TECHNOLOGY FOR WITHIN STROKE ANALYSIS IN SWIMMING

Barry D. Wilson

Sport Performance Research Institute New Zealand (SPRINZ), Auckland University of Technology, Auckland, New Zealand

This study reports the development of technology for within-stoke assessment of net force and propulsion and drag in swimming. The first phase was the development of an instrumented, variable resistance, sled towed by a swimmer. The sled measures and transmits at 50 Hz, net force applied to the sled and speed of the swimmer. The second phase was development of an iPad APP that provided video synchronised with the sled data, displayed in a split screen image in soft real time.

KEYWORDS: swimming, within-stroke assessment, net force production, propulsion, drag.

INTRODUCTION: Propulsion in swimming is achieved as the net of propulsive and resistive forces acting on body of the swimmer in motion. In training large efforts are made to increase the propulsive ability and the swimming technique of the athlete. While the “less than smooth motion” associated with resistive drag forces are recognised and addressed in technique training, the resistive drag cannot be directly measured. The importance of resistive drag forces was clearly demonstrated when the development of the Speedo low drag swimming suit resulted in an exceptional number of new swimming records, alternative suit designs and ultimately limitations on swim suit design. The low drag suits reduced the swimmers surface drag by small amounts, the order of 2%, for a swimmer manikin towed in a flume. Later swim suit designs claimed to also reduce form drag. In swimming freestyle at maximal speed total resistive drag is composed of surface drag <5% of total drag, form drag perhaps 30 to 40 % of total drag, and wave drag 60 to 70% of total drag (Wilson, and Thorp, 2003; Vennel, Pease and Wilson, 2006). Knowledge of how active drag can be controlled and managed will influence training techniques and has the potential to improve performance of swimmers and will be of immense benefit to coaches and swimmers. Technique training that can reduce form or wave drag only if there are accurate and reliable measurements of drag reduction achieved by the particular parameter being trained.
The methods used to measure active drag are difficult to apply and have not produced comparable results. Wilson and Thorp (2003) in a review of active drag studies reported that there appeared to be systematic differences between the Measurement of Active Drag (MAD, Hollander et al, 1986), and other approaches. Toussaint (2004) also reported systematic differences between MAD and VPM results partially attributed to the equal power assumption of the VPM. At a two week workshop on active drag measurement held at the AIS in Canberra in January 2013, VPM, ATM and RTM methods were compared for 15 swimmers. Results from the different methods of active drag testing were not generally in agreement (Mason et al., 2013 (a), 2013(b)).
The technology for within stoke assessment of net force and propulsion and drag has been developed in two phases: First, the development of an instrumented, variable resistance, sled towed by the swimmer that measures at 50 Hz, net force applied to the sled and speed of the swimmer. The second phase was development of an iPad APP that provided video data synchronised with the sled data, displayed in a split screen image in soft real time.

METHODS: Two sleds, see Figure 1, were designed and subsequently calibrated for load and speed in the Otago University swimming flume. Swimmers who were able to swim repeat sets at a given pace with consistent times for each length were considered for iSwim testing. Typically 200 m pace was used for repeat trials on a given day. Swim trials were performed after warmup as part of the swimmers normal training. Consistent instruction of the swimmer was essential. Underwater video captured at the same time is recommended to provide information on the arm and leg actions that may help explain aspects of the net force and speed curves.

Figure 1. The two sled models (prototype on left)

Items required at poolside: Fully charged sled, Wifi modem, iPad with iSwim App installed, waist belt and 5 m towline to connect sled to the swimmer. With the sled touching poolside, the swimmer walks out approx 4 m, and then begins a slow swim to start the sled tow. The swimmer then increases speed to the desired pace by the 15 m mark (typically 200 m pace). Recording begins at the 15 m mark by pressing record button in iPad app and continues until the swimmer touches the pool end. When filming with the iPad, the iPad operator walks at poolside keeping pace with the swimmer in lane 1. The swimmers image should be filmed in the top half of the ipad screen, with iPad orientation in landscape. The lane rope image was used to help in keeping the iPad horizontal and steady. The iPad camera was not panned. After recording, the captured file content can be checked before the next trial. The swimmers image appears in the top half of the iPad screen with the sled outputs, force applied to the sled and sled/swimmer speed, on the lower half of the screen.

ANALYSIS: Video of the swimmer captured at the same time as the swimmers speed and force applied to the sled are shown on the iPad screen. The video can be dragged to a particular point in the screen to look at specific parts of the stroke within; e.g. entry to catch, pull, push and recovery. The curve of force applied to the sled is the net of propulsive force and resistive drag. When the net force is the same as the drag resistance of towing the sled, the swimmers speed is constant. When the force applied to the sled is increased the swimmer will accelerate (speed increasing when propulsive forces exceed drag forces). Thus the speed of the swimmer fluctuates within each stroke. Net force curves are shown for two swimmers in Figure 2.
Trial records are best viewed by the coach on the iPad using the iSwim App so that the film record can be advanced frame by frame to identify key events in the stroke such as pushout or hand/arm entry. The timing of maximum net force applied to the sled and speed of the swimmer can then be related to key events in the stroke.
For subsequent quantitative analysis and detailed reporting to the coach, a PC application can be used to plot sections of the CSV files as figures. Phases of the stroke can be highlighted as well as key events such as entry, catch and pull and push phases.

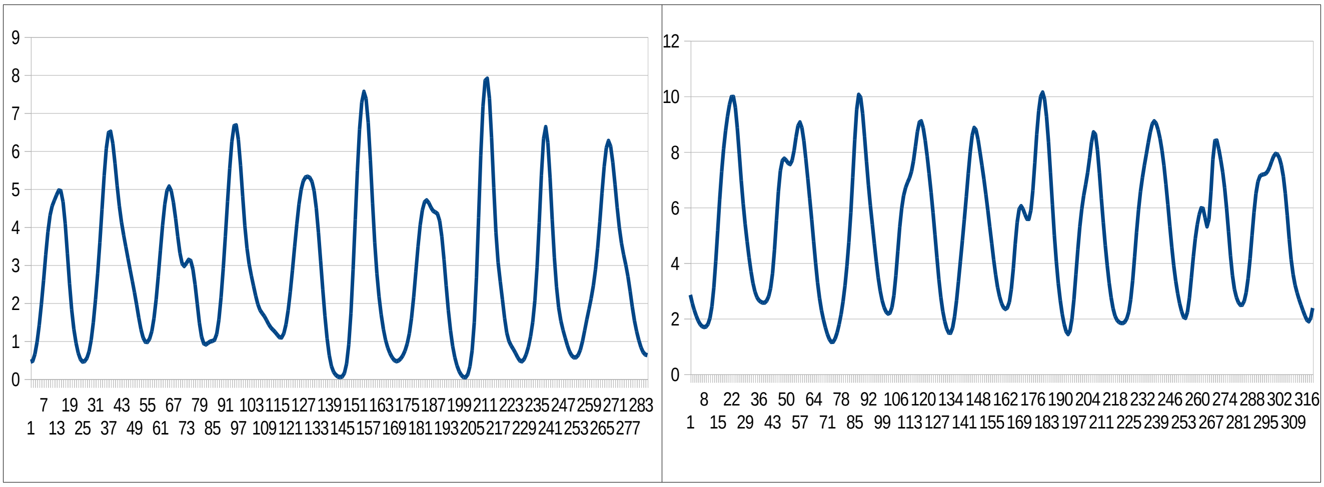

Figure 2: Net force (N) vs time (frames) curves over 5 strokes for two swimmers with first peaks at right hand pull phase

The iSwim APP when used with the instrumented towing sled provides information for poolside qualitative analysis of a swimmers stroke. Ideally, for freestyle and backstroke: The load curves corresponding to left and right arm strokes for a particular swimmer should have the same pattern and be relatively consistent over the trial. Patterns should be very similar for repeated trials at the same swim speed performed on the same day. The peaks and troughs in the load and speed curve should be minimised, implying that the swimmer should swim at near to constant speed as possible. “Smooth through the water” can be a catch phrase. At competitive swimming speeds form and wave drag contribute more than 95% of drag with wave drag the largest component- and the most difficult to judge from the swimmers action. Peaks and troughs should correspond to specific parts of the stroke, e.g. Maximal arm/hand force is applied in pushout in freestyle. If maximal net force does not correspond to pushout of one arm then poor entry and catch of the opposite hand and arm may be adding drag, or the range of motion of the same leg dominant kick may be adding drag. The swimmers actions at the time of dips or troughs in the force applied curve should be examined in particular. What actions are holding the swimmer back? “Taking the brakes off” is something the swimmers like to hear!

Towing the sled adds a small load to the swimmer. The sled aquaplanes when being towed at swimming speed to provide a relatively constant preset load throughout the speed variations within each stroke of freestyle and backstroke. The load on the swimmer is controlled via the iSwim APP.

The propulsion and drag of a swimmer can be assessed using the sled by applying different loading on the swimmer via the sled control settings. The Calculate mode of the iSwim APP determines the mean active drag and propulsive force for the particular swimmer. The calculation is based on the drop in speed of the swimmer when performing trials of zero load condition compared to added load condition.

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