B4-3 ID158

# COMPARISON BETWEEN ACTIVE DRAG VALUES ESTIMATED USING BOTH THE VELOCITY PERTURBATION METHOD AND THE A.I.S. ASSISTED TOWING METHOD

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An accurate measure of active drag and propulsion in swimming provides possibly the best quantitative measure of a swimmer's technique. Presently the MAD, the VPM and the ATM are commonly used in an attempt to accurately obtain active drag values as an assessment of swimmer technique. The ATM system is relatively new compared to both the MAD and VPM systems. The ATM has been developed on similar grounds to that of the VPM with the exception that it uses assisted towing as well as resisted swims. Similar conditions for testing in both the VPM and ATM are required. A major difference between both is that the ATM produces intra stroke active drag and propulsion profiles rather than only a mean measure of active drag. This research tested swimmers using both ATM and VPM to compare the mean active drag values at maximum swim velocity.

**KEY WORDS**: Swimming, Biomechanics, Active drag, Analysis, ATM, VPM

**INTRODUCTION:** The Measurement of Active Drag (MAD) system (Hollander et al, 1986) was the first advanced system to attempt to measure mean active drag. Here the swimmer progressed down the pool, while pulling and pushing on paddles under the water while the propulsion force was measured with a force transducer. A major criticism of the MAD system was how well the actions of the swimmer related to real swimming and the fact that the feet were kept buoyant using a pull-buoy. Another big step forward was the development of the Velocity Perturbation Method (VPM) (Kolmogorov & Duplishcheva, 1992). The VPM estimated a measure of mean active drag using a resisted method, but only estimated the mean active drag at the swimmer's maximum swim velocity. In this system the swimmer completed two trials, one free swimming and the second swimming while pulling a hydrodynamic body. This method relied on three assumptions: 1) that the swimmer exerted equal power in both the free swim condition and when being resisted, 2) that the swimmer maintained a consistent mean swim velocity through all trials and 3) that the swimmer performed with similar stroke mechanics. The calculation of mean active drag was based upon the free mean swim velocity versus the resisted mean swim velocity as well as the resistive force applied against the swimmer's motion. Another system by which active drag was assessed was developed at the Australian Institute of Sport (Alcock & Mason, 2007). The Assisted Tow Method (ATM) approach was based on similar assumptions as the VPM; however, the protocol involved assisting and resisting rather than just resisting the swimmer. A powerful dynamometer was used to tow the swimmer at a constant velocity equal to five-percent greater than the swimmer's mean maximum swim velocity. A force platform, upon which the dynamometer was mounted, measured the varying force profile required to tow the swimmer. As was the case of the VPM, the active drag of the swimmer could only be computed at the swimmer's maximum mean swimming velocity. The ATM produced an active drag profile that varied throughout the stroke. Most of the initial research using the ATM involved the use of a constant velocity tow. Using a computed propulsive force profile (Mason et al, 2012), an analysis system that incorporated both that profile alongside underwater video images of the swimmer's stroke mechanics was able to be used to assist the coach in stroke correction. Recent research (Mason et al, 2011) revealed the benefits of towing the swimmer whilst allowing for intra-stroke velocity fluctuations. Using the A.I.S. ATM method both an assisted and resisted method of assessing active drag have recently been developed. As both the VPM and the ATM (assisted and resisted) report to estimate a swimmer's mean active drag at the swimmer's maximum swim velocity, there is a real need to compare values obtained from both these methods of assessment.

**METHOD:** A two week workshop at the Australian Institute of Sport (A.I.S.) which involved international researchers in swimmer active drag was conducted in January, 2013, to identify any deficiencies in the A.I.S. ATM approach. These researchers conducted investigations to look at the methods and the results obtained using both the VPM and ATM methods of estimating a swimmer's mean active drag. Thirteen elite swimmers were tested using both the VPM and ATM approach. Early in the workshop seven of the swimmers were tested with the VPM and the ATM over a 10m test interval. Later in the workshop another six swimmers were tested with the VPM and the ATM over a 20m interval.

**RESULTS:** Three tables below provide the data obtained from the testing of the 13 swimmers involved using both the VPM and the ATM. Table 4 provides the relationship obtained between the four modes of ATM assessment and VPM. Observation indicated that the active drag values from Assisted ATM were higher than those of VPM testing. Resisted ATM testing values tended to be lower than VPM values.

**Table 1** Provides results from the ATM mean active drag testing. Mean tow force, tow and swim velocity with active and passive drag over different trial conditions.

| Subj | Sex | Trial | Test Dist (m) | Mean Tow Force (N) | Mean Tow Vel (m/s) | Mean Swim Vel (m/s) | Mean ATM $D_a$ (N) | Passive Drag (N) |
|---|---|---|---|---|---|---|---|---|
| A | F | Assist | 10 | 20 | 1.79 | 1.65 | 75 | 52 |
| A | F | Resist | 10 | 12 | 1.51 | 1.65 | 49 | 52 |
| B | F | Assist | 10 | 21 | 1.84 | 1.71 | 93 | 63 |
| B | F | Resist | 10 | 12 | 1.57 | 1.71 | 49 | 63 |
| C | F | Assist | 10 | 15 | 1.74 | 1.61 | 60 | 49 |
| C | F | Resist | 10 | 13 | 1.50 | 1.61 | 58 | 49 |
| D | F | Assist | 10 | 22 | 1.69 | 1.55 | 83 | 64 |
| D | F | Resist | 10 | 12 | 1.41 | 1.55 | 43 | 64 |
| E | M | Assist | 10 | 35 | 1.84 | 1.68 | 123 | 120 |
| E | M | Resist | 10 | 13 | 1.57 | 1.68 | 63 | 120 |
| F | M | Assist | 10 | 28 | 2.03 | 1.86 | 105 | 106 |
| F | M | Resist | 10 | 17 | 1.76 | 1.86 | 111 | 106 |
| G | M | Assist | 10 | 30 | 2.16 | 1.98 | 113 | 93 |
| G | M | Resist | 10 | 16 | 1.87 | 1.98 | 94 | 93 |

| Subj | Sex | Trial | Test Dist (m) | Mean Tow Force (N) | Mean Tow Vel (m/s) | Mean Swim Vel (m/s) | Mean ATM $D_a$ (N) | Passive Drag (N) |
|---|---|---|---|---|---|---|---|---|
| H | M | Assist | 20 | 12 | 1.79 | 1.68 | 63 | 59 |
| H | M | Resist | 20 | 21 | 1.52 | 1.68 | 73 | 59 |
| I | M | Assist | 20 | 12 | 1.85 | 1.76 | 73 | 76 |
| I | M | Resist | 20 | 16 | 1.66 | 1.76 | 93 | 76 |
| J | M | Assist | 20 | 11 | 2.10 | 1.99 | 66 | 93 |
| J | M | Resist | 20 | 15 | 1.87 | 1.99 | 89 | 93 |
| K | M | Assist | 20 | 25 | 1.89 | 1.79 | 141 | 83 |
| K | M | Resist | 20 | 15 | 1.69 | 1.79 | 84 | 83 |
| L | M | Assist | 20 | 14 | 1.98 | 1.83 | 66 | 94 |
| L | M | Resist | 20 | 18 | 1.73 | 1.83 | 112 | 94 |
| M | M | Assist | 20 | 17 | 1.85 | 1.74 | 95 | 104 |
| M | M | Resist | 20 | 15 | 1.64 | 1.74 | 82 | 104 |

**Table 2**. Provides the results from the VPM active drag testing. Subject heights, weights and VPM mean velocity, mean active drag and mean power

| Subj | Sex | Height (m) | Mass (Kg) | Mean VPM Velocity (m/s) | Mean VPM Active Drag(N) | Mean VPM Power (W) |
|---|---|---|---|---|---|---|
| A | F | 1.6 | 55 | 1.61 | 51 | 83 |
| B | F | 1.73 | 62.7 | 1.65 | 58 | 96 |
| C | F | 1.7 | 49.5 | 1.61 | 38 | 61 |
| D | F | 1.73 | 82 | 1.54 | 54 | 83 |
| E | M | 1.83 | 87.5 | 1.61 | 85 | 137 |
| F | M | 1.86 | 70.5 | 1.83 | 84 | 153 |
| G | M | 1.7 | 68.8 | 1.99 | 87 | 173 |
| H | M | 1.75 | 66 | 1.68 | 74 | 124 |
| I | M | 1.73 | 71.9 | 1.76 | 73 | 128 |
| J | M | 1.7 | 68.8 | 1.99 | 87 | 173 |
| K | M | 1.78 | 75 | 1.79 | 92 | 164 |
| L | M | 1.77 | 76.7 | 1.82 | 71 | 129 |
| M | M | 1.92 | 79.5 | 1.71 | 59 | 100 |

**Table 3**. Provides a comparison between VPM & ATM testing result values.

| Subject | Gender | Trial | ATM (m) | ATM Mean Swim Vel (m/s) | ATM Mean $D_a$ (N) | ATM K (Velocity Indep Drag Coeff) | VPM Mean Swim Vel (m/s) | VPM Mean $D_a$ (N) | VPM K (Velocity Indep Drag Coef) |
|---|---|---|---|---|---|---|---|---|---|
| | | | 10 | 1.65 | 75 | 28 | 1.61 | 51 | 20 |
| | | | 10 | 1.65 | 49 | 18 | 1.61 | 51 | 20 |
| | | | 10 | 1.71 | 93 | 32 | 1.65 | 58 | 21 |
| | | | 10 | 1.71 | 49 | 17 | 1.65 | 58 | 21 |
| | | | 10 | 1.61 | 60 | 23 | 1.61 | 38 | 15 |
| | | | 10 | 1.61 | 58 | 23 | 1.61 | 38 | 15 |
| | | | 10 | 1.55 | 83 | 35 | 1.54 | 54 | 23 |
| | | | 10 | 1.55 | 43 | 18 | 1.54 | 54 | 23 |
| | | | 10 | 1.68 | 123 | 43 | 1.61 | 85 | 33 |
| | | | 10 | 1.68 | 63 | 22 | 1.61 | 85 | 33 |
| | | | 10 | 1.86 | 105 | 30 | 1.83 | 84 | 25 |
| | | | 10 | 1.86 | 111 | 32 | 1.83 | 84 | 25 |
| | | | 10 | 1.98 | 113 | 29 | 1.99 | 87 | 22 |
| | | | 10 | 1.98 | 94 | 24 | 1.99 | 87 | 22 |
| | | | 20 | 1.68 | 63 | 22 | 1.68 | 74 | 26 |
| | | | 20 | 1.68 | 73 | 26 | 1.68 | 74 | 26 |
| | | | 20 | 1.76 | 73 | 24 | 1.76 | 73 | 23 |
| | | | 20 | 1.76 | 93 | 30 | 1.76 | 73 | 23 |
| | | | 20 | 1.99 | 66 | 17 | 1.99 | 87 | 22 |
| | | | 20 | 1.99 | 89 | 22 | 1.99 | 87 | 22 |
| | | | 20 | 1.79 | 141 | 44 | 1.79 | 92 | 29 |
| | | | 20 | 1.79 | 84 | 26 | 1.79 | 92 | 29 |
| | | | 20 | 1.83 | 66 | 20 | 1.82 | 71 | 21 |
| | | | 20 | 1.83 | 112 | 33 | 1.82 | 71 | 21 |
| | | | 20 | 1.74 | 95 | 31 | 1.71 | 59 | 20 |
| | | | 20 | 1.74 | 82 | 27 | 1.71 | 59 | 20 |

Table 4 provides the correlation coefficients between VPM values for mean active drag and those obtained from ATM. Similarly, the correlation coefficients for the K values for both the resulting values from the VPM and ATM testing are listed. K is the velocity independent drag coefficient and calculated by dividing the active drag value by the square of the maximum swim velocity. The correlation coefficients are calculated with respect to the ATM testing interval distance and whether assisted or resisted ATM testing was utilised.

**Table 4** Provides correlation coefficients and correlation coefficients squared to compare ATM and VPM resulting values using assisted and resisted as well as the testing interval.

| **Correlation Coefficients** | | **Assisted (10m)** | | | **Resisted (10m)** | |
|---|---|---|---|---|---|---|
| **ATM v VPM** | | K | $D_a$ | | K | $D_a$ |
| | | r = 0.94 | r = 0.96 | | r = 0.21 | r = 0.72 |
| | | $r^2$ =0.88 | $r^2$ = 0.93 | | $r^2$ = 0.05 | $r^2$=0.52 |
| | | | | | | |
| | | **Assisted (20m)** | | | **Resisted (20m)** | |
| | | K | $D_a$ | | K | $D_a$ |
| | | r = 0.57 | r = 0.38 | | r = -0.24 | r = -0.07 |
| | | $r^2$ = 0.33 | $r^2$ = 0.14 | | $r^2$ = 0.06 | $r^2$ = 0.01 |
| **K = Velocity Independent Drag Coefficient** | | | | | | |
| **$D_a$ = Active Drag Force** | | | | | | |

**DISCUSSION and CONCLUSIONS:** In the majority of cases, the ATM resisted testing resulted in active drag values that were less than those obtained with the VPM and with ATM assisted testing. Similarly, the ATM assisted testing resulted in values that were generally greater than those obtained with the VPM. A method of obtaining a single ATM active drag value from both the assisted and resisted ATM is being investigated. It can be observed from the correlation coefficient table (table 4) that results obtained from ATM assisted testing with an ATM testing distance interval of 10m was far more closely related to the VPM active drag values than the other three ATM protocols. Further subject testing to provide greater numbers of data in the correlations are needed to confirm this observation. Overall, assisted ATM testing was more closely related to VPM results than was ATM resisted testing. This may be a consequence of ATM resisted testing being implemented relatively recently and with a greater amount of testing, the protocols will hopefully become more refined and the active drag values more consistent. The results from different methods of active drag testing certainly are not generally in agreement with one another. Research and development in this area will result in progressive testing protocol improvements and in much closer values for active drag if such research continues. At present active drag testing and within stroke analysis results is possibly the only quantitative assessment of a swimmer's technique and therefore it is important that research in this area continues.

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