How Swimming Pace Affects Whole-Body Kinematics in Front-Crawl

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Summary

Swimming efficiency is lower than in land-based sports due to kinetic energy dissipation in water. Kinematic analysis is crucial for technical optimization. While studies have identified differences in hand trajectories and hip/shoulder roll between front-crawl sprinters and endurance swimmers, individual variations with increasing pace remain unexplored. This study examines whole-body kinematics across different paces using an underwater motion capture system. Six swimmers performed 25 m front-crawl trials at 80%, 90%, and 100% of their maximum speed, with movements recorded at 100 Hz. Results showed decreasing hand displacement correlations with increasing pace, alongside a larger bias. Hand velocity varied significantly despite the high correlations, while shoulder and hip roll remained highly associated across all conditions. Knee angles showed no significant differences. These findings confirm that increasing pace alters hand kinematics in line with distance specialization, while body roll and knee angles remain steady.

Introduction

In swimming, performance efficiency is lower than in land-based sports due to kinetic energy dissipation in water [1]. Kinematic analysis is crucial for technical optimization. Front-crawl sprinters adjust hand trajectories and hip/shoulder roll amplitude compared to endurance swimmers [2]. These variations have been studied between groups but not at an individual level as pace increases. Previous research has examined kinematic changes in different conditions, such as free vs. resisted swimming [3], collecting data at various paces within the same subject but analyzing only the condition-based differences rather than progressive pace variations. This study investigates whole-body kinematics in front-crawl swimming at different paces using a motion capture system.

Methods

After a warm-up, six participants (M, 76 kg, 180 cm, 6 train/week, national level) performed 25 m front-crawl trials at 80% and 100% of their maximum speed, previously measured over a 10 m sprint. The protocol was repeated twice. Their movements were captured using 9 synchronized underwater cameras (Qualisys, Miqus, Sweden) at 100 Hz, calibrated to a 7 × 2.5 × 1.3 m volume, capturing at least one full stroke cycle per trial. Thirty-five reflective markers were attached to the swimmers for 3D reconstruction. Swimmers followed a pacing light and swam without breathing. Hand velocity, hand displacement, knee angle, shoulder roll, and hip roll were analyzed. The comparison of intensity conditions was examined using correlation analysis and *RMSD*, which are presented as mean values.

Results and Discussion

Hand displacement differences change as swimming pace increases (*RMSD* = 0.15 m), mainly due to variations in horizontal displacements (*RMSD* = 0.28 m), despite consistently high movement associations ($r = 0.74$). Similarly, hand velocities increased between paces (*RMSD* = 0.28 m/s) with high correlation (r mean = 0.56). In contrast, shoulder and hip roll maintain a similar pattern and magnitude as pace increases (*RMSD* = 15.4 and 14.0 deg; $r = 0.80$ and 0.82). No significant differences were observed in knee angles (*RMSD* = 7.8 deg; $r = 0.54$).

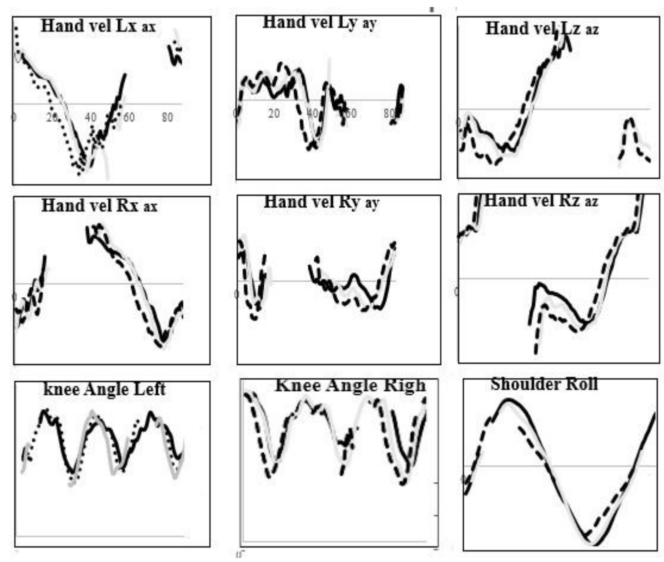

Figure 1: Results of a representative swimmer (solid 80$; grey 90%; dashed 100% in percentage of stroke cycle duration)

Conclusions

It is well known that hand and trunk techniques differ between sprint and endurance swimmers [3]. The results of this study confirm that, within the same swimmer, as the pace increases from endurance to a sprint pace, technique changes in the same direction of distance specialization. With increasing pace, swimmers reduce the magnitude of the hand displacement, optimizing hand velocity. In contrast, body roll and knee angles are not affected.

References

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