Movement Variability and Smoothness Measures may Support Coordination Assessment for Para Swimming Classification

Yu-Hsien Lee[1], Dawn N. O'Dowd[1], Emma Hodson-Tole[1,2], Adrian Burden[1], Tomohiro Gonjo[3] and Carl J. Payton[1]
[1] Manchester Metropolitan University Institute of Sport, Dept. Sport and Exercise Sciences, Manchester, UK
[2] Department of Life Sciences, Manchester Metropolitan University, Manchester, UK
[3] Heriot-Watt University, School of Energy, Geoscience, Infrastructure and Society, Institute for Life and Earth Sciences, UK
Email: yu-hsien.lee@stu.mmu.ac.uk

Summary

Classifying swimmers with central motor and neuromuscular impairments (CMNI) for competition is problematic because reliable, ratio-scaled measures of CMNI severity are not employed in the current system. This study established neuromuscular differences between CMNI (n = 6) and control swimmers (n = 6) using surface electromyography (sEMG) and accelerometry during an upper-limb tapping task. CMNI produced more inconsistent and non-smooth sEMG and acceleration profiles evidencing that a more objective classification of CMNI swimmers should include measures of movement variability and smoothness.

Introduction

Ensuring fair competition in Para swimming requires accurate classification of athletes yet the current classification system lacks scientific rigour and objective measures [1] often disadvantaging certain impairment types. CMNI swimmers, such as those with cerebral palsy, face unique motor coordination challenges despite having all limbs intact. Our team is validating standardised, objective, ratio-scaled tests of coordination which measure speed and accuracy of hand and foot tapping between pads [2,3]. This study quantifies the movement variability and smoothness in these tests.

Methods

Six highly trained Para swimmers with CMNI (cerebral palsy hemiplegia [*n* = 3], cerebral palsy tetraplegia [*n* = 1], and traumatic brain injury [*n* = 2]) and six control (CTRL) swimmers (three non-disabled and three Para swimmers without CMNI) participated. sEMG and acceleration data were collected from the most affected (CMNI) or dominant (CTRL) upper limb during three maximum-effort 15-second tapping tasks using a 10 cm target width on pads with a 19.5 cm inter-pad distance. Wavelet analysis resolved the total intensity of myoelectric signals in time and frequency domains [4]. Data were segmented into individual tapping cycles then within- and between-trial variability of wrist acceleration and sEMG intensity were assessed using variance ratio (VR). Within-trial movement smoothness was calculated using a relative frequency threshold from Fourier analysis, representing the frequency capturing 95% of the acceleration signal, with lower values indicating smoother tapping movements.

Results and Discussion

CMNI swimmers exhibited greater within-trial movement variability in acceleration (CMNI VR: 0.66 ± 0.23; CTRL VR: 0.29 ± 0.10, $p < .01$; Figure 1) and sEMG intensity (CMNI VR: 0.89 ± 0.03; CTRL VR: 0.64 ± 0.05, $p < .001$; Figure 1) than CTRL swimmers; between-trial movement variability did not differ between the groups. Movement smoothness was also greater (jerkier tapping) in CMNI than CTRL swimmers (CMNI: 12.4 ± 0.9; CTRL: 8.6 ± 0.9, $p < .001$; Figure 2).

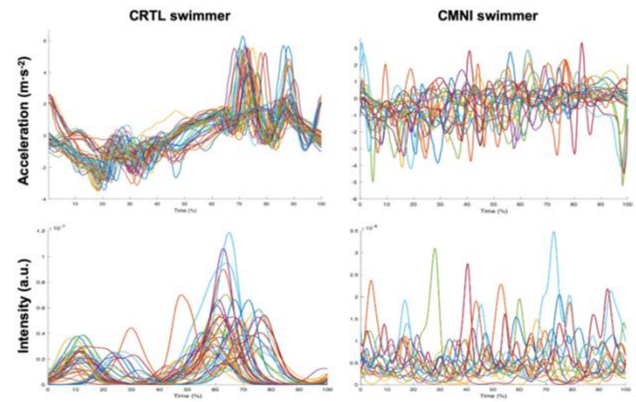

Figure 1: Exemplar acceleration x-axis signal (*top row*) and sEMG intensity of the anterior deltoid muscle (*bottom row*) of a CRTL swimmer (*left*) and a CMNI swimmer (*right*) during each tapping cycle within a single 15 s tapping task. Solid colored lines are individual tapping cycles.

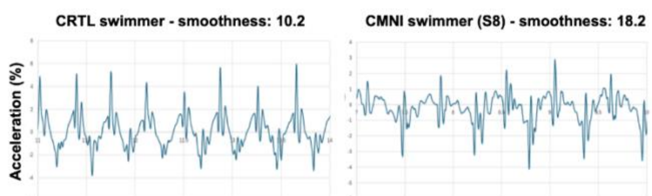

Figure 2: Exemplar acceleration traces (represents three seconds of tapping) for a CRTL swimmer (*left*) and a CMNI swimmer (*right*).

Conclusions

CMNI swimmers struggled to maintain consistent intensity and acceleration curves between tapping cycles. Within-trial movement variability and smoothness may be useful metrics for differentiating between swimmers with and without coordination impairment, thereby enhancing the objectivity and fairness of the classification process.

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