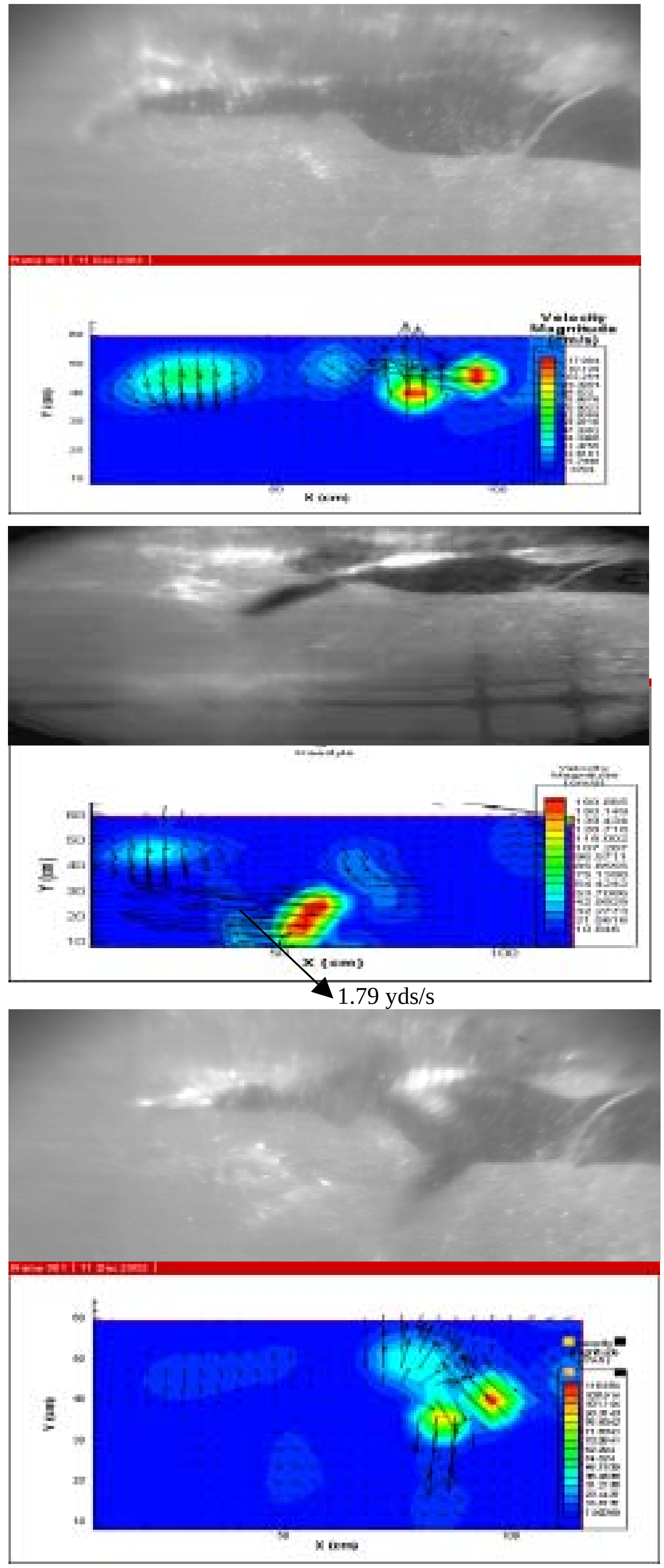


**Figure 1. DPIV Images and Velocity Profiles**