# COMPARISON BETWEEN VELOCITY PROFILES OF THE ASSISTED TOWING METHOD AND FREE SWIM VELOCITY

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Active drag is computed based upon three variables: free swimming velocity, towing velocity and belt force. Mason et al. (2011) assumed that the shape of towing velocity profile was similar to the shape of free swim velocity profile. The aim of this study was to compare these two velocities profiles. Four national male swimmers performed two free swim trials using a velocity transducer and two assisted towing trials using the dynamometer. Relative maximum to minimum velocity of the mean value for free swimming trials and the towing trials was approximately 19% and 13% respectively. The different phases of the right arm stroke for both velocity profiles were compared and the result showed significant differences between all phases except the downsweep phase. It can be concluded that using the assisted towing method may change stroke mechanics.

**KEYWORDS:** Intra stroke velocity, velocity transducer, towing velocity, front crawl

**INTRODUCTION:** Active drag is the water resistance acting to oppose the swimmer while propelling the body forward (Mason et al., 2011). Therefore, elite swimmers must try to optimise propulsion force, while minimising the drag force. A number of measurement techniques have been developed to assess active drag directly (Clarys, 1979; Hollander et al., 1986) or estimate indirectly (Kolmogorov & Duplishcheva, 1992; Mason et al., 2011), however, there has been controversy, as the techniques used have often reported varying values.

Indirect techniques were designed to estimate active drag based upon three assumptions; the swimmer was able to generate a constant mechanical power output in both conditions (free swimming and swimming with additional drag force), the swimmer maintained a constant mean average velocity during each trial, and that drag was assumed to change in proportion to velocity squared (Kolmogorov & Duplishcheva, 1992; Mason et al., 2011). Mason et al. (2011) determined the value of active drag by towing a swimmer at 5% greater than the mean maximum swim velocity. This Assisted Tow Method (ATM) was designed to allow swimmers to have the natural fluctuations that occur and enabled them to maintain their normal stroke technique whilst being towed.

The advantage of the ATM method with the fluctuating velocity is that it allows the active drag and the towing velocity to be displayed graphically and plotted against time instead of providing only a single mean values (Kolmogorov & Duplishcheva, 1992). To determine the active drag during free swimming, Mason et al. (2011) assumed that the free swim velocity profile is approximately similar to the towing velocity profile, if the mean towing velocity only reduces 5% to 8%. However, no research has examined the relationship between the free swim velocity and the towing velocity, whether a similarity exists as proposed by previous research (Mason et al., 2011). The purpose of this research was to compare the towing velocity profile with the free swimming velocity profile.

**METHOD:** Four national level male swimmers (FINA point rank of over 700) participated in this research. Participants were required to complete all tests in one day starting with a 20 minute warm-up before performing at least one practice trial. Swimmers were then given 5 minutes rest between each trial to eliminate the influence of fatigue on their performance.

Each participant completed two free swim trials at maximum effort. To determine intra stroke velocity fluctuations, a velocity transducer device, developed and constructed at the Australian Institute of Sport was used, similar to the cable speed meter devised by Vilas-Boas et al. (2010). A belt was attached to the back of the swimmers' waist and a non-stretch cable attached to the belt by a reel. A small amount of force maintained a tension on the cable and prevented oscillations on the cable. Swimmers started from the wall and the velocity profile was recorded between the 7.5 m and 20 m locations down the pool. A trigger

was used to synchronise the video footage with the velocity data for identifying different phases of a stroke. Two side-on cameras were located on the pool deck to capture underwater video (Swim pro analogue camera) and above water video (Model 301 underwater video analogue camera, Applied Micro video, USA). Both cameras were mounted on a moveable trolley that travelled along beside the swimmer. Images were mixed with an Edirol video mixer (EDI-8V).
Participants were then requested to swim two trials at maximum effort whilst attached to a dynamometer mounted directly on a calibrated Kistler™ force platform (Kistler Instruments Type Z20916) via a belt around the swimmers' waist (Figure 1). Four complete stroke cycles were captured starting from 20 m out from the wall to capture active drag trials. The cable pulled the swimmers at approximately 5% to 8% higher than their free swim velocity with a maximum force level set low enough to allow intra-stroke velocity fluctuations to occur (Mason et al., 2011). The maximum force level was set between 25% to 50% of passive drag force and adjusted if assisted swim velocity was not between the range of 5% to 8% more than free swim velocity.

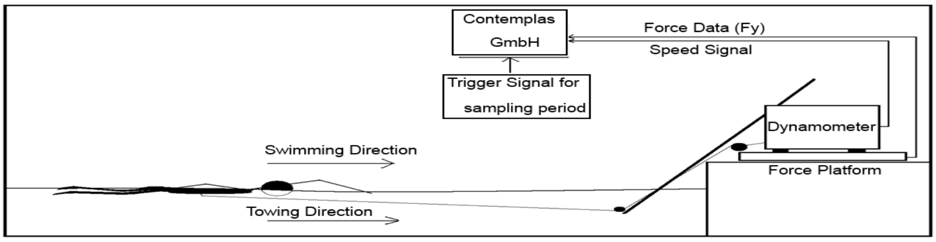


**Figure 1: Assisted Towing Method set up**

To analyse the velocity distribution within stroke cycle, five stroking phases were used as described by Maglischo (2003) including: entry and stretch, downsweep to catch, insweep, upsweep and recovery phase. The average of each phase of right arm was obtained from two right arm strokes. A Paired t-test was used to compare each phase of free swim velocity and each phase of towing velocity. SPSS software (Windows version 19) was used for statistical analyses and a statistical significance set at the 95% confidence level ($p<0.05$).

**RESULTS AND DISCUSSION:** The purpose of this study was to obtain the towing velocity profile from the ATM method. The velocity profiles obtained from the ATM method was compared with the free swimming velocity profiles obtained from the velocity transducer. Both the free swim velocity profile and the towing velocity profile of one of the subjects are presented in figure 2. Observation of the profiles indicated that the free swim velocity profile obtained from the velocity transducer was not identical to the tow velocity profile obtained using the dynamometer.
As expected, the mean tow velocity of swimmers was 5% to 8% greater (2.05±0.04 m/s) than that of the mean free swim velocity (1.92±0.02 m/s); however, there was greater variation between the maximum and the minimum velocities in each stroke for the free swim trial. Regardless of the swimmer's level, the relative maximum to minimum velocity of the free swim trials were approximately 19% of the mean free swim velocity and for the assisted towing trials were approximately 13% of the mean tow velocity. The dynamometer prevented the velocity of the swimmer from decreasing during the non-propulsive phase as much as in the free swimming (Figure 3). The dynamometer applies enough force to maintain velocity of the swimmer near to the target average velocity as set up on the dynamometer. Therefore, during the towing, if the instantaneous velocity of the swimmer decreases (recovery and hand entry phases) below the target average velocity, the dynamometer force automatically increases to prevent the velocity of swimmer dropping too far below the target velocity. On the other hand, if the instantaneous velocity of the swimmer increases above the target velocity then the dynamometer reduces the dynamometer force. Therefore, the swimmers did not swim too fast (Figure 2) and are able to maintain their normal stroke mechanics.
The result of this study in regards to the relative maximum to minimum velocity in free swimming was in line with Craig and Pendergast (1979) (20%) but not with Psycharisk et al.

(2010) (11%). The large differences between the results of previous studies are due to the different methodologies. Craig and Pendergast (1979) measured velocity of the hip using a speed cable. However, Psycharisk et al. (2010) measured velocity of the centre of mass calculated from film. The centre of mass method would be expected to have less variation because of the mutual movement of the arms.

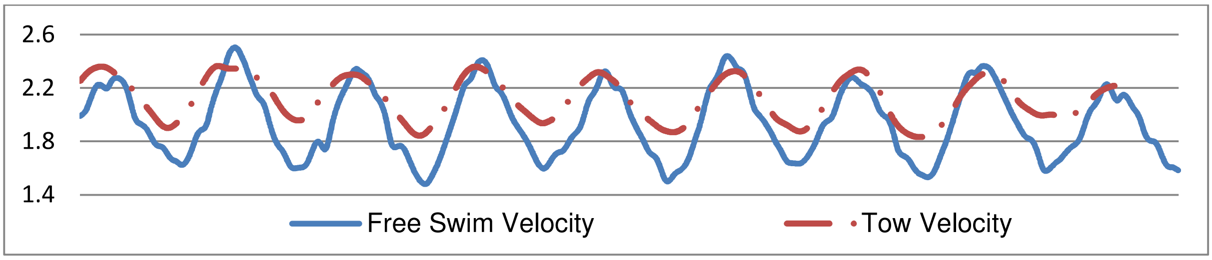


**Figure 2: Free swim velocity profile from the velocity transducer and the tow velocity profile using the dynamometer of subject 1**

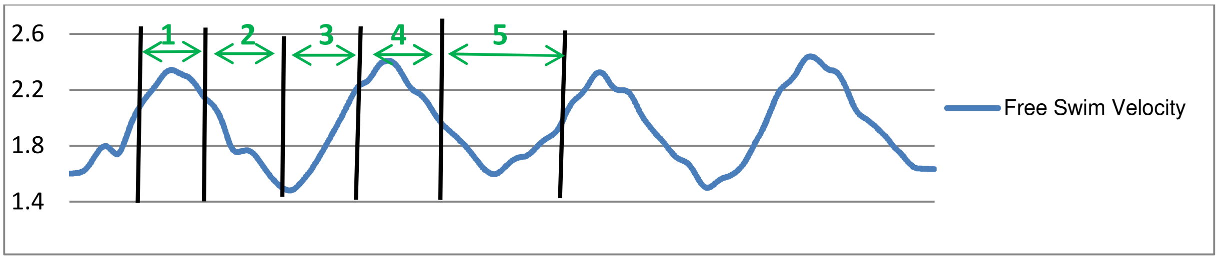


**Figure 3: Free swim velocity profile for subject 1. 1=right hand entry and stretch, 2=right hand downsweep and catch, 3=right hand insweep, 4=right hand upsweep, 5=right hand recovery (Maglischo, 2003)**

Mason et al. (2011) compared the velocity and active drag profiles obtained from the ATM method at a constant velocity with the velocity and active drag profiles obtained from the ATM method with fluctuating velocity. It was reported that the constant towing velocity profile had less variation from minimum to maximum velocities in the stroke, than the fluctuating towing velocity profile. Also, the constant towing velocity had a smoother shape than the fluctuating towing velocity. However, the result of this study indicated that the towing velocity graphs obtained from the dynamometer had a smoother shape than the free swim velocity graphs obtained from the velocity transducer (Figure 2). According to the results of Mason et al. (2011) and this study, it can be concluded that although the ATM method has a fluctuating velocity, these fluctuations are not as large as those that occur during free swimming.

**Table 1**
**The time spent on each phase, as a percentage of a single right hand stroke (mean ± s)**

| | E&SP | DS&CP | ISP | USP | RP | Propulsive | Non-propulsive |
|---|---|---|---|---|---|---|---|
| Free swim | 17.0±3.2* | 16.7±2.9 | 13.2±1.9* | 16.6±1.5* | 36.5±2.7* | 46.5±5.6 | 53.5±5.6 |
| Tow Trial | 23.8±5.7 | 16.7±1.5 | 11.8±2.4 | 15.3±2.1 | 33.7±1.5 | 43.8±6.4 | 57.5±6.0 |

E & S = Entry and Stretch Phase; DS & C P = Downsweep and Catch Phase; ISP = Insweep Phase; UPP = Upsweep Phase; RP = Recovery Phase; * = statistically different between free swim velocity and towing velocity at p<0.05 level

Table 1 presents the mean percentage value ± SD of the time spent by the subjects for each phase. Statistically significant differences were found between the insweep phases (p=0.031), the upsweep phases (p=0.039) and the recovery phases (p=0.037) of the free swimming velocity versus the towing velocity. The subjects spent shorter time during these

three phases for the towing trials than the free swimming trials. It is suggested that the swimmers encountered a smaller amount of resistive force by the water while towing, therefore increasing the swimming velocity and spending a shorter time during the insweep, upsweep and recovery phases.
Another significant difference was found between the entry and stretch phases of the towing trials versus the free swimming trials (p=0.046). The subjects spent a longer time during the entry and stretch phase in the towing trials than in the free swimming trials. It is likely that by spending more time during the entry and stretch phase while towing, the subjects attempted to maintain their arm coordination, as the other arm spent more time during the recovery phase. On the other hand, no significant differences were observed for the downsweep and catch phase between two trials (p=0.99). In summary, although significant differences were found for all phases except the downsweep, no significant differences were observed between the propulsive phases (p=0.19) and non-propulsive phase of the free swimming trials versus the towing trials (p=0.12). Therefore, it can be concluded that towing faster than their mean maximum velocity may change stroke mechanics.

**CONCLUSION:** This study measured the velocity profile of free swimming using the velocity transducer to evaluate whether the dynamometer measures a similar towing velocity to that of the free swim velocity. The result of this study indicated that the free swim velocity profiles had greater variations from the maximum to the minimum points during intra stroke (19% of the mean free swim velocity) than the towing velocity profiles (13% of the mean towing velocity). Also, the shape of towing velocity is smoother than the free swim velocity. Therefore, the result of this study showed that the towing velocity profile does not closely resemble that of the free swimming velocity profile. The assumption of a consistent velocity pattern between free and assisted swimming has not been demonstrated, therefore, further methods to obtain velocity fluctuations during the ATM towing should be considered.

**REFRENCES:**

Clarys, J.P. (1979). Human morphology and hydrodynamics. in: *Swimming III, International Series on Sport Sciences*. Baltimore: University of Park Press, 3–41.

Craig, A.B., & Pendergast, D.R., (1979). Relationships of stroke rate, distance per stroke, and velocity in competitive swimming. *Medicine and Science in Sports*, (11), 278–283.

Hollander, A. P., De Groot, G., Van Ingen Schenau, G. J., Toussaint, H. M., De Best, H., & Peeters, W., (1986). Measurement of active drag during front crawl arm stroke swimming. *Journal of Sports Sciences, (4)*, 21-30.

Kolmogorov, S. V., & Duplishcheva, O. A. (1992). Active drag, useful mechanical power output and hydrodynamic force coefficient in different swimming strokes at maximal velocity. *Journal of Biomechanics, 25*(3), 311-318.

Maglischo, E.W., (2003). Swimming fastest. Human Kinetics, Champaign, IL.

Mason, B., Sacilotto, G., & Menzies, T. (2011). Estimation of of active drag using an assisted tow of higher than max swim velocity that allows fluctuating velocity and varying tow force. Paper presented at the *29th International Society of Biomechanics in Sports*, Portugal, 327-330.

Psycharakis, S.G., Naemi, R., Connaboy, C., McCabe, C., & Sanders, R. H. (2010). Three-dimensional analysis of intracycle velocity fluctuations in frontcrwal swimming. *Scandinavian Journal of Medicine and Science Sports*, (20), 128-135.

Vilas-Boas, J.P., Costa, L., Fernandes, R.J., Ribeiro, J., Figueiredo, P., Marinho, D., Silva, A.J., Rouboa, A., & Machado, L. (2010). Determination of the drag coefficient during the first and second gliding positions of the breaststroke underwater stroke. *Journal of Applied Biomechanics,* (26), 324–331.



*Acknowledgement*

The authors would like to thank the support from the Aquatic Testing, Training and Research Unit at the Australian Institute of Sport for this research and also thank all subjects for participation (AIS squad swimming team and ACT Swim Clubs).