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RECOMMENDATIONS ARISING FROM A WORKSHOP OF EXPERTS TO MAKE THE A.I.S. ATM ACTIVE DRAG ASSESSMENT SYSTEM MORE RELIABLE AND ACCURATE

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There is a real need in biomechanics to provide objective quantifiable parameters associated with free swimming to enhance the swimming performance of elite athletes. Active drag and propulsion profiles, with synchronised video footage of performance, are used at the Australian Institute of Sport (A.I.S.). The A.I.S. ATM assisted and resisted active drag system is used to achieve the above goal in real time. An active drag workshop was held at the A.I.S. to investigate the protocols and procedures that are used in the system and provide recommendations which if implemented would improve the system's accuracy and efficiency. This paper addresses the suggestions provided by those world leaders of active drag research who were in attendance, in order to improve the capabilities of the A.I.S. ATM active drag system.

KEY WORDS: Swimming, Biomechanics, Active drag, Propulsion, Free Swim, Analysis

INTRODUCTION: There is a real need in competitive swimming for biomechanists to provide the coach with objective, quantifiable information about the propulsive forces that are produced during free swimming. This should be done in conjunction with underwater video of the swimmer's actions, to enable objective decisions to be made concerning changes to the swimmer's stroke mechanics that are needed to achieve performance enhancement.

It has long been recognised that swimming speed was related to the propulsive actions of the swimmer and the active drag which opposed the swimmer's forward movement. Up until the 1970's it was believed that the mean active drag on a swimmer could be estimated by a measurement of mean passive drag. It was in the late 1970's that scientists recognised the problems with using the mean passive tow force as an estimate of active drag and attempted to assess the active drag profile utilising tethered swimming, by measuring the force on the restraining cable. This force profile was then considered as being equivalent to the propulsive force that occurs during free swimming. A major step forward in the practical estimation of mean active drag over a range of swim velocities was made with the Measurement of Active Drag (MAD) system (Hollander et al., 1986) in which the swimmer progressed down the pool, while pulling and pushing on paddles under the water which were attached to rigid vertical rods connected in turn to a long horizontal rod which transferred the force to the pool wall through a force transducer. This provided a measurement of mean active drag through a range of swim velocities. A major criticism of the MAD system was the concern as to how well the actions of the swimmer related to real swimming and the fact that the feet were not used and were kept buoyant using a pull-buoy. Another 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. 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 velocity through all trials and 3) that the swimmer performed all trials with similar stroke mechanics. The calculation of mean active drag was based upon the free mean swim velocity versus the resisted mean swim velocity and the resistive force. A system by which active drag was assessed was developed at the Australian Institute of Sport (A.I.S.) (Alcock & Mason, 2007). The Assisted Tow Method (ATM) approach was based on similar assumptions as the VPM; however, the protocol involved assisting rather than 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 the 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 was developed.

METHOD: The protocol used in the ATM method involved assessing the swimmer's maximum swim velocity using a number of free swimming trials over a 10m interval. Next the passive drag of the swimmer was measured by towing the swimmer at that maximum swim velocity through the water with the swimmer maintaining a streamline position. The force measured to tow the swimmer was the passive drag force. Next the active drag testing was performed using both an assisted and resisted method. The tow velocity in the assisted method pulled the swimmer while the swimmer swam with maximum effort at a tow velocity of between 5 to 10% greater than their maximum swim velocity. In the resisted method the swimmer performed with maximal effort against a resistance that resulted in a decreased velocity of between 5 to 10% slower than the maximum swimming velocity. In all trials the swimmer performed with maximum effort. The assumptions were: that equal power was produced by the swimmer in free swims and when being assisted or resisted, the mean velocity of the swimmer was maintained at a constant level over all trials and the propelling efficiency should be kept constant over all trials. Three trials of each was performed.

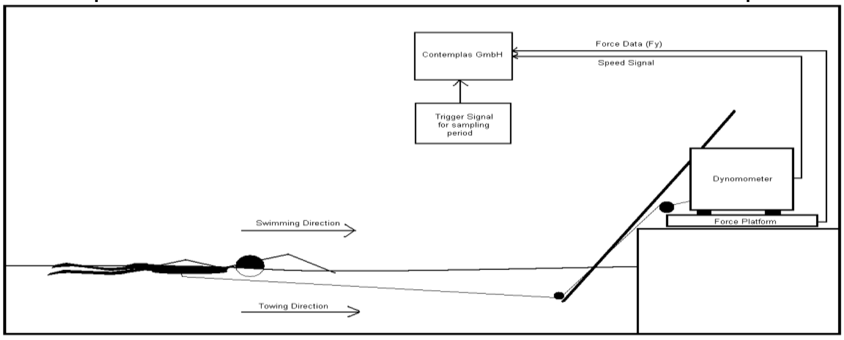

Figure 6: Assisted Towing Method set up

The formula used to compute active assisted drag was $$Da = \frac{(Ftow*Vassist*Vfre**2)}{(Vassist**3 - Vfree**3)}$$

The formula used to compute active resisted drag was $$Da = \frac{(Ftow*Vresist*Vfre**2)}{(Vfre**3 - Vresist**3)}$$

Using the equation: $Propulsion = \frac{d}{dt}(mv) - Da$, the propulsive force profile of the swimmer was able to be computed. (Mason & al., 2012)

The **resultant** or **net force** was computed as the sum of **Drag Force** and **Propulsion**.

Recommendations:

* There is a need to reduce the number of trials to a minimum which are performed during the testing of active drag. Too many trials may cause some swimmer fatigue, resulting in possible unreliable results.

* A maximal swim at the conclusion of testing should be used to evaluate whether there was a decline in power output over the testing period.

* Assisted and resisted trials should be alternated.

* To assess maximum mean swim velocity, the A.I.S. ATM method presently used a 10m swim distance (15 to 5m from wall). This should be increased to 20m (25 to 5m from wall) to minimise error measurement as the 20m is more representative of a race distance.

* Passive Drag testing distance should be increased from 10 to 20m (25 to 5m from wall).

* Data collection for the assisted active drag testing should commence at about the 25m mark from the wall (at right hand entry) and consist of 8 complete strokes in the direction toward the wall.

* Data collection for the resisted active drag testing should commence at about the 10m mark from the wall (at right hand entry) and should consist of 6 complete strokes in the direction away from wall.

* Increase the time of recovery between testing trials but use active rest so swimmers don't get cold. At least a 5 minute break is required between tests and should include a 100 or 200m slow swim.

* Prior to the commencement of testing, ensure the subjects are fully conversant with all aspects of the testing protocols. Swimmers are instructed to warm up, which should consist of a modified race warm up focusing upon a short freestyle sprint.

* In the resisted active drag towing, set the height of the pulley at only 1.25m rather than the 2.3m above the water that is presently used. This is to reduce the additional longitudinal torque upon the force platform due to the long pulley lever attached to the dynamometer, as well as to ensure a reduction in the oscillatory movement of the lever and cable. The drag testing should aim at using a 1.25m height above water level. This height may be modified to a greater height if the swimmer kicks the cable.

* In assisted and resisted testing, accept only those trials that only have a velocity change of between 5 and 8% - faster than maximum mean swim velocity for the assisted trials and slower than maximum mean free swim velocity for the resisted towing.

* In both assisted and resisted active drag testing accept only those trials with a mean acceleration of no more than $0.05 ms^{-2}$. This is to ensure a consistent mean swim velocity occurred within the trial.

* In the active drag testing, the tow/drag force or resistance force should measure between 10 and 20N for resisted drag analysis and between 10 and 30N for assisted.

* The overall testing protocol should include 2 free swims to estimate maximum mean swim velocity followed by 2 passive tows. The mean value of each is to be used as an estimate of swim speed and passive drag. A third free swim or third passive tow trial should be completed if the swim speeds are more than $0.05 ms^{-1}$ different and passive drag values greater than 5N different from each other. Where a third trial is required, the mean of the closest 2 trial values should be used. In the active drag tests, the assisted and the resisted drag testing trials should be alternately trialled. This is to avoid a skewed fatigue affect in either condition. Use only two trials each if the values are within 10N of each other and calculate the mean. Otherwise do a third trial and take the mean of the closest 2 trial values.

* To obtain a single resultant active drag force estimate from the result of both assisted and resisted towing, utilise the mean value of both.

* A power output value should be provided for each swimmer tested.
Power = maximum mean swim velocity * **mean active drag at that velocity**

***** Either a dimensionless coefficient of drag Cd or a velocity independent drag coefficient K should also be provided for each active drag trial.

* The mass used in equations could use the swimmer mass multiplied by 1.2 to equate for the swimmer and added mass of moving water. However, the passive drag value at maximum swim velocity would adequately suffice.

* The ATM equation to calculate mean Assisted active drag is **Da =(Ftow*Vassist*Vfre**2)**
(Vassist **3 – Vfree3)**

The A.I.S. ATM method used this formula to also compute instantaneous active drag. The problem here was that acceleration was not included into the calculation. To rectify this problem the following change was made when calculating instantaneous assisted active drag.

Calculation Active Assisted drag **Da=ma(Vassist*Vfre**2 –Vfre**3)-(Ftow*Vassist*Vfre**2)**
(Vassist **3 – Vfree3)**

Where the following parameters are:
Da = active drag
Ftow = tow force as measured by force plate
Vassist = tow velocity as measured by dynamometer
Vfre = Free swim velocity computed from Vassist
a = acceleration profile (derivative of Vassist OR Vfre)
m = inertia (passive drag value at max swim velocity)

NB. **Vfre** for assisted trials is identical in shape to **Vassist** but is reduced by a value equal to: **(mean assisted velocity – mean maximum free swim velocity)**

The ATM equation used to calculate Mean Resisted active drag **Da= (Ftow*Vresist*Vfre**2)**
(Vfre3 – Vresist**3)**

The AIS ATM method was using this formula to also compute instantaneous active drag. The problem here was that acceleration was not included into the calculation. To rectify this problem the following change was made when calculating instantaneous resisted active drag.

Active Resisted drag is **Da = ma(Vresist*Vfre**2 –Vfre**3) - (Ftow*Vresist*Vfre**2)**
(Vfre **3 – Vresist3)**

Where the following parameters are:
Da = active drag
Ftow = resist force as measured by force plate
Vresist = resist velocity as measured by dynamometer
Vfre = Free swim velocity computed from Vresist
a = acceleration profile (derivative of Vresist OR Vfre)
m = inertia of swimmer (passive drag at max swim vel)

NB. **Vfre** is a parameter representing free swim velocity in the resisted trials and is identical in shape to the **Vresist** parameter but is reduced by a value equal to:
(mean maximum free swim velocity – mean resisted velocity)

LIMITATIONS: There is a need to better estimate of the relationship between active drag and the power of swimming velocity. Currently ATM and VPM both estimate the active drag as a function of velocity squared, which is only appropriate for fully submerged bodies.

CONCLUSIONS: The A.I.S. ATM active drag estimation has produced reliable results with elite swimmers who are able to produce consistent power and technique over the trials used in testing. It is believed that the inclusion of these recommendations into the testing protocols will enhance the A.I.S. ATM assessment system's reliability, accuracy and consistency.

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