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Variations in expert rower coordination when rate increases on ergometer concept2®

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1. Introduction

Continuous relative phase (CRP) represents at each time a quantitative valuation of coordination between two body segments (Burgess-Limerick et al. 1993) or two joints (Scholz 1993). In 1998, Pudlo et al. (1998), via an adapted using of CRP, has shown up technical weakness of two French local rowers. In 2004, Découfour and Pudlo (2004) have computed CRP between elbow and knee for 11 French national level rowers. Authors' results are based on the best rower and show that is on recovery phase the coordination changes when stroke rate increases. Nevertheless, authors were not able to conclude objectively on the effect of stroke rate increase on the movement of expert rowers. The aim of this paper is to use these numerical data to conclude on coordination modifications when stroke rate increases in the light of results for the expert rowers population.

2. Methods

Nine national level rowers, five males and four females, rewarded or finalists at France championship, participated. After a warm up, rowers had to row with imposed stroke rates (cad18, 20, 24, 28, 32, 36, 40 strokes per minute) and that during 20 s on a concept2® Model C ergometer. For each rate, the eighteen reflectors, disposed on rower, are recorded with the three-dimensional motion analysis system VICON 612 (eight cameras, 120 Hz). The 3D positions measured were filtered with a 6 Hz low-pass second order zero lag Butterworth filter. Propulsive phase and recovery phase are delimited by extreme handle positions on antero-posterior axis.

Sphere fitting method is used to estimate functional hip joint centre and shoulder joint centre. Joint centres of knee, ankle, elbow and wrist are considered like the middle of articulations. At last, three flexion/extension joint angles were computed for elbow and knee and between trunk and vertical axis in sagittal plan. CRP computation is realised with the method of Hamill et al. (1999). Normalization of joint angles and angular velocities distributes data around '0'. Phase plans are then dressed with those two types of normalised data. CRP is the difference of the two flexion/extension phase angles. The sign of CRP permit to conclude on the advance or the late of a joint compared to another. A CRP equal to '0°' (modulo 360°) represents an 'in-phase' state. A CRP equal to '180°' (modulo 360°) represents an 'anti-phase' state. A constant value of the CRP represents a 'synchronisation'. CRP peaks and their dates of appearance are statistically analysed with an ANOVA followed by a Tukey Post-Hoc test.

3. Results

CRP presented are computed between right elbow joint and right knee joint ($CRP_{e/k}$), between trunk angle and right knee joint ($CRP_{t/k}$) and between trunk angle and right elbow joint ($CRP_{t/e}$). Figure 1 shows $CRP_{e/k}$, $CRP_{t/k}$ and $CRP_{t/e}$, on 100% of each phase of the rowing movement (propulsion and recovery). Arrows show significant modifications on CRP peaks.

- On propulsive phase, the $CRP_{e/k}$ peak is unchanged what the maintained rate is. The $CRP_{t/k}$ peak is modified insignificantly for all rowers, so, those two joints are in 'anti-phase'. They are also 'synchronous' because $CRP_{t/k}$ stays around $-180°$ with some oscillations during all the propulsive phase. The $CRP_{t/e}$ peak stays near 90° whatever the stroke rate.
- On recovery phase, the $CRP_{e/k}$ peak decreases significantly (-20 to $-160°$) and its date increases significantly (35–55%) when stroke rate increases. $CRP_{t/k}$ peak decreases significantly (-80 to $-135°$) and its date is not modified with stroke rate. The $CRP_{t/e}$ peak decrease significantly (-65 to $-10°$) and its date increase significantly (30–60%) when stroke rate increases.

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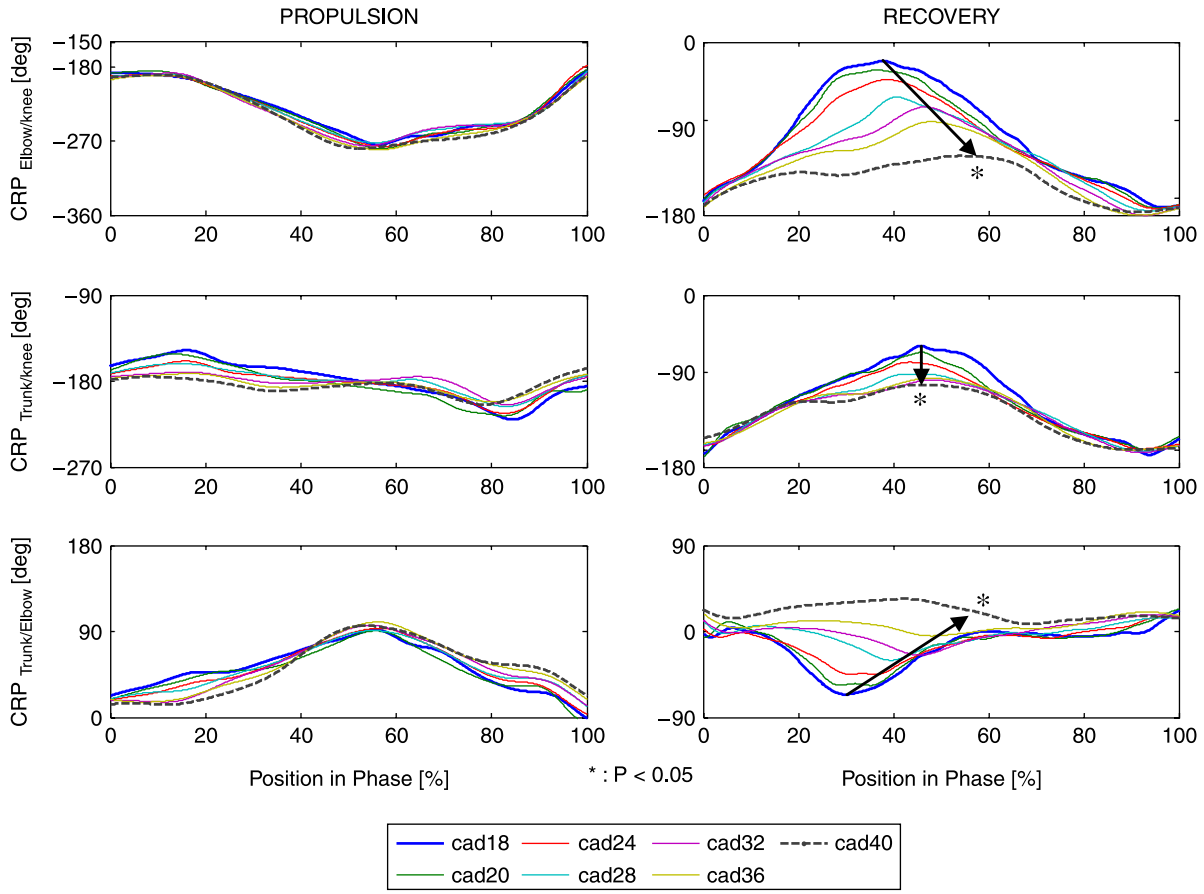

Figure 1. $CRP_{k/e}$, $CRP_{t/k}$, $CRP_{t/e}$ during propulsive and recovery phases. Significant changes on CRP peaks and date of appearance (arrows and ∗: $P < 0.05$). Available in colour online.

4. Discussion

Results show that expert rowers modify their coordination only on recovery phase and not on propulsive phase when they increase their stroke rate on a concept2® rowing ergometer.

On recovery phase, the $CRP_{e/k}$ peak tends towards ' − 180°' and so become more and more in an 'anti-phase' coordination. The $CRP_{e/k}$ peak date changes when stroke rate increases, so elbow and knee activation dates differ with stroke rate. The $CRP_{t/k}$ peak tends towards ' − 180°' but the peak always exists too. The $CRP_{t/k}$ peak date is insignificant changed with stroke rate, trunk and knee are out of phase but it appears in recovery phase at the same relative time. The organisation of both joints can be considered as unchanged in recovery phase, not like $CRP_{e/k}$. The $CRP_{t/e}$ peak tends towards '0°' and so trunk and elbow become more and more 'in-phase' with stroke rate increase. And as $CRP_{t/e}$ seems to be quasi constant, the two joints are quasi synchronous during recovery phase and are re-organised when stroke rate increases.

Our past results (Découfour and Pudlo 2004) cannot permit us to conclude on a population of expert but only on one. Here, our results confirm those past ones and give more information. Firstly, elbow, knee and trunk change their maximal inter-limb coordination when stroke rate increases on recovery phase. Secondly, when elbow is include in a CRP computation, the peak date changes with stroke rate. The elbow seems to be the joint differently organised with the other joints when rate increases.

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