ACTIVE DRAG AT LOW SWIMMING VELOCITIES

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The purpose of this study was to measure active drag when swimming at velocities encountered in longer swimming events. An adaptation of the Kolmogorov and Duplishcheva (1992) technique is proposed, whereby steady state VO_2 is monitored to ensure an equal power output in the two different (free and semi-tethered) conditions. Active drag values calculated were 20±4.7N (mean±SD) for the six experienced male swimmers, at velocities of 1.1±0.1 m/s (mean±SD). These values are comparable with other values predicted for this velocity.

KEY WORDS: active drag, swimming, front crawl, VO_2.

INTRODUCTION: Active drag is the resistance on a swimmer whilst moving through the water. Drag is an important performance-determining factor in swimming (Touissant, 1992). Reducing the active drag would either reduce the propulsive force required to swim at a constant velocity, or enable the swimmer to move faster (Rushall et al., 1994). However, most investigations of active drag have focused upon swimmers swimming fast (Hollander et al., 1985;Nomura et al., 1994). This paper investigates swimming at velocities associated with triathlon swimming. Swimming at a different velocity implies a difference in the proportional drag from wave, form, and skin resistance (Vorontsov & Rumyantsev, 2000). The aim of this research was to measure active drag in a flume, based on the method of Kolmogorov and Duplishcheva (1992).

METHOD: Six experienced male swimmers participated in this experiment after providing informed consent as approved by the Ethics Committee of the University of Otago. A semi-tether system (figure 1) (eg: Magel, 1970) was used whereby through the use of pulleys and ropes, weights added to a basket would increase the pull backward on a belt worn by the swimmer. This would increase the resistance on the swimmer by a known amount. Correction was made for losses in the system due to friction in the pulleys and drag due to the water.

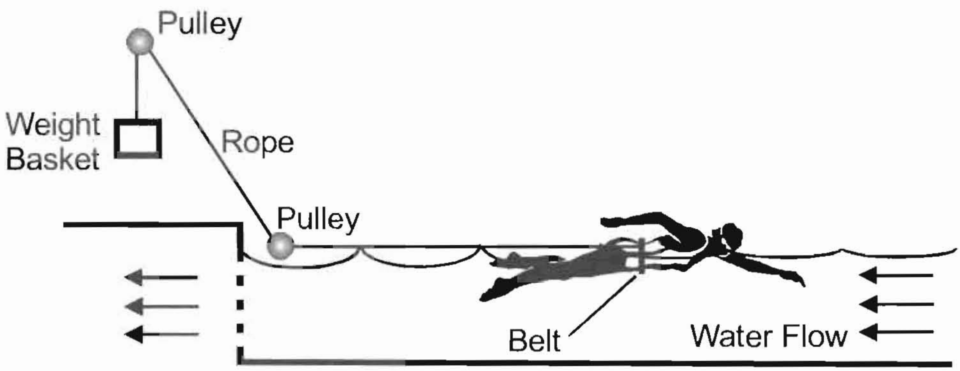

Figure 1. Semi-tether system in the University of Otago Swimming Flume, showing belt worn by subject, rope and pulley system, and weight basket. The swimmer is stationary relative to the semi-tether system; the water flows past the swimmer from right to left. Two ropes attach to the belt at the hips of the swimmer, and join at the weight basket.

There were three swimming conditions: swimming freely at a constant velocity (SV); swimming semi-tethered (with extra resistance) at a constant velocity, 10% slower than the free velocity (SST), and swimming freely at a constant velocity, 10% slower than the free velocity (SSV). All of the swims were for four minutes; the exhaled air from the final 80 seconds was analysed to ensure a steady state VO_2 measurement. Testing was completed in one session per swimmer. Following a familiarisation and warm-up swim, there were four swims: SV, SST, SV, SSV. SV was repeated to determine whether there was any fatigue effect. There was a 5-10 minute rest between the four swims. All swimmers were instructed to swim at the same power in each of the SV and SST conditions. This is an important assumption in this method of calculating active drag (Kolmogorov & Duplishcheva, 1992). The instruction to swim at the same power was emphasised in the initial subject briefing, and repeated and reinforced throughout the session. Instructions included emphasis on swimming at "the same power", or "the same effort". VO_2 was measured and compared to ensure that the same power was consumed and therefore produced (Touissant et al., 1990). Expired gas was collected with a respiratory valve (Touissant et al., 1987), and analysed with a Sensormedics Metabolic Cart model 2900Z BXB (Sensormedics Corporation, California, USA). The Sensormedics was calibrated with gases of known concentrations before each testing session. Any extra drag caused by the valve was neglected.

RESULTS AND DISCUSSION: Results of active drag measurement are shown in table 1.

Table 1. Subject Characteristics, Anthropometric Measures and active drag performance from the current study.

Subject	Age (years)	Height (m)	Top Velocity (m/s)	Active Drag (N)
ED	22	1.77	1.1	25
DA	29	1.84	1.1	23
PA	26	1.80	1.1	23
MA	20	1.85	1.3	21
SH	26	1.68	1.0	13
JO	24	1.72	1.0	16
MEAN	24.5	1.78	1.1	20
SD	3.2	0.07	0.1	4.7

The values from this experiment are compared to other calculated values in table 2.

Table 2. Predicted active drag values for 1.1m/s, and formulae for curve fitting from various experiments.

Research	1.1 m/s		$Drag_{Active}=Kv^a$			
			K		a	
	Mean	SD	Mean	SD	Mean	SD
Hollander et al., 1985	27	4.7	22	3.1	2.2	0.2
Nomura et al., 1994	36	4.9	28	3.3	2.5	0.2
Touissant et al., 1988	35	7.1	29	5.1	2.1	0.2
Current Experiment	20	4.7	-	-	-	-

Measurement of VO_2, in order to infer the same power output in both SV and SST conditions, showed a significant difference ($p<.01$) between SV and SSV, and between SST and SSV conditions. There was no significant difference ($p<.01$) between SV and SST, reinforcing the equal power assumption (table 3). There was a good correlation in the retesting of SV ($r=.767$, $p<.01$), implying that there was no fatigue effect.

Table 3. Mean and Standard Deviations of the three separate conditions in the measurement of active drag.

	VO_2 (ml/min)	
Condition	**Mean**	**SD**
SV	3059	352
SST	3166	384
SSV	2159	292

CONCLUSION: The results show that using steady state oxygen cost analysis to monitor power requirements is an appropriate method to validate the measurement of active drag at low intensities, where the assumptions of steady state exercise apply. This technique would be most pertinent in triathlon races, because the velocity of the swimmer is lower. A disadvantage of the Kolmogorov and Duplishchiva (1992) technique has been that it only gives one drag estimate at maximum swimming velocity (Touissant et al., 2000). The adaptation developed in this experiment overcomes this disadvantage by enabling measurement at different speeds.

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