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INFLUENCE OF ALTERING BREATHING TECHNIQUES ON PASSIVE DRAG: A PRELIMINARY REPORT

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The purpose of this study was to examine if passive drag could be altered by adopting different breathing techniques; chest breathing technique and abdominal breathing technique. Six male subjects participated in this study. Each Subject was towed at a constant towing force in the glide position with inflating their chest or abdomen. The steady-state velocity was measured and the drag coefficients was calculated for each breathing technique. Results showed that the towing velocity was significantly greater with abdominal breathing technique than with chest breathing technique ($p<0.1$). The drag coefficients were significantly lower ($p<0.1$) with abdominal breathing technique (0.028±0.003) than with chest breathing technique (0.030±0.003). These results suggest that breathing technique affects the magnitude of passive drag.

KEY WORDS: swimming, abdominal breathing, glide position

INTRODUCTION: Maintaining an ideal glide position is one of the essential techniques for reducing the drag in swimming. The ideal glide position may be characterized by (a) the long-axis of all body segments being aligned along a straight line and (b) the long-axis of the entire body being directed horizontally. Recently, the body's ability to float horizontally in water was found to be altered by breathing techniques. Maruyama et al. (2012) reported that the leg-sinking moment of buoyant force around the center of mass of the body was reduced by adopting abdominal breathing technique (inhaling air by raising the abdominal wall, rather than by raising the rib cage [which defines chest breathing technique]). The abdominal breathing technique might, therefore, be the preferred technique over the chest breathing technique to reduce the drag by promoting the horizontal alignment of the entire body. The purpose of this study was to examine if the passive drag could be altered by adopting different breathing techniques; chest breathing technique and abdominal breathing technique.

METHODS: Six male subjects participated in this study. Before experiment, each subject underwent multiple practice sessions to learn (a) the breathing techniques to inhale air by inflating the specified body part (chest for chest breathing and abdomen for abdominal breathing) and to hold the air with the inflated configuration, and (b) a technique to maintain the lower back straight to configure a proper gliding position. Each practice session consisted of three practice trials in each of which the subject was asked to inhale air with the chest or abdominal breathing technique and to maintain the body configuration. An observer examined each practice trial carefully and evaluated if the specified body part was inflated correctly and if the lower back was maintained straight throughout the trial. Verbal feedback was given to the subject if he failed to execute proper techniques. Each practice session lasted for 30 minutes and repeated on the next day.

A specialized towing machine (Torrent E-Rack Electronic Swim Power Trainer, Hector Engineering Inc., USA) was used to tow the subject with a constant force (58.9N) and to record time-series data of towing velocity for the trial (Fig 1). Subject was towed along the length of 25m pool at 0.65m depth via the nylon rope and the harness wrapped around subject's shoulders. Only in the first 5m of the towing distance, the subject was allowed to adjust the depth through which the body was moving and, after the 5m point the subject was asked to maintain the extended arms beside the trunk with ribcage or abdominal wall being raised. A gas meter (NDS-2A-T, Shinagawa Co, Japan) was used to measure the volume of

air that the subject had to inhale, so that the buoyant force and the gravitational force acting on the subject were perfectly balanced.
A portable panning periscope system (Yanai et al. 1996) was mounted on the side wall 15m away from the start point and used to monitor the body movements and posture during each towing trial. A successful trial was defined as follows; (a) the subject didn't create any noticeable waves during the towing trial, (b) the subject moved straight through water at depth between 0.3m and 0.8m from the water surface, (c) the subject maintained the low back straight, and (d) the specified body part was properly raised for the given breathing technique. The observer examined the posture of the towed subject on the video images to evaluate if the given trial was successful. The trial was repeated until three successful trials were recorded for each subject.

The steady-state velocity was determined for each trial as the average towing velocity over 3 seconds over which the towing velocity was near constant. The drag coefficient for each trial was determined from the following drag equation:

$$C_d = \frac{2F_D}{\rho A V^2} \qquad (1)$$

where C_d was the drag coefficient, F_D was the magnitude of towing force, ρ was the density of water, A was the surface area of body, which was estimated from the subject's mass and height, V was the steady-state velocity of the trial.
Two-sample t-tests with repeated measures were used to test the influence of the breathing technique to the steady-state velocity and the drag coefficient. The p value of 0.1 was chosen as the level of statistical significance. For each subject, the coefficient of variance across the three trials for the towing velocity and drag coefficient were calculated to represent the repeatability of measurements. The summarized data were presented as the mean and standard deviation of each variable across all subjects.

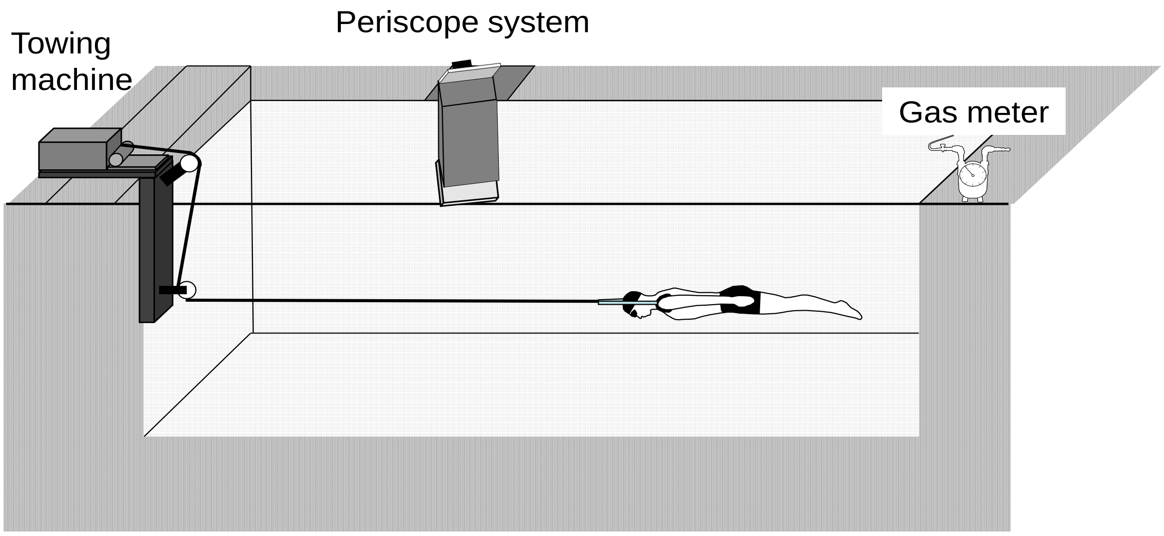

Fig. 1 Experimetal set up of towing measurement

RESULTS: The steady-state velocity was 1.48 ± 0.08 m/s for chest breathing technique and 1.53 ± 0.09 m/s for abdominal breathing technique. The drag coefficient was 0.030 ± 0.002 for chest breathing technique and 0.028 ± 0.002 for abdominal breathing technique (Fig 2). Two-sample t-tests revealed that the difference in the mean value between the breathing techniques was statistically significant for both steady-state velocity and drag coefficient ($p<0.1$). The repeatability test revealed that the coefficients of variance of steady-state velocity were 1.7 % for chest breathing technique and 2.0 % for abdominal breathing technique.

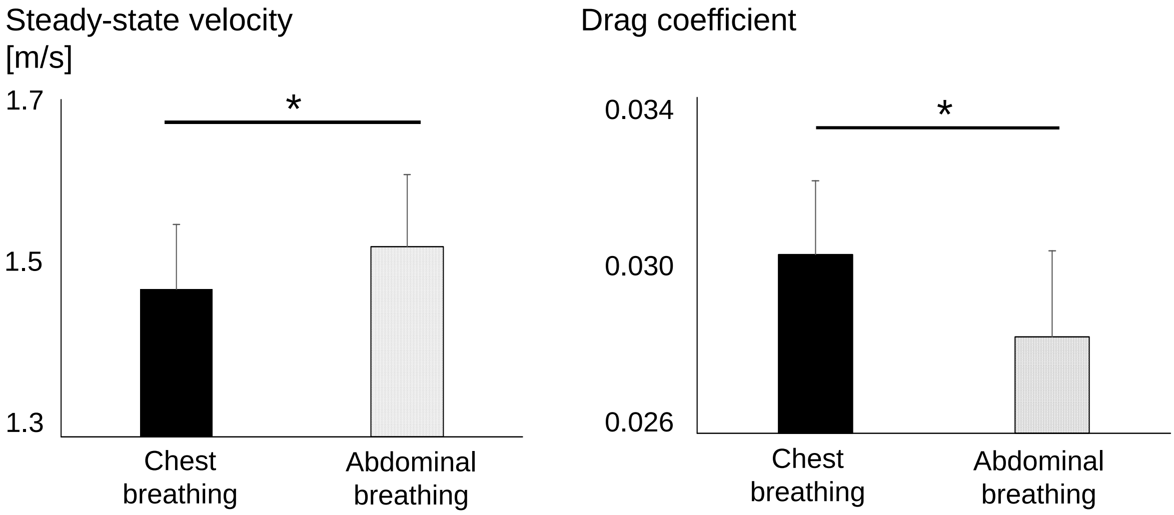

Fig. 2 Steady-state velocitiy and drag coefficient for the chest and abdominal breathing techniques. The * indicates significant difference between the breathing techniques ($p<0.1$).

DISCUSSION: This study was conducted to examine if the passive drag could be altered by adopting different breathing techniques; chest breathing technique and abdominal breathing technique. The steady-state velocity for a given towing force was higher with abdominal breathing technique than chest breathing technique, and the drag coefficient was smaller with abdominal breathing technique. These results suggest that the breathing technique adopted by a swimmer could influence the magnitude of passive drag that would act on the swimmer. One reason for the magnitude of the passive drag being decreased with the abdominal breathing technique may be that the buoyant force acting on the subject's body generated a smaller magnitude of leg-sinking moment (Maruyama et al. 2012) and the body was able to maintain a well-aligned horizontal glide position. The external forces that could generate the moment around the center of mass of a body consist of the buoyant force, the hydrodynamic forces and the towing force. During the towing experiments during which the towed subject maintained all body segments on a same straight line and moved at a constant velocity, the towing force and the resultant hydrodynamic force acting on the subject had to form a couple that counterbalanced against the leg-sinking moment of the buoyant force. The magnitude of the couple moment is determined by the perpendicular distance between the two forces (moment arm) which, in turn, is determined by the inclination angle of the entire body's long-axis. Thus, the less moment about the center of mass the buoyant force generates, the less magnitude of couple moment needed and the swimmer was able to align the body's long-axis horizontally to reduce the drag coefficient.

Another reason for the difference in the magnitude of the passive drag may be the difference in the shape of the trunk segment. The anterior-posterior thickness of the trunk measured along the length (Fig. 3) illustrates reduced depths of concavity and convexity along the length of the trunk segment with the abdominal breathing technique, indicating that the trunk segment was configured in a better streamlined shape with the abdominal

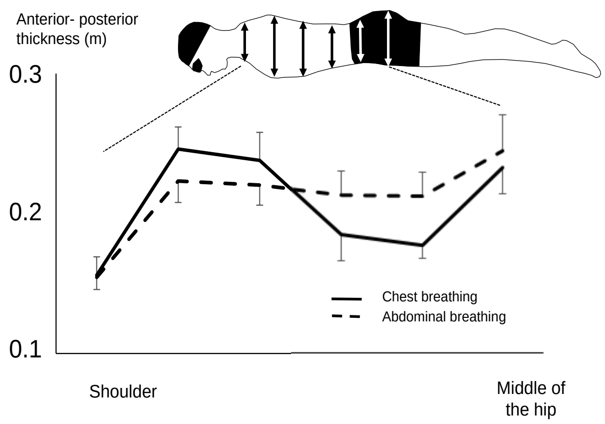

Fig. 3 Anterior-posterior thicness of both

breathing technique. With this better streamlined shape, the separation point of water flow might be shifted caudally and the magnitude of drag might be reduced consequently.

The abdominal breathing technique reduced the drag coefficient by 6.5%. This is similar to the amount reduced by wearing the fastskin suits. Chaterd and Wilson (2008) reported that the magnitude of passive drag was reduced by 4.7~6.2% when the subjects changed the swim suits from a conventional one to the fastskin suits. Thus, adopting the abdominal breathing technique is expected to have a considerable positive effect on swimming performance.

In this preliminary study, one magnitude of towing force was selected and the towing velocity was limited to 1.50 ± 0.08 m/s. The influence of altering the breathing technique at the higher or lower velocity could not be discussed. Further study is indicated to test the influence of adopting abdominal breathing technique at the wide range of towing velocity.

CONCLUSION: The adopting the abdominal breathing technique reduces the magnitude of passive drag by 6.5% when male subjects were towed approximately at 1.5 m/s of velocity.

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