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A Method to Estimate Active Drag over a Range of Swimming Velocities which may be used to Evaluate the Stroke Mechanics of the Swimmer

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This research project aimed to estimate values of active drag over a range of swimming velocities. The data required to do this was the passive drag values for the swimmer at various swim velocities, together with the active drag force value for the individual at their maximum swim velocity. The drag force is represented by an exponential equation $F = a \cdot e^{(b \cdot V)}$, where a and b are constants for a particular swimmer. The constant a_p (passive) reflects the more innate characteristics of the individual swimmer and their suitability to aquatics motion. The constant a_{a-p} (active- passive) reflects the efficiency of the swimmer's technique. In both cases, the lower the constant's value, the better suited the swimmer is to aquatics motion or to technical efficiency. The a_{a-p} and the a_p provide an index to evaluate a swimmer's capabilities.

Keywords: Biomechanics, swimming, active drag, passive drag, stroke mechanics

INTRODUCTION

A swimmer's ability to swim faster is depended upon an increase of propulsive force, which exceeds the drag force presently acting on the swimmer's motion. However, active drag increases exponentially with a progressive increase in the swimmer's mean velocity. When the active drag and mean maximal propulsive force generated by the swimmer reach equilibrium, the swimmer attains their mean maximum swim velocity. However, at any constant swim velocity, mean active drag is equal in magnitude to the mean propulsive force exerted by the swimmer. Knowing the magnitude of the mean active drag opposing the forward motion provides information that may be used to evaluate the swimmer's mean propulsive force.

Initially it was thought that tethered swimming would provide a reasonable measure of the swimmer's propulsion. Researchers have discounted this theory (Mason et al, 2009a). The MAD system developed in the Netherlands provided a measure of active drag at different velocities (Toussaint et al, 2004). However, researchers have questioned whether the swimming actions using the MAD system represent swimming propulsive technique. The major challenge researchers faced was the ability to measure total propulsive force generated by the swimmer during the free swim phase. Therefore, methods were developed to estimate the swimmers' mean propulsive force. The Velocity Perturbation Method provided a value for active drag, however only at the swimmer's maximum velocity (Kolmogorov & Duplishcheva, 1992). Similarly, a method developed at the Australian Institute of Sport also identified the magnitude of active drag at maximum swim velocity (Formosa et al., 2009). Both these methods used to evaluate active drag were dependent upon the assumption that the swimmer applied equal power while swimming at their maximum velocity during the free swim and assisted/resisted conditions. Passive drag is measured at various velocities by towing the swimmer in a streamline position. Researchers have identified that the measurement of passive drag was highly correlated to that of active drag at the swimmer's maximum velocity (Mason et al, 2009b). This high relationship between active and passive drag justified the procedures used in this present research project. The aim of this study was to develop a method to estimate the active drag of the swimmer over a full range of swimming velocities. The method developed relied upon having mean passive drag measures of the swimmer over a range of velocities, as well as the mean active drag of the swimmer at the swimmer's maximum swim velocity.

METHODS

Eleven Australian (2 male; 9 female) national freestyle swimmers participated in the study. Seven were members of the Australian swimming team at the Beijing Olympics.

Each of the subjects completed all the tests required in a single individual testing session. The subjects were given sufficient rest between test trials so that fatigue would not be an issue. Firstly, subjects completed three maximum velocity trials over a 10 m interval, starting from 25 m out and the velocity was measured from 15 m to 5 m out from the wall. The velocity was determined using video cameras with a resolution of 0.02 s. The fastest trial was utilised to determine the subject's maximum swim velocity.

The equipment used in the active and passive drag testing consisted of a motorised towing device that could tow a swimmer over a range of constant velocities. The towing device was mounted on a Kistler force ™ platform which enabled the force required to tow the subject to be monitored. The eight component force signals from the force platform were captured by computer at a 500 Hz sampling rate. Only the Y component was utilized and was smoothed with a 5 Hz low pass digital filter. Four complete stroke cycles were captured for analysis and extra data on either side of these strokes was also collected to allow for smoothing. The velocity of the towing device was also monitored for accuracy with the video camera system.

In the passive drag testing the tow rope was attached to the swimmer by way of a loop through which the subject's fingers could grasp. Following passive drag familiarization, three passive drag trials were completed at the subject's constant maximum swim velocity and the mean tow force value from the three trials used. The subject was towed through the water ensuring a shallow laminar flow over the body. A series of passive drag trials was next completed over a range of 10 different tow velocities from 2.2 to 1.0 m·s -1. Only a single trial was completed for each velocity.

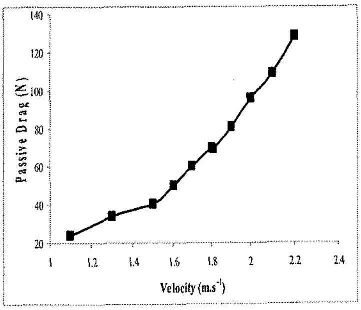
Finally, in the active drag testing the rope was attached to a belt around the swimmer's waist. The five active drag trials were completed at a five percent greater velocity than the swimmer's maximum swim velocity to ensure a force was always applied by the towing device. The swimmers were instructed to swim at maximum effort for each of the trials. The detailed equations used to determine active drag from the recorded towing force that represented active drag at the swimmer's maximum velocity are described in previous articles by the researchers (Formosa et al, 2009). The mean of the middle three values was used as the value for active drag.

RESULTS

The exponential function used to determine the passive drag equations was as indicated. $F = a \cdot e^{(b \cdot V)}$ where a and b are constants for a particular swimmer.

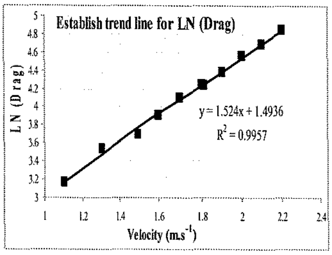
The first step to create the equation was to plot the curve for passive drag and obtain LN (logarithmic value to the base e) values for passive drag. The processes for subject 7 are displayed and illustrate the procedures used.

Tow Velocity ($m \cdot s^{-1}$)	Raw Passive drag (N)	Raw LN (Passive Drag)
2.2	128.43	4.855
2.1	108.79	4.689
2	95.88	4.563
1.9	80.64	4.390
1.81	69	4.234
1.8	69.95	4.248
1.7	60.22	4.098
1.6	50.1	3.914
1.5	40.5	3.701
1.3	34.29	3.535
1.1	23.88	3.173



The next stage in the process was to find a linear trend line for the graph of LN(drag) against time and the equation that represented that trend line. The smoothed passive drag values could then be computed as $EXP(1.524 \cdot Velocity + 1$

Tow Velocity ($m \cdot s^{-1}$)	Smoothed LN(Pass drag)	Smoothed Pass Drag (N)
2.2	4.85	127.28
2.1	4.69	109.29
2	4.54	93.84
1.9	4.39	80.58
1.8	4.25	70.25
1.8	4.24	69.19
1.7	4.08	59.41
1.6	3.93	51.01
1.5	3.78	43.80
1.3	3.47	32.29
1.1	3.17	23.81



The smoothed curve of passive drag against velocity was then able to be plotted and the exponential equation for passive drag determined.

$$F = a \cdot e^{(b \cdot V)}$$

$$a = EXP(1.4936) = 4.454$$

$$b = 1.524$$

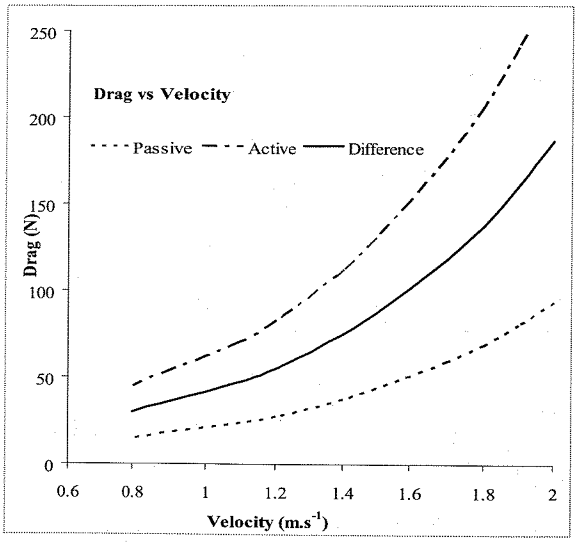
Tow Velocity ($m \cdot s^{-1}$)	Smoothed LN(Pass drag)	Smoothed Pass Drag (N)
2.2	4.85	127.28
2.1	4.69	109.29
2	4.54	93.84
1.9	4.39	80.58
1.8	4.25	70.25
1.8	4.24	69.19
1.7	4.08	59.41
1.6	3.93	51.01
1.5	3.78	43.80
1.3	3.47	32.29
1.1	3.17	23.81

Tow Vel ($m \cdot s^{-1}$)	Smoothed Passive Drag (N)
2.2	127.31
2.1	109.31
2	93.86
1.9	80.59
1.8	69.20
1.7	59.42
1.6	51.02
1.5	43.81
1.4	37.61
1.2	27.73
1.1	23.81
0.8	15.07

The variable for the active drag equation could then be computed through substitution knowing the one value for active drag at the swimmer's maximum swim velocity.

where 210 N = active drag at 1.81 m·s⁻¹

Velocity ($m{\cdot}s^{-1}$)	Passive (N)	Active (N)
2.2	127.31	380.49
2.1	109.31	326.71
2	93.86	280.53
1.9	80.59	240.87
1.8	69.20	206.82
1.7	59.42	177.59
1.6	51.02	152.49
1.5	43.81	130.93
1.4	37.61	112.42
1.2	27.73	82.89
1.1	23.81	71.17
0.8	15.07	45.05



where b used for active and passive drag

$$F = a \cdot e^{b}$$

$$a = F / e^{b} = 210 / e^{(1.524\times1.81)} = 13.31204$$

$$b = 1.524$$

Table 1: Characteristics of each swimmer, together with the constants used to derive the active and passive drag equations. a_a is the constant for active drag, a_p is the constant for passive drag and a_{a-p} is the constant for the difference between active and passive drag. b is a constant representing a swimmer's overall drag.

Subject	Gender	Event (m)	R^2Trend	a_p	b	a_a	a_{a-p}
1	M	200	0.9921	8.01	1.21	19.97	11.96
2	F	200	0.9702	3.91	1.59	18.68	14.78
3	F	200	0.9944	3.81	1.48	18.92	15.11
4	F	100	0.9831	5.21	1.29	22.97	17.77
5	F	100	0.9779	5.60	1.28	22.12	16.52
6	F	400	0.9718	5.99	1.29	14.63	8.64
7	M	200	0.9957	4.45	1.52	13.31	8.86
8	F	200	0.9859	4.84	1.45	11.42	6.59
9	F	100	0.9768	6.43	1.21	19.85	13.41
10	F	200	0.9819	4.91	1.36	24.57	19.67
11	F	200	0.9879	6.07	1.31	15.83	9.76

DISCUSSION

In both active and passive drag equations, the value of the drag force is represented as an exponential function of swimming velocity. The active drag values will however rise or increase more rapidly than that of passive drag. There will still be a similar exponential relationship between the two curves and only the increased rate of rise will differentiate between the active and passive drag equations. Given that the rate of rise between the active and passive drag equations is represented by a single constant, these two constants may be used as an index to describe the individual swimmer's capabilities. The constant in the equation for passive drag would represent an index of the swimmer's innate physical characteristics such as size, shape and cross sectional frontal surface area. A lower index indicates a more efficient body shape for aquatics movement. The difference between the constant used in the active drag equation and the constant in the passive drag equation could be used as an index to represent the efficiency of the swimmer technique. This index may provide insight as to the capability of the swimmer to compete in particular events.

Exponential functions for both active and passive drag were expressed by the equation $F = a \cdot e^{(b \cdot V)}$, where b was constant for a particular swimmer and a defined the active or passive drag constant. The a_a represented the constant used in the active drag equation, a_p represented the constant used in the passive drag equation and a_{a-p} represented the constant used for the difference between active and passive drag. The constant a was useful, in that a_p defined the unique aquatic characteristics of the individual. This research suggested that the lower the number, the more effective the individual characteristic was with respect to movement through water. The constant a_{a-p} provided valuable insight into the efficiency of the swimmer's technique. Once again, the lower the value of a_{a-p} the more efficient was the technique. For example, subject six was the Australian 400 m freestyle champion over a number of consecutive years. The data identified that subject six had a lower a_{a-p} value than all but one other subject. This highlighted that subject six had an efficient technique. Similarly, subject eight presented the lowest a_{a-p} value and she demonstrated excellent technical skills. Subject one had the highest a_p value and this indicated his anthropometric characteristics were not ideal for swimming. However, the a_{a-p} value demonstrated good technical efficiency in the swimmer. The examination of the a_{a-p} of swimmers at various times in the season may identify changes in technical efficiency.

CONCLUSION

The present study demonstrated the importance of being able to generate an equation to represent a swimmer's active drag over a range of velocities. This novel concept may provide insight as to the suitability of the individual to swim specific swimming events, as well as, indicate the efficiency of the swimmer's technique. This will provide valuable information to coaches and swimmers regarding the athlete's suitability to the sport, as well as provide an evaluation of improvement in technical efficiency.

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50m Race Components Times Analysis Based on a Regression Analysis Model Applied to Age-Group Swimmers

20 366

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This investigation aimed to develop a regression model of the Race Component evolution in a large sample of regional age-group Spanish swimmers. Subjects were 280 regional swimmers selected of different clubs. The time spent starting (ST), the time spent stroking (STT1 - STT2), the time spent turning (TT) and the time spent finishing (FT), were used for analysis. Inverse function approximation of the partials times by aging and was carried out. Furthermore, regression analysis of partials times and event time for age and genders were calculated, respectively. It seems that the times of the swimmers studied have a tendency to resemble internationals swimmer´s times. The estimation formula applied was different time according to gender. The crossing age in the swimming partials times were about 12-14 years old.

Key words: performance development, competition analysis, technique testing

INTRODUCTION

The dynamic process of training needs as much information as possible from competitive performance, which, together with information from training and testing, will help to the coach to monitor the training program.

Race components (RC) data must be considered when analysing swimming performances during international swimming competitions (see www.swim.ee). To improve the swimmer testing efficiency, this analysis has also to include the results of swimming tests made during a training season or several training seasons.

The RC is composed of the starting time (ST), stroking (STT), turning (TT) and finishing (FT) (Pai, Hay, & Wilson, 1984). Swimming training has to be oriented to improve all racing components, but the lack of a specific model makes it difficult to know which are the strongest and weakest race components of any individual. The coach must train the swimmer according to swimming time and age. The 50m freestyle performances should improve with age in each period of growth, in parallel with the RC.

Some studies have been published where regression equations were applied in the analysis of RC obtained from different competitions (Absaliamov & Timakovoy, 1990; Arellano et al., 1996; Nomura, 2006). The study aim was to develop a regression model of the RC evolution in a large sample of regional age-group Spanish swimmers.

METHODS

The sample was composed of 180 regional swimmers (162 males and 118 females). The age of these subjects ranged from 9 to 22 years.

The procedures that have been used to record the times obtained by swimmers during the performance test of 50 m freestyle were: a) references were put on the swimming pool at the distances selected (5, 10, 15 and 20 m) to know when the head crossed this line; b) the 50m trials were recorded by five video cameras connected to a mini DV video recorder through a video-timer and video selector; c) the images from the first two video cameras were mixed to see the over- and under- water phases of the start in the same frame (until 5m); d) third and fourth cameras were used to measure the 10 and 15 m time; the fifth camera was placed at the end of the swimming pool for video recording the turning phase (20 and 25 m) and; e) all the images from the cameras