VALIDITY OF ESTIMATING ACTIVE DRAG USING THE BOTH ASSISTED AND RESISTED TECHNIQUES WITH FLUCTUATING VELOCITY

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The main purpose of this study was to examine the validity of assisted and resisted techniques which are used for active drag estimation. Ten national and international male sprint swimmers performed two maximum effort free swims, two passive trials and two active drag trials in each technique. The computation of active drag for both techniques was based upon assumptions of the Velocity Perturbation Method (VPM) of Kolmogorov and Duplishcheva (1992). Results of a one-way ANOVA with repeated measures indicated there was no statistical significance between the active drag values obtained from the assisted and resisted techniques (p=0.05). There was however variation between active drag values. This is likely due to different power outputs that were applied during the test conditions and also, active drag varies as a function velocity squared.

KEYWORDS: Swimming, Resistance, Active drag, fluctuating velocity, Front Crawl

INTRODUCTION: In competitive swimming, it is important that an elite swimmer applies more propulsion and less drag force to achieve a better result. Water resistance or drag force is defined as “the rate of removal of momentum from a moving fluid by an immersed body” (Vogel, 1994, pp.81). Determination of drag force is an important issue assisting in swimming performance. A number of measurement techniques have been developed to assess and estimate active drag directly or indirectly, however, there has been controversy as the techniques used often reported varying values (Clarys, 1979; Kolmogorov and Duplishcheva, 1992; Toussaint et al., 2004; Mason et al., 2011).

Hollander et al. (1986) designed a measurement of active drag (MAD) system which is the only system that measures propelling forces directly. The MAD system calculated active drag by measuring the propulsive force applied to paddles fixed to a force transducer in the pool and assumed that mean drag and mean propulsive forces are equal when swimming at constant velocity. Kolmogorov and Duplishcheva (1992) estimated active drag using the Velocity Perturbation Method (VPM) at maximal swim velocity; once with a hydrodynamic body attached that produces an additional known resistance, and once without the added resistance. The measurement of active drag was based upon assumptions; the swimmer was able to generate a constant mechanical power output in both conditions, the swimmer maintained a constant average velocity during each trial, and that drag was assumed to change in proportion to velocity squared.

Mason et al. (2011) determined the value of active drag at maximal swim velocity by towing a swimmer 5% greater than the mean maximum swim velocity. The Assisted Tow Method (ATM) was designed to allow swimmers to have a fluctuating velocity which enabled them to maintain their normal stroke technique whilst being towed. Hazrati et al. (2014) developed a new system to estimate active drag by using an electrically braked resisted force which resulted at 5% to 8% lowering than average swim velocity, while allowing for intra-stroke velocity fluctuations. The measurement of active drag was based upon the same assumptions as the VPM technique (equal power output in the free swimming and the towing).

Toussaint et al. (2004) assessed the difference between the active drag values measured with the MAD system (Hollander et al., 1986) and the active drag values estimated by the VPM technique (Kolmogorov and Duplishcheva, 1992). They reported that the main reason for the difference in active drag results was likely to have been an unequal power output when swimming with and without added resistance during the VPM method. The purpose of the present research was to examine the validity of the active drag estimation using the both the assisted and resisted techniques and, also to help researchers find a valid testing protocol for estimating the active drag in the future.

METHOD: Ten national and international male swimmers (mean ± standard deviation SD: age= 20.5 years; height= 183 cm; weight= 70.5 kg, FINA point rank of over 750) participated in this research. Swimmers were required to complete all tests in one day starting with a 20 minute warm-up. Swimmers performed at least one practice trial to become familiar with the nature of the experiment and were given 5 minutes rest between each trial to eliminate the influence of fatigue on their performance. Firstly, each swimmer completed two maximum free swim velocity trials over a 20 m interval, starting from 35 m out and the velocity measured over the interval from 25 m to 5 m out from the wall using two 50 Hz cameras. The velocity was averaged to determine the swimmer's maximal free swim velocity. Secondly, two passive drag trials were completed at the swimmer's free swim velocity. Finally, swimmers were then requested to swim four trials with maximum effort whilst a belt was attached around swimmers' waist connected to a dynamometer mounted directly on a calibrated Kistler™ force platform (Kistler Instruments Type Z20916) (Figure 1 and 2). Eight complete stroke cycles were captured for the assisted trials and six complete stroke cycles for the resisted trials. Dynamometer force was adjusted to achieve a velocity of between 5-8% faster and slower than maximum mean swim velocity for the assisted and resisted trials respectively. Subjects were randomised so that half performed the assisted trials before the resisted while the other half reversed this order.

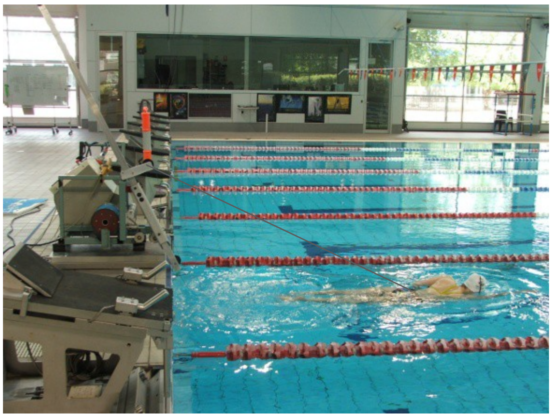

Figure 1: Set up for the Resisted technique

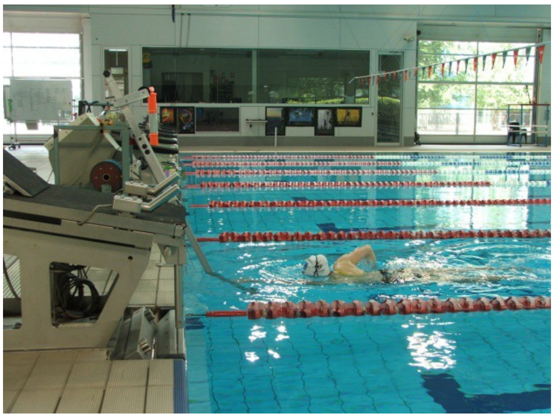

Figure 2: Set up for the Assisted technique

Active drag was calculated from the free swim and towed trials using the formula of Kolmogorov & Duplishcheva (1992):

$$F_d = \frac{F_B V_2 V_1^2}{V_1^3 - V_2^3}$$

Where F_B is the force needed to increase or decrease the swimmer to the desired velocity as measured with the force platform, V_1 is the swimmer's free swim maximum mean velocity, and V_2 is the velocity during the towing trials.

Data was collected using motion analysis software (Contemplas GmbH) and then processed using an export/import function in Contemplas linked to an AIS customized analysis program. The average from two active drag assisted trials and two active drag resisted trials of each subject was calculated to use for the determination of the validity of the techniques. A one-way ANOVA with repeated measures was used to test validity of the technique. SPSS software (Windows version 19) was used for statistical analyses and a statistical significance set at the 95% confidence level (p<0.05).

RESULTS: Fluctuating velocity assisted and resisted active drag parameters were computed for each of the swimmers. Mean value (Mean) ± standard deviation (SD) of the passive drag and the assisted and resisted active drag were calculated for each swimmer. Table 1 presents the average active drag value of the assisted and the resisted trials and also, the mean value of passive drag for each swimmer at the maximal swim velocity.

Table 1
The mean values of Assisted, Resisted and Passive drags at the mean maximal swim velocity

Participant	Mean max velocity	Mean Assisted Active drag ± SD	Mean Resisted Active drag ± SD	Mean Passive drag
1	1.80	92.0±5.5	86.8±0.8	94.0±2.51
2	1.91	115.3±0.3	96.0±7.6	109.7±3.6
3	1.92	153.3±1.5	75.2±7.4	108.2±2.3
4	1.79	94.7±8.3	62.0±12.7	103.6±6.3
5	1.82	87.1±3.9	104.3±4.3	76.2±1.8
6	1.88	142.6±6.0	92.7±4.2	92.3±4.3
7	1.99	92.9±5.1	83.5±8.4	91.0±1.5
8	1.83	91.5±2.5	124.4±6.5	93.5±3.6
9	1.74	106.9±4.4	82.1±8.6	103.8±5.8
10	1.76	77.6±4.5	100.9±11.5	76.0±6.5
Mean	1.83	105.3±24.7	90.7±17.1	94.8±12

The average active drags for the assisted and the resisted techniques were 105.3±24.7 N and 90.7±17.1 N respectively and also, the averaged passive drag was 94.8 N. One-way general liner model (ANOVA) revealed no significant differences between the active drag calculated by the assisted and resisted techniques and the passive drag value ($p=0.05$).

DISCUSSION: In the majority of swimmers, the values of active drag obtained from the assisted technique were higher than the passive drag values; however, the values of active drag calculated from the resisted technique were lower than the passive drag values. Previous resisted techniques have reported that the active drag values were lower than the passive drag values (Kolmogorov and Duplishcheva, 1992; Shimonagata et al., 1998) which were similar to the result of resisted technique of the present study. Although another study by Clarys (1979), estimating active drag from the forces required to change the velocity of swimmer in a flume at constant velocity and reported that their active drag measurement were higher than passive drag. This result is similar to the result of assisted technique of the present study. It seems likely that the contradictions between results are caused by using different techniques.

The results of this study indicate that there was no significant difference between the active drag calculated by the assisted and resisted techniques. This lack of significant difference should be interpreted as being the result of high variability between the active drag values obtained from both techniques (e.g. swimmers 3, 6 and 8) rather than indicating consistency between the two methods. A major component of the difference in active drag values can be explained by the difference in power output between the free swimming trial and the assisted and resisted towing trials. Another study compared the active drag values obtained from the MAD system with the VPM technique (Toussaint et al., 2004). The MAD system calculated the active drag (66.9 N) higher than the VPM technique (53.9 N) at a maximum swim velocity of 1.64 m/s. The result of current study was consistent with Toussaint et al. (2004).

A difference in values between techniques for individual subjects can be explained by the swimmers producing different external power output during each technique. For example: swimmer number 3 had the higher value in the assisted trials, while the swimmer number 8 had the higher value in the resisted trials. Therefore, it seems that the swimmer number 3 produced more power during the assisted trials while, the swimmer number 8 produced more power during the resisted trials. If power was increased during resisted swimming and decreased during assisted swimming (or vice versa), then, that could be another possibility for the difference between the assisted and resisted techniques.

Another issue affecting active drag values from the assisted and resisted techniques could be the assumption that drag is proportional to velocity squared. Toussaint et al. (2004) reported that drag values at different velocities were dependent on the value of the exponent of the power, and found a 20% difference between active drags calculated using the VPM technique and the MAD system at an exponent value of 2.34. Another study utilising the MAD system to examine the effect of the different exponent on the active drag value observed errors of 15% when velocity was raised to a power within the range of 1.9 to 2.8 (Toussaint et al. 1988).

CONCLUSION: The results of this study indicate that there was no significant difference between the active drag values obtained from the assisted and resisted techniques. There was high variability between the two methods in respective of the swimmers having a high or low drag value. The reasons for the high variability between both techniques could be due to unequal power that was produced by each swimmer during towing and free swimming trials, and drag is proportional to velocity squared. Further study should be undertaken to improve testing protocols to achieve much closer values from the both techniques.

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