THE EFFECT OF STROKE LENGTH ON ACTIVE DRAG IN SWIMMING

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INTRODUCTION

The main resistive force in swimming is due to drag on a swimmer’s body from the water. There are two forms of drag, one is active drag \( (F_D) \), which is the drag encountered while propelling the body through the water. The other is passive drag or the drag encountered while gliding during a push-off after a turn or after entering the water from the start. These different types of drag are both proportional to the frontal area (the projected area that is perpendicular to the direction of travel) and approximately proportional to the square of the swimmer’s velocity (Clarys, 1978). Minimizing the frontal area of the body in the water can reduce drag and is achieved both by streamlining and by increasing buoyancy in the water (such that more of the body is out of the water and/or the body is positioned more horizontally) (Kolmogorov et al., 1997). It was also determined that the best swimmers have been able to find a way to minimize active drag. Others have found low passive drag to be a good predictor of performance (Chatard et al., 1990).

The speed at which a swimmer moves through the water can be broken down farther into two components, the stroke length \( (SL) \) and stroke rate \( (SR) \). Velocity \( (V) \) can be calculated by the equation \( V = SR \times SL \). When swimming at a constant velocity, reduced drag tends to alter the \( SL \times SR \) combination selected for that velocity by increasing \( SL \) and decreasing \( SR \) (Chatard & Wilson, 2003). In other words, drag affects the \( SR \times SL \) relationship chosen for a selected velocity.

Toussaint and colleagues (1989) looked at density changes and found when density is reduced performance is improved due to a reduction in drag. They used a system called the Measurement of Active Drag (MAD) system. The MAD system is composed of equally spaced rigid pads placed beneath the surface of the water that the swimmers push against to propel them through the water. The force applied to each pad is recorded to determine the propulsive force, which on the average is numerically equal to the resistive force when traveling at a constant velocity. The purpose of this study is to investigate the relationship between active drag and SL at a constant velocity. It is hypothesized that there will be a minimum active drag for each swimmer.

METHODS

Subjects were recruited from an NCAA Division I swim team with a mean age of 19.1 ± 1.2 years for the men and 18.6 ± 1.1 years for the women. Ten men and 10 women participated and signed informed consent forms approved by the institutional review board. The mean mass was 79.0 ± 6.9 kg and 69.4 ± 5.2 kg for the men and women, respectively. The mean height of the male subjects was 1.82 ± 0.055 m, while the mean height for the female subjects was 1.73 ± 0.050 m.
A MAD-type system (Toussaint, et al., 1989) was constructed and placed in the water below the swimmers. Three different sets of paddles were used. These paddle sets had a between paddle distance of 1.25 m, 1.35 m, or 1.45 m. Each set of paddles was constructed with 27.4 m of ¼ inch galvanized cable with standard lane line end components. Each swimmer was given as long as needed to become comfortable with the SL and SR for each trial. The order of SL was balanced to remove any learning that may have occurred during the three trials. The SR was chosen to create a velocity of 1.5 m/s and was maintained by using a Tempo Trainer (Finis, Livermore, CA) and checked by looking at the onset of force at each paddle over the entire length. Only lengths with an error of no greater than 5% of the selected SR were analyzed.

RESULTS AND DISCUSSION

The results showed a significant between subjects effect of gender (p<.05) as expected from previous studies. Women had a significantly lower drag than men (p<.05). The SL manipulation resulted in significant active drag changes (p<.05). Both men and women had a within subject effect of active drag. The men and women had a significantly lower active drag for the 1.35 m SL condition compared to the 1.25 m and 1.45 m conditions (Figure 1). Both men and women had a significant quadratic effect (p<.05) and minimum active drag force for 1.5 m/s. Each subject had their own SL that resulted in a minimum active drag when the data was fit by a second order polynomial.

These results demonstrate that each swimmer is unique and will have their own active drag-SL relationship. Investigating a large enough sample size would help demonstrate whether ability level is also a factor in the SL that minimizes active drag.

SUMMARY/CONCLUSIONS

Understanding the active drag and SL relationship in freestyle swimming can lead to an improvement in swimming and training techniques. Designing a training program to improve SL at a given velocity’s minimum active drag will improve performance in all race distances. Another technique could be to lower active drag at a given velocity and SL. These two techniques could be used to enhance all levels of swimmers from recreational to triathletes to Olympians.

Figure 1: The results of the stroke length manipulations on active drag in freestyle swimming.

REFERENCES