A novel approach for swimming analysis in main swimming styles using a single sacrum-worn IMU sensor

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Introduction: Today, inertial measurement units (IMU) provide promising solutions for swimmers' motions analysis [1-3]. However, most studies focused on few parameters, often during strokes of front crawl style [4]. For swimming training session monitoring, there is a need for automatic detection of swimming and lap periods, styles and more details within each lap. This study proposes a general approach starting with macro-level analysis to detect swimming bouts, laps and styles, going to micro-level analysis related to specific phases of swimming. **Method**: 17 professional swimmers performed four 50-m trials in main swimming styles, i.e. front crawl (FC), backstroke (BaS), breaststroke (BrS) and butterfly (BF), in a 25-m indoor pool. Acceleration and angular velocity were recorded at 500Hz sampling rate with a single sacrum-worn waterproofed inertial sensor (Physilog® IV, Gait Up, CH). Five cameras (GoPro Hero 7 Black, GoPro Inc., US) were used for validation. In macro-analysis, swimming bouts were recognised from rest periods through sharp changes on sacrum inferior-superior acceleration and its derivative. Within each bout, peaks of sacrum anteroposterior (A/P) acceleration were used to mark turns for separating laps. FC and BaS styles were classified from the dominant angular velocity, identified by principal component analysis (PCA) and gravity direction. Frequency analysis of A/P acceleration was used for differentiating between BrS and BF. In micro-level analysis, based on peak detection, zero-crossing, thresholding and PCA different swimming phases were detected as: wall push-off, glide, strokes preparation, strokes and turn. **Results:** Swimming bouts were detected with 97.5% accuracy, 99.4% sensitivity and 99.8% precision. All turns have been detected correctly. FC and BaS styles were identified with no error, while the accuracy, sensitivity and precision reached respectively 97.2%, 97.2% and 97.9% for BrS, and 97.9%, 97.9% and 97.2% for BF. Finally, errors (in ms) for the onset of each phase were: -20 ± 89 (wall push-off), 5 ± 100 (glide), -31 ± 105 (strokes preparation), 28 ± 205 (strokes), 24 ± 97 (turn), -2 ± 65 (next wall push-off). **Discussion**: By automatic assessment of swimming and rest bouts, laps number and duration, swimming styles as well as swimming phases within each lap using a single sacrum-worn IMU, this study offers coaches and swimmers an easy to use tool for monitoring swimming training sessions. Compared to other studies [5-6], style identification reached better accuracy. While the performance of the system for phase detection is acceptable, it can be improved by adding IMU sensors to other body locations.

References

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