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Stroke regulation timing according to final performance during international open-water races : a race analysis using embedded sensors

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INTRODUCTION:
Race analysis of open-water swimming is of crucial interest to provide valuable feedbacks on performance that drive construction of further training plans or race strategies. Thus, some studies look at pacing during these events but were restricted to split time and rank [1, 2, 3, 4] or intermediate stroke rate (SR) [5]. Then, there is a need for continuous monitoring of biomechanical aspects during open-water swimming associated with performance, especially because timing of kinematical regulation along the race remain unclear. The aim of this study was to analyze cycle-to-cycle SR and jerk cost (JC) profiles and identify the dependency of biomechanical regulations timing on final performance during international open water races.
METHODS:
12 elite swimmers were analyzed during 18 races of two legs of LEN European open water cup including both a 10km, and a 5km race for one leg, with an Inertial Measurement Unit (Xsens DOT, The Netherlands) on the sacrum. Data were divided into 4 segments of 25% (S1 to S4) and swimmers were pooled on 3 balanced group according to final rank (G1 to G3). Cycle-to-cycle SR and JC were computed [6] and fitted using 3rd order polynomials to defined kinematical profiles. A two-way mixed ANOVA was used to compare SR and JC values using segments as within and group as between-subjects factor and Bonferroni post-hoc procedures for significant effects. Significance was set at $p<0.05$.
RESULTS:
Kinematical profiles displayed specific regulations as J-shape, U-shape and reverse L-shape for G1, G2 and G3 with significant effect of segment on SR and JC for G1 ($p<0.001$, $\eta^2=0.24$ and $p<0.05$, $\eta^2=0.15$) and G2 ($p<0.001$, $\eta^2=0.46$ and $p<0.01$, $\eta^2=0.02$). We highlighted two tipping-points (TP1 and TP2) at respectively 30% and 75% of the race related to final performance because they were greater in G1: ΔG1: -0.04 ; ΔG2: +0.10 g^2/s^2x10^3 for TP1 and ΔG1: +2.25 ; ΔG2: +0.87 cycles/min and ΔG1: +1.06 ; ΔG2: +0.13 g^2/s^2x10^3 for TP2.
CONCLUSION:
This work provided the first cycle-to-cycle monitoring of stroke parameters coming from in-situ data collection during full international open water events. We showed the importance of SR and JC control to support effective pacing leading to open water performance through two tipping-points. Such points led to a typical J-shape profile of best performers driven by milestones in stroke regulation. Then, TP1 reflected the end of a stroke economy period (0-30%) and TP2 the end of a progressive increase in kinematics (30-75%) towards end-spurt (75-100%). Results indicated that open water races followed high-grading dynamics requiring specific timing of biomechanical regulation. Best swimmers displayed a stroke rate reserve and a specific management of stroke smoothness to follow the both tipping-points respectively related to preserving energy and launching decisive end-spurt.
1. Rodríguez & Veiga (2018) 2. Veiga et al. (2019) 3. Saavedra et al. (2018) 4. Baldassarre et al. (2019) 5. Rodríguez et al. (2021) 6. Ganzevles et al. (2019)

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32937