The Balance Between Thrust and Drag Forces in Swimming: Sex Differences Across Four Techniques

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Summary

In line with Newton's third law, the opposing force acting on a swimmer must be equal to the thrust force (F_t) generated. While this force balance has been demonstrated in front crawl, it remains unverified across all swimming techniques. This study aimed to experimentally confirm whether the balance of forces exists in all four techniques and whether it remains consistent between males and females. Twenty-three swimmers (11 males, 12 females) performed full-tethered trials to measure F_t and semi-tethered trials to estimate active drag force (F_d). Repeated-measures ANOVAs revealed no significant interaction between force and technique (p = 0.276), confirming that F_t equals F_d across all techniques. Additionally, when sex differences were considered (p = 0.394), the balance between F_t and F_d remained consistent, although absolute force values were higher in males. These findings support the theoretical equilibrium between thrust and drag forces in swimming, independent of technique and sex.

Introduction

According to third Newton's law, the only opposing force acting on the swimmer is drag and it must be equal to the thrust force generated [1]. Thrust force (F_t) is measured in various direct and indirect ways, with full-tethered measurement being highly correlated with performance [2]. On the other hand, the residual thrust methods for measuring the swimmer's active drag force (F_d) seem consistent [3]. However, this force balance has been demonstrated only in front-crawl [4], the aim of this study is to experimentally verify whether the balance of forces exists across all the four swimming techniques and if it is consistent between males and females.

Methods

Twenty-three swimmers (11 male, 12 female, 590 and 575 WA points respectively) performed full-tethered trials consisting of 8 stroke cycles to measure F_t, which was calculated as the average force of the central 6 stroke cycles. Based on data from four semi-tethered trials (8 cycles each) at 20%, 40%, 60%, and 80% of individual F_t, speed-specific active drag (k_a) was computed [3]. Thus, F_d was estimated using drag equation ($F_d = k_a \cdot v_{max}^2$) where v_{max} represents maximal velocity in free-swimming. F_t and F_d protocols were repeated randomly across the four swimming techniques (front-crawl, backstroke, breaststroke, butterfly). Repeated-measures ANOVAs were conducted to examine differences in force (F_t and F_d) and technique, with sex considered as a between-subjects factor.

Results and Discussion

No ANOVA interaction between force and technique (p = 0.276) reveals that F_t is equal to F_d in all four techniques. When sex differences are considered (interaction between force, technique, and sex), the balance between F_t and F_d is confirmed by the absence of significant differences (p = 0.394). Additionally, the forces generated by and on the swimmer are higher in male than in female, but consistent across technique (see Figure 1).

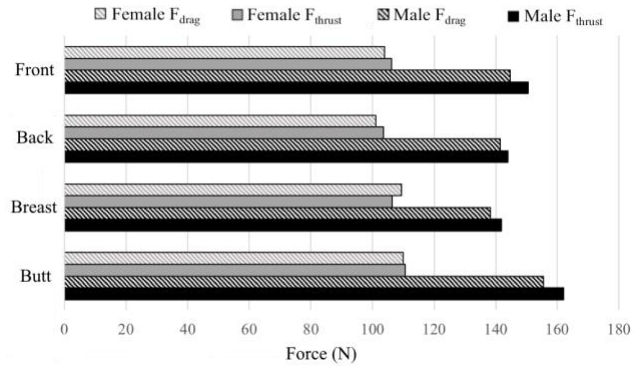

Figure 1: Ft and Fd for each swimming technique and sex.

Conclusions

Theoretically, the force opposing the swimmer is equal to the force propelling them forward. In this study, we experimentally confirm this hypothesis across all swimming techniques. This balance between thrust and drag forces remains consistent considering for sex differences also.

References

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