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RELIABILITY OF ESTIMATING ACTIVE DRAG USING THE ASSISTED TOWING METHOD (ATM) WITH FLUCTUATING VELOCITY

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The aim of this study was to examine the reliability of active drag values obtained using a method that compared free swim velocity with measurements taken by towing swimmers slightly faster than their maximum swim speed, while allowing for intra stroke velocity fluctuations. Using nine national level swimmers on two alternate days, reliability was determined using within-subject intra-class correlation coefficients (ICC) within each day and between the days. The ICCs for days one and two were 0.80 and 0.84 respectively, while the comparison of mean active drag values between days was 0.92. Results found that the ATM method with fluctuating velocity to be only moderately reliable within a single test. Taking average values improved this reliability, even when measured over different days. Further investigation is suggested to improve the current method.

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

INTRODUCTION: For both swimmer and coach alike, the goal of competitive swimming is to finish the required distance in the shortest possible time. The majority of race time is spent in free swimming, requiring the swimmer to propel the body by pushing against the water to overcome the negative force of drag. Active drag is the water resistance acting to oppose the swimmer while propelling the body forward (Mason et al. 2011). Several methods have been developed to assess active drag directly or indirectly; however there is no consensus on the best method. Two major methods for measuring active drag have been developed by Holander et al. (1986) (the measurement of active drag [MAD]) and Kolmogorov (1992) (Velocity Perturbation Method [VPM]).

The MAD system (Hollander et al. 1986) determined active drag by measuring the propulsive force applied to paddles fixed to a force transducer in the pool whilst the swimmer performing the front crawl action. A small pull-buoy was situated between the swimmer's legs to prevent using the legs during swimming while maintaining the body in a horizontal position. The VPM method (Kolmogorov & Duplishchea 1992) estimated active drag using a resisted method to compare free swimming velocity with velocity of swimmer while a hydrodynamic body attached by a cable to the swimmer's waist. The measurement of active drag was based upon two assumptions; first, the swimmer was able to generate a constant mechanical power output in both conditions, and second, the swimmer maintained a constant average velocity during each trial.

Alcock and Mason (2007) assessed active drag by using the Assisted Tow Method (ATM) at the Australian Institute of Sport (AIS). The method was similar to the assumptions of the VPM method except that the swimmer was assisted by a motor driven cable at a constant mean swim velocity rather than having a force resisting the swimmer. A criticism of the method developed by Alcock and Mason (2007) was that in free swimming, there are intra-stroke velocity fluctuations, which are not present when towed at a constant velocity. Recent research (Mason et al. 2011) allowed the swimmer to have a fluctuating velocity which enable them to maintain their normal stroke technique whilst being towed, making it much more like free swimming than the constant velocity tow condition. The purpose of the present research was to examine the reliability of using a fluctuating velocity tow when estimating active drag and, also help the researchers to find a reliable testing protocol for a resisted method in the future.

METHOD: Nine national age and open level swimmers (5 males and 4 females, 17.7±2.9 years) participated in this study. Participants were required to complete all tests on two alternate days starting with a 20 minutes warm-up. Participants 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 participant completed four maximum free swim velocity trials over a 10 m interval, starting from 25m out and the velocity measured over the interval 15 m to 5 m out from the wall using two 50 Hz cameras. The mean velocity was used to determine the swimmer's free swim velocity. Secondly, three passive drag tests were completed at the swimmer's free swim velocity. Finally, participants were then requested to swim five trials with maximum effort whilst a belt was attached around participants' waist connected to the dynamometer mounted directly on a calibrated Kistler™ force platform (Kistler Instruments Type Z20916) (Figure 1). Four complete stroke cycles were captured for the analysis of the active drag trials. The cable pulled the swimmers at approximately 5% higher than their free swim velocity with a maximum force level set low enough to allow intra-stroke velocity fluctuations to occur (Mason et al. 2011). The maximum force level was set between 25 to 50% of passive drag force and adjusted if assisted swim velocity was more than 10% faster than free swim velocity.

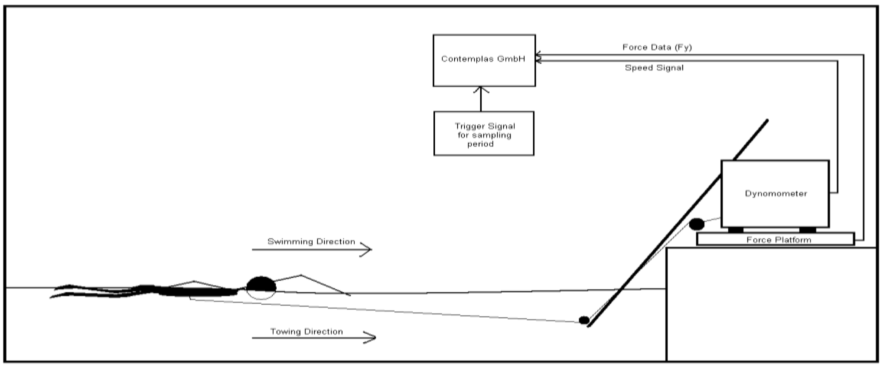

Figure 7: Assisted Towing Method set up (Sacilotto et al. 2012)

Active drag was calculated from the assisted towing formula of Alcock and Mason (2007) a revised version of the equation derived by (Kolmogorov & Duplishcheva 1992). Consequently, the formula for estimating active drag was:

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

Where F_t is the force required to pull the swimmer at the increased velocity, as measured with the force platform, V_1 is the swimmer's free swim maximum mean velocity, and V_2 is the increased tow velocity taken from the dynamometer.

All five trials collected were selected for statistical analysis. A one-way intra-class correlation coefficient (ICC) was used to test with-in subject reliability on days one and two. The average from five active drag values of each subject was calculated to use for the determination of ICC between days. SPSS software (Windows version 19) was used for statistical analyses and a statistical significance for the reliability coefficient was set at the 95% confidence level ($p<0.05$).

RESULTS: The reliability of active drag values of both days and also a comparison between mean values were calculated for each subject (Table 1). For repeated trials within days one and two, ICCs were 0.80 and 0.84 respectively, with 95% confidence intervals ranging between 0.59 to 0.94 for day one and 0.66 to 0.95 for day two. Between days, the ICC of average values was 0.92, with 95% confidence interval between 0.71 and 0.98.

Table 1
Individual values of active drag (N) with fluctuating velocity in day 1 and 2

Participan	Gender	Mean max velocity	Trial1	Trial2	Trial3	Trial4	Trial5	Mean ± SD
Day one								
1	F	1.58	102.1	106.3	73.6	84.3	72.9	88±16
2	F	1.61	87.8	84.4	87.1	114.4	93.8	93±12
3	F	1.65	59.5	67.3	71.5	69.3	65.1	66±5
4	F	1.60	86.1	83.3	88.4	104.4	68	86±13
5	M	1.87	112.4	109.2	118.6	82.1	98.9	104±14
6	M	1.93	125.1	148.8	158.6	152.1	190.8	155±24
7	M	1.78	123.9	123.7	160.9	132.2	156.4	139±18
8	M	1.87	138.5	108	158.3	185.4	140.2	146±28
9	M	1.87	157.2	164.7	158.5	163.3	145.1	157±8
Day two								
1	F	1.57	74.2	60.5	61.2	82.3	73.6	70±9
2	F	1.63	59.2	115	42.3	98.3	118	86±34
3	F	1.65	65	65.8	66.5	70.1	64	66±2
4	F	1.58	54.9	54.8	66.6	73.4	70.4	64±9
5	M	1.88	99	131.2	102.4	132.6	112.8	115±16
6	M	1.92	138.2	139.8	131.9	155.6	164.8	146±14
7	M	1.80	132.6	115.8	108.5	148.9	149.4	131±19
8	M	1.88	181	164.9	169.3	179	150.9	169±12
9	M	1.87	158.3	123	154.6	137.3	130.8	140±15

DISCUSSION: Prior to the current investigation, no research had described the reliability of the current ATM method for estimation of active drag with fluctuating velocity. The result of this study indicated that using the ATM method with fluctuating velocity is moderately reliable in regards to within-subject values on each day (ICCs = 0.80 and 0.84). This method is more reliable, however, when using the average value of active drag from both days (ICC = 0.92). Therefore, using the average active drag value of five trials in the current testing protocol will produce a more reliable result.

As expected, the males in this research had higher active drag values than the females (Kolmogorov & Duplishcheva 1992; Xin-Feng et al. 2007). Mason et al. (2011) utilised the current ATM method with fluctuating velocity and revealed similar values for their males (112 and 124 N at maximum velocity of 1.83 and 1.82 m/s respectively for two subjects) compared to the current research. However, the mean values of the female subjects from Mason et al. (2011) (for example, two subjects had 128 and 119 N at maximum velocity of 1.61 and 1.69 m/s respectively) were considerably higher than present research. The difference in active drag values between studies may possibly be explained by a difference in age, size and/or technique of the swimmers.

The active drag values collected in the current research and by Mason et al. (2011) were significantly higher than the results previously reported by Hollander et al. (1986), Kolmogorov et al. (1992) and Xin-Feng et al. (2007). For example, Xin-Feng reported that the active drag value and additional drag (F_t) of one of the male was 57.25±3.04 and 13.96 N at a mean maximum velocity of 1.85 m/s while in the present research, the mean active drag value and mean additional drag (F_t) of subject 9 at day 2 were 140.8±15 and 32.75 N at a mean maximum velocity of 1.86 m/s. The higher value of active drag in the present study was probably the consequence of a higher tow force (F_t). Another reason for a difference active drag value may be the result of the Xin-Feng et al. (2007) being resisted whereas the present study used an assisted method to assess active drag. This is an important area of future investigation.

ICC values from the current research (0.80 and 0.84) were significantly lower than previous studies 0.99 and 0.91 respectively reported by Formosa et al. 2010 and Sacilotto et al. 2012. Sacilotto et al. 2012 analysed reliability from three of five active drag trials using a different statistical calculation (Hopkins, 2011). The difference in the reliability result could be due to differences in the testing protocol, the standard of swimmer, and/or the statistical calculation. Dufek et al. (1995) reported that to achieve better reliability, it is necessary to maximise the number of trials per subject. The swimmers' fatigue, however, should also be considered when increasing the number of the trials. Connaboy et al. (2010) examined fifteen subjects to find the optimum number of trails and concluded that five trials per session, with five minutes rest between each trial, provides a suitable measure of reliability. Connaboy's research did not investigate the number of swimmers required to reach a sound value for reliability. Morrow et al. (1993), however, recommended that at least 30 subjects are required to achieve reliable measurements. Considering the difficulty in finding 30 subjects with the high swim performance level required for these measures, it is proposed to follow the suggestion of Connaboy et al. (2010) for a sample size of 15.

CONCLUSION: The result of this study identified that ATM method with fluctuating velocity is moderately reliable within-subject in a single day, while high reliability has been found for the average active drag values across different days. The positive result for the average value of active drag obtained between days persuades the researches to increasing the sample size to progress this study. Future investigation should be performed to assess the validity of this method compared to other measurement techniques.

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