INTRA-RELIABILITY OF ACTIVE DRAG VALUES USING THE ASSISTED TOWING METHOD (ATM) APPROACH

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The purpose of this research was to test the intra-reliability of the assisted towing method (ATM) approach at a constant velocity when estimating for active drag. Seven national level front crawl swimmers completed three trials of maximal free swimming and five active drag trials. The computed active drag values were analysed using within-subject intraclass correlation coefficients (ICC) and typical error coefficient of variance percentages (%CV_{TE}). Results revealed a nearly perfect confidence level (ICC=0.91 with a range of 0.58 to 0.98 and a %CV_{TE} of 11.7). Therefore, using the ATM approach to estimate active drag in its current formatting will produce reliable results and should be used to pursue further research in active drag estimations.

KEYWORDS: swimming, resistance, forces, front crawl.

INTRODUCTION: An elite swimmer's swim performance is largely influenced by the free swim phase of the race. Successful free swimming is the ability of the swimmer to minimise active drag, whilst optimising propulsive force (Formosa, Mason & Burkett, 2010). Active drag is the water resistance acting upon the swimmer during the dynamic swimming motion. For many years in swimming research, attempts have been made to accurately measure active drag. There has been much controversy as the methods used often produce varying values. The most frequently used experimental approaches in measuring active drag include the Measuring Active Drag (MAD) System (Hollander et al., 1986), and the Velocity Perturbation Method (VPM) (Kolmogorov & Duplishcheva, 1992).

The VPM approach is based on two assumptions; 1) the swimmer is capable of producing a consistent mechanical power output, and 2) the swimmer will maintain a consistent mean velocity in all trials. The ATM approach is based on the same assumptions as the VPM; however, the protocol involves assisting rather than resisting the swimmer. Most of the initial research using the ATM involves the use of a near constant velocity tow. However, recent research revealed the benefits of towing the swimmer whilst allowing for intra-stroke fluctuations (Mason, Sacilotto & Menzies, 2011). Prior to future research involving a tow velocity allowing for intra-stroke fluctuations, the reliability of individual active drag values using the ATM approach must be determined using a constant tow velocity. Due to the large number of variables when allowing for intra-stroke fluctuations, testing the initial experimental protocols which are considered to have a smaller number of variables is warranted.

Hopkins (2010) refers to reliability as the reproducibility of a measurement. In the case of the current study this involves an individual's ability to reproduce consistent active drag measures. Researchers have completed brief preliminary studies into the reliability of the ATM (Alcock & Mason, 2007; Formosa et al., 2010). However, since previous research was completed using the ATM approach, the motorised towing device (dynamometer) utilised in this research has been reengineered to enable more accurate and consistent velocity settings and further reassessment must be conducted before future studies are undertaken. Therefore, the purpose of this research was to test for reliability of the current ATM approach using a constant velocity tow when estimating active drag.

METHODS: Seven national level swimmers (5 males and 2 females, 19.86 ±2.91 y, 662.86 ±64.29 FINA points) participated in this investigation. Participants were required to complete a 20 minute race warm-up focusing on short front crawl sprints after which they were instructed in the testing protocols. Each participant was allowed a minimum of one

familiarisation trial before each phase of testing. In determining the swimmer's maximal swim velocity, participants were required to complete three maximal free swim trials over a 10 m interval. Starting from the 25 m mark with their mean velocity being measured between the 15 m to 5 m marks from the wall using two 50 Hz cameras (Samsung model: SCC-C43101P). Using a custom program from the Australian Institute of Sport (AIS), the mean velocity was calculated for each trial. The trial with the median velocity value was used to determine the swimmer's maximum swim velocity. Following the free swim trials, the participants completed five maximal swims in order to determine their active drag values. During these five trials, participants were towed by a flux vector dynamometer mounted directly on a calibrated Kistler™ force platform (Kistler Instruments Winterthur Switzerland Dimensions: 900 x 600 mm Type Z20916). These trials were completed with the mean tow velocity equal to five-percent (Formosa, Mason & Burkett, 2011) greater than the maximum free swim velocity. The trials were completed with a high dynamometer force selection of 550 newtons. This resulted in a near constant tow velocity. All trials were completed with the participants actively swimming front crawl with an Eyeline® tow belt attached around their waist and connected to the dynamometer. During each trial, velocity and force data were captured from the dynamometer and force platform (see
Figure **4**). Data capture was collected using Contemplas GmbH Motion Analysis software and then processed using an export/import function in Contemplas linked to an AIS customised analysis program. The amplifier's sensitivity was set at 5000 pC and the data was processed using a 12 bit A to D card, sampled at 500 Hz. An 8 Hz Butterworth low pass digital filter was applied to the force data (Alcock & Mason, 2007; Formosa et al., 2010). All trials were video recorded using three genlocked cameras at 50 Hz and were used purely for feedback to the participants. The cameras were positioned side-on underwater, side-on above water and head-on. The side-on above and underwater cameras were mixed with an Edirol video mixer (EDI-V8) to produce a single moving above/below image.

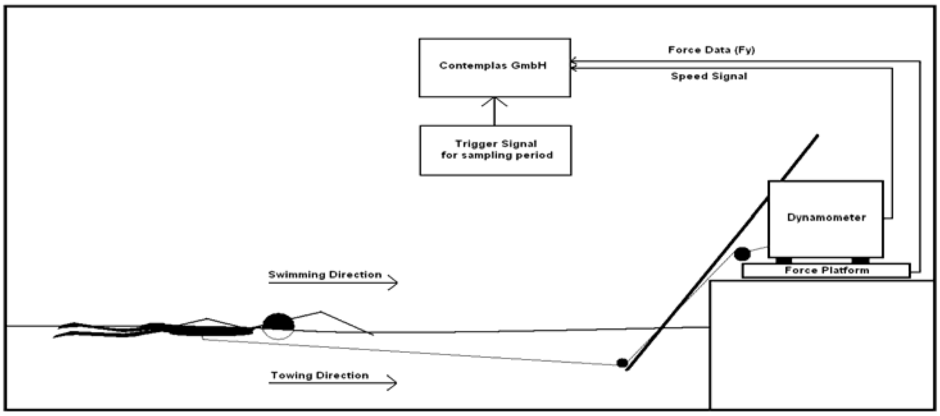

Figure 3: Assisted Towing Method set-up.

Active drag (D_A) was computed using the difference between maximal free swimming velocity and the towed velocity, as well as the force needed to pull the swimmer at the increased velocity. Active drag was calculated using the same equations as Kolmogorov and Duplishcheva (1992) and modified for assisted towing as determined in Alcock and Mason (2007) therefore providing an equation for estimating active drag as:

$$D_A = \frac{F_b v_2 v_1^2}{v_2^3 - v_1^3}$$

where F_b is the force needed to pull the athlete at the increased velocity as measured by the force platform, v_1 is the swimmer's maximum free swim velocity and v_2 is the tow velocity taken from the dynamometer. In the case of constant velocity both v_1 and v_2 are considered as constants in deriving the variable force parameter representing active drag.
Three trials of the five trials collected were selected for statistical analysis. The three trials selected included the median of the original five and the two trials that were nearest in value to the original median. The two remaining drag values were considered outliers and were not used in any of the calculations. All statistical calculations for this investigation were carried

out from the Reliability Windows Excel spreadsheet created by Will Hopkins (Hopkins, 2002). The reliability spreadsheet was most recently updated in September 2010. All statistics were calculated from the active drag values corrected for small sample bias, with the exception of the $\%CV_{TE}$. The ICC was derived by weighting the standard deviation and sample number of each value set by their degree of freedom. An ICC was selected as a test-retest reliability measure to limit the small sample bias associated with the more commonly used Pearson product moment reliability test (Hopkins, 2002). According to Hopkins (2002) if the ICC was between 0.90 and 1.00, then the reliability of the correlation was considered to be nearly perfect to perfect. A confidence interval (CI) was set at 95% for reporting on reliability coefficients. The $\%CV_{TE}$ was calculated through a 100 x log transformation as the change in mean values was less than 50% (Hopkins, 2002).

RESULTS: Table 6 represents the individual towing velocities and mean active drag values. The mean active drag value for the sample was 188 ±63 N at a mean maximum velocity of 1.86 ±0.12 m/s. The $\%CV_{TE}$ within-subjects mean active drag values was 11.7. The ICC of mean active drag values within-subjects was 0.91 and the likely range was 0.58 to 0.98 at a 95% confidence interval.

Table 6: Individual values of active drag (N) using a constant velocity tow.

Participant	Tow Velocity (m/s)	Trial 1	Trial 2	Trial 3	Mean ±SD
1	1.73	154	128	128	137 ±15
2	1.90	173	170	179	174 ±5
3	2.02	215	195	193	201 ±12
4	1.67	103	130	117	116 ±14
5	1.88	200	223	180	201 ±22
6	1.88	184	167	194	182 ±14
7	1.96	293	355	264	304 ±46

DISCUSSION: The aim of this research was to assess the reliability of the current ATM approach using a constant velocity tow for the estimation of active drag in order to prepare the system for use in future fluctuating velocity investigations. The results of the study indicate that the use of the ATM approach for active drag estimation is reliable in regards to within-subject variation when analysing three of the five trials.

The active drag values collected from this sample were, on average, considerably higher than other values from previous investigations (Hollander et al., 1986; Kolmogorov & Duplishcheva, 1992). Surprisingly, the current study's mean active drag values also varied from previous studies using the same method. Alcock and Mason (2007) concluded that their results were in agreement with prior studies using the MAD-System (Hollander et al., 1986) and the VPM approach (Kolmogorov & Duplishcheva, 1992) with a mean male active drag value for front crawl of 95.83 ±2.86 N. However, this study was prior to the dynamometer being reengineered and only included one subject. Another study utilising the ATM approach for active drag collection revealed a mean value of 228.4 ±10.80 N (Formosa et al., 2010). In this study, Formosa et al. (2010) recruited ten male Australian national level front crawl swimmers for testing and the conclusion made in regards to the larger active drag values was simply a difference in testing protocol, i.e. results were compared to MAD and VPM values (Formosa et al., 2010). However due to the fact that the current study and the study completed by Formosa et al. (2010) were conducted with the same protocol and equipment, the difference in active drag values could be the males selected in the study had faster velocities than the mixed gender group in the current study. An increase in swim velocity has been speculated to increase a swimmer's drag values (Mason et al., 2011).

Morrow and Jackson (1993) outlined that a small sample size reliability study produces potentially unstable reliability estimates for a population. Particularly in the lower limit, a lower limit CI estimate of .60 from a sample size of 10 has a 95% CI lower limit of .074, which suggests quite unstable measurements in the sample. Therefore, to further this study in order to set foundations for future research using this method of active drag estimation it is recommended that a sample size of 30 who represent the intended population be used to determine a more reliable confidence limit (Morrow & Jackson, 1993). However, this number may not be feasible, therefore a target sample of 20 will be established which is in line with another swimming reliability study which has a sample size of 15 (Connaboy, Coleman, Moir & Sanders, 2010). The results obtained in the current study reveal reasonably stable confidence limits despite the low sample size, specifically when compared with another study using the ATM approach. Mason et al. (2011) was the first study to use the ATM approach to investigate using a fluctuating velocity when collecting for active drag. Collection of both fluctuating and constant velocity trials were undertaken in this study which was conducted prior to the reengineering of the dynamometer. When looking at the constant velocity drag values only, the ICC (0.87) is within a very large correlation, which is the range of values below those values from the current investigation. Also the lower CI (0.34 at the same confidence level of 95%) would seem to indicate that the active drag values obtained in this previous study were quite unstable. This instability could also be due to the small sample size, which again reiterates the need to sample a larger number of elite swimmers in order to progressively understand more about this form of active drag estimation.

CONCLUSION: The present study demonstrated the importance of testing for intra-reliability prior to undertaking extensive research in a new area of active drag. The positive results obtained will encourage the pursuit of a larger sample size to progress this study. Future investigations using the ATM approach should be undertaken to progress this area of swimming biomechanics in understanding the forces during free swimming. However presentation of the reliability of the results should be noted to increase the impact of the study undertaken.

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