Longitudinal Change in Passive Drag, Body Surface Area, and Drag Coefficient in Adolescent Female Swimmers

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Summary

The present study investigated longitudinal changes in passive drag (D_p), body surface area (*BSA*), and drag coefficient (C_d) in 23 female swimmers. While *BSA* increased annually, changes in D_p and C_d were less pronounced, suggesting complex interactions between growth and hydrodynamics.

Introduction

In swimming, D_p is the water resistance acting on the swimmer without an active movement (typically holding a streamlined position). D_p is primarily affected by the body size, shape, and technique of maintaining the low-resistance position. The purpose of the present study was to investigate how D_p, together with anthropometry, change over the adolescent period of female swimmers.

Methods

Twenty-three female swimmers were assessed annually over five years, starting at age 11. At baseline, participants had a height of 1.499 ± 0.078 m and a weight of 40.50 ± 6.26 kg. All testing sessions were conducted in a 25 m swimming pool (28 °C water temperature). D_p was obtained by towing each swimmer at 1.5 m/s over 20 m using a robotic resistance device (1080 Motion, Lidingö, Sweden), which recorded the towing force at 333 Hz. The participants were instructed to hold a streamlined position, without breathing, at the water surface. The towing trial was repeated three times each year. D_p was assumed to be the mean towing force in the middle 10 m of the trial, and the mean of the three trials was selected as a representative value of each year. The median value was used instead of the mean when there was a clear outlier among the three results. C_d was calculated as

$$C_d = \frac{2 \cdot D_p}{\rho \cdot BSA \cdot v^2}, \quad \text{(equation 1)}$$

where ρ is the water density at 28 °C (996.31 kg/m^3), and v is the towing velocity. *BSA* was estimated from height and weight using an established formula [1]. The effect of the testing year on D_p, *BSA*, and C_d was investigated using repeated measures ANOVA with multiple comparisons with Holm-Bonferroni correction using the Pingouin package in Python 3.1.2, with alpha = 0.05.

Results and Discussion

A significant year effect was observed for all three variables (F = 7.62, 211.42, and 4.87; partial η^2 = 0.09, 0.48, and 0.11 for D_p, *BSA*, and C_d, respectively. All $p \leq 0.001$). Multiple comparisons revealed a significant year-on-year increase in *BSA*. *Dp* was higher in years 4 and 5 compared to year 1, while C_d was lower in year 5 than in year 1.

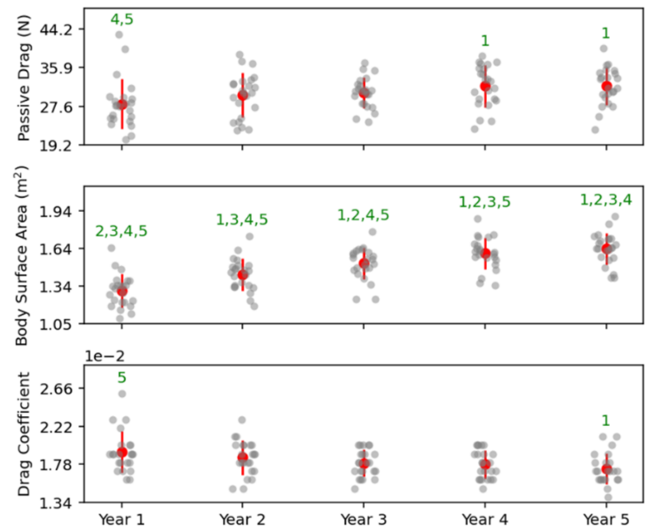

Figure 1: Raw data (grey dots) and mean ± SD (red dots and error bars) for the analysed variables. 1, 2, 3, 4, and 5 show significant differences from years 1, 2, 3, 4, and 5, respectively.

As presented in equation 1, D_p and *BSA* are supposed to have a directly proportional relationship ($D_p = 0.5 \cdot C_d \cdot \rho \cdot BSA \cdot v^2$), meaning that measured D_p and *BSA* should follow the same results when C_d is unchanged. However, this was not the case. These results suggest that, despite the change in D_p and C_d from 11 to 15 years old, the pathway of the change is broadly varied among swimmers. One possible explanation is changes in body composition, such as increased fat mass (and thus body density decrease) affecting buoyancy and body position. However, without direct body composition measurements and body position data, this remains speculative and warrants further investigation.

Conclusions

The findings of the present study suggest that while growth leads to an increase in body size (as evidenced by the increase in *BSA*), it does not necessarily result in a proportional increase in D_p. Practitioners should carefully consider not only the effects of the anthropometry or hydrodynamic efficiency (e.g. body position and streamlined posture) on the drag but also how these factors interact alongside the growth.

References

[1] Gehan and George (1970). *Cancer Chemother Rep*, **54**: 225-235