A COMPARISON BETWEEN THE VALUES OBTAINED FROM ACTIVE DRAG ANALYSIS COMPARED TO FORCES PRODUCED IN TETHERED SWIMMING

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The purpose of this study was to identify in a maximum swim effort by elite freestyle swimmers, if the mean force produced in tethered swimming over a set number of whole strokes could reliably be utilised as an alternative measure for mean propulsive force over the same number of whole strokes. Tethered force can be measured relatively easily. Although mean propulsive force at a maximum swim velocity may be derived, the process of doing so is not direct, is time consuming and requires an extensive setup. Stepwise regression analysis indicated that mean tethered force was not an acceptable alternative for mean propulsive force. Therefore the use of mean propulsive power to monitor training would require the measurement of mean propulsive force rather than simply measuring the mean tethered force in a maximum swim effort.

KEY WORDS: biomechanics**,** swimming, tethered, active drag, propulsive force

INTRODUCTION: Regular assessment of effective power output may be utilised as an indicator of how an elite competitive swimmer is progressing in the free swimming aspect of performance during the preparation phase for a major swim meet. Mean propelling power may be computed by averaging the product of the swimmer's instantaneous propelling force by the swimmer's velocity at the same instant in time throughout a full stroke cycle. To obtain a reliable measure of propelling force during a swim trial, the swimmer must produce a maximal effort for the measure to be accurate. While swimming at a constant velocity, the measure of the active drag force and that of the swimmer's propelling force are identical in magnitude but opposite in direction. While instantaneous propulsive force or drag force assessment may be obtained throughout the stroke cycle, a measure of instantaneous velocity is very difficult to ascertain during that assessment. However, mean swimming velocity while swimming with maximum effort is easily obtained in an unaided trial by dividing the distance swam over a set interval, by the time taken to do so.

The mean propelling force of the swimmer is not as easily measured as mean velocity. However there are several methods available that can achieve such a measure. The MAD System as described by Toussaint et al. (1988) used in the Netherlands, the velocity perturbation method (VPM) as developed in Russia by Kolmogorov et al. (2000) and the method as used in China by Xin-Feng et al. (2007) are different methods that have been utilised to obtain a measure of mean active drag or mean propelling force in swimming. In a maximal effort, the mean active drag force may be considered as identical in magnitude to the mean propulsive force, as the swimming velocity may be considered as constant. The Australian Institute of Sport has developed a variation on the VPM as reported by Alcock et al. (2007) by towing the swimmer at a constant velocity that is greater than the swimmer's top velocity by a factor of five percent. The powerful dynamometer that pulls the swimmer determines the constant velocity at which the swimmer travels through the water. The force platform on which the dynamometer is mounted measures the force required to pull the swimmer at this velocity. The AIS method assumes that a maximal propulsive effort is applied by the swimmer during the active towing trials as well as the unaided trials used to assess the top swimming velocity. This implies an equal power input by the swimmer in both situations. The active drag and hence propelling force can be computed from the force required to pull the swimmer at the increased velocity. The propelling force so obtained will represent the force required by the swimmer to travel through the water at the swimmer's top unaided swimming velocity. This and previous methods of active drag assessment rely on computing active drag by an indirect method rather than measuring the force independently. The assessment of propelling force and following on from that, power output, requires the use of sophisticated scientific apparatus and a complex testing session. This project was performed to identify whether propelling force and hence mean propelling power may be assessed for a swimmer by utilising tethered swimming using simply a force link to measure propelling force during a maximal effort tethered swim. This would thus make the process of monitoring average power for free swimming in a maximum effort, a far less complicated task. Intuitively, it is feasible proposition that the magnitude of the propelling force in free swimming would be very similar to the force derived from utilising tethered swimming.

METHODS: Data Collection: Thirteen Australian swimmers (6 males and 7 females) were tested in the A.I.S. aquatics laboratory. The calibre of the swimmer was such that each had the ability to reach the final in at least one of the three freestyle events (50m, 100m and 200m) at the Australian National Open Swimming Championships. All testing included only the Australian crawl swimming stroke. The testing included three separate tests.

The first test involved obtaining the peak swim velocity of each swimmer. Here the subject was instructed to swim at their maximum speed through a 10m interval. A swim-in of 10m was used as a lead into the testing interval to enable the swimmer to attain maximum swimming velocity before reaching the start of the timing interval. The timing of each trial was performed utilising a video system (50 hertz) which included two cameras with one focused on the start and the other at the end of the timing interval. Each camera's view included vision of an elapsed electronic timing clock, synchronised in each camera view and accurate to a hundredth of a second, to assess the time taken to swim the 10m interval and hence enable calculation of the subject's maximum swimming velocity. Three such trials were conducted on each swimmer and the trial with the quickest time was chosen to represent the swimmer's maximum swim velocity.

The second test involved obtaining a measurement of active drag for each swimmer at the swimmer's top swimming velocity. Here the swimmer was familiarised with the active drag tow protocols used to obtain the swimmer's active drag at the subject's top swimming velocity. The Kevlar tow attachment to the swimmer was connected to the belt worn around the waist and attached at the anterior side of the body. Five trials were conducted with each swimmer at a tow velocity that was 5% faster than the subject's top swimming pace. The first press button trigger for the collection of kinetic data occurred at the beginning of a stroke (right hand entry) and the data was captured for four complete strokes (each stroke being right hand entry to right hand entry). The termination of data capture was denoted by a second press button trigger at the forth right hand entry after the initial button press. The force data collected in these trials represented the additional force required to tow the swimmer at the subject's 5% higher velocity beyond that required at the swimmer's top pace. It was sampled as the Y component of force from the Kistler force platform. The active drag measurement for the swimmer's maximum velocity was then able to be computed under the assumption that an equal effort was produced by the swimmer in both the maximum swim trials and the active drag trials. The mean value for active drag force over the four complete strokes was computed for each of the five trials. Each of the mean scores representing the five separate trials, was utilised to obtain the mean propulsive force for the swimmer.

The third test involved a measurement of tethered force during which the swimmer performing a maximal swim effort. The swimmer was familiarised with the testing procedure prior to testing. The Kevlar tether attachment to the swimmer was connecting to the belt worn around the waist and was attached at the posterior side of the body. The other end of the Kevlar non stretch cable was attached to the force platform. Three trials were conducted for each swimmer performing at maximum effort. The first trigger for the collection of data occurred at the beginning of a stroke and the kinetic data was captured for four complete strokes as denoted by a second press button trigger. The force data (total Y force from the force platform) collected in these trials represented the swimmer's pulling force during swimming, on the tether cable and against a rigid stationary object that measured the force. The tethered force measurement for the swimmer's maximum effort was computed under the assumption that an equal effort was produced by the swimmer in the free swim maximum swim trials, the active drag trials and the tethered swimming trials. The mean force value for the tethered swimming over the four complete strokes was recorded for each of the three trials. The three mean scores, each representing different trials, were utilised in the computation of the mean tethered force for the swimmer.

Data Analysis: The data representing the swim velocity, the mean propulsive force and the mean tethered force for each of the 13 swimmers was tabulated. A stepwise regression analysis was performed on the data with the mean propulsive force used as the dependent variable and swim velocity, swim velocity squared and mean tethered force used as the independent variables. A significance level of 0.05 was chosen as acceptance into the regression equation and 0.10 for rejection.

RESULTS

Subject Number	Gender	Velocity (m/s)	Mean Propulsive Force (N)	Mean Tethered Force (N)	Mean Power (watts)
1	M	1.9	161.7	179.5	307.3
2	M	1.92	226.4	183.9	434.7
3	M	1.92	151	175.5	289.9
4	M	1.85	235.7	128.2	436
5	M	1.91	256.5	156.4	489.9
6	M	1.89	302.2	181.2	571.1
7	F	1.76	127.4	125.5	224.3
8	F	1.71	77.5	137.7	132.4
9	F	1.74	164.6	136.8	286.4
10	F	1.69	171.3	113	289.5
11	F	1.61	95.3	119.5	153.4
12	F	1.64	89.3	105.4	146.5
13	F	1.64	100.1	106.6	164.2

The correlation coefficient for each of the independent variables with the dependent variable was for velocity 0.751, for velocity squared 0.749 and with mean tethered force 0.604. Velocity squared was utilised in this analyses, as force is a function of velocity squared. The analyses indicated that velocity explained 56% the variance in propulsive force where mean tethered force explained only 36%. The significance level for the correlation between the dependent variable and both velocity and velocity squared was 0.002, making both statistically significantly related to mean propulsive force at the 0.01 level. The significance level for the correlation between the dependent variable and mean tethered force was 0.014, making it not significant statistically at the 0.01 level. In the regression equation only swim velocity was accepted into the equation and mean tethered force was rejected. This was partly due to the fact that the correlation coefficient between velocity and mean propulsive force was very high at 0.890 indicating that mean tethered force contributed very little extra to the equation. The conclusion drawn from the statistical analysis was that mean tethered force could not be used as a reliable alternative for propulsive force in swimming.

DISCUSSION: A regular monitoring of propelling power in free swimming provides valuable information about the state of progress in an elite swimmer's free swim performance. The ideal method to compute mean propelling power would be to compute the mean of the product of instantaneous velocity with instantaneous propelling force produced by the swimmer. It is here that the solution to this problem becomes quite difficult. Instantaneous propelling force is measured by an indirect method. Because the method by which the force values are obtained requires towing of the swimmer through the water at a constant velocity it becomes impossible to obtain a measure of the swimmer's instantaneous velocity in an unaided condition. The mean velocity of the swimmer is used as a substitute for instantaneous velocity and therefore the measure of propulsive force is most readily provided as mean propulsive force. Due to the fear of being inaccurate by using mean velocity and mean force in the computation of mean power, an analysis of the possible inaccuracies was assessed. In this assessment the product of the instantaneous propulsive force with the velocity as represented by a sine wave in and slightly out of phase with the force curve was performed. The sine wave representing velocity was such that the mean value was equal to the mean velocity obtained in the free swim with an amplitude of the curve equal to approximately 7% of the mean velocity. When the sine wave was more out of phase with the force curve, the difference between the original computed value of power derived from using mean values and that derived from the sine wave simulation was more divergent. However, even when the phase shift was as much as 10 deg out of phase with the force curve, the difference between the mean computed value for power and that derived from the sine curve simulation was less than one percentage point. This result indicated that mean values for propelling force and velocity could be used reliably in the computation of mean propelling power. The measurement of mean propulsive force required an extensive setup. The use of mean tethered force as an alternative would have made the task far less difficult. However, this project found that mean tethered force was not a reliable alternative indicator of mean propulsive force to be used in the derivation of mean propulsive power.

CONCLUSION: This study identified that both velocity and mean tethered force were related to some degree with mean active drag and hence mean propulsive force. However, the relationship between mean velocity and mean tethered force was also highly related. When the relationship between mean velocity and mean tethered force was removed from the tethered force variable, mean tethered force was identified not to be closely related to mean active drag and hence mean propulsive force. Therefore, mean tethered force was found not to be a suitable alternative to mean propulsive force in the computation of mean propelling power.

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