

AMBULATORY 3D ANALYSES OF MOVEMENT IN ROWING

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INTRODUCTION

In rowing an oarsman depends on his/her technical skills, coordinative abilities, physical shape and motivation. Optimizing the technical skills and coordination of the rower is a key element for maximum power and endurance.

The rowing stroke has been frequently analyzed in two dimensions on an ergometer [e.g. 4]. To our knowledge so far no 3D methods were used in actual on water rowing. Newly developed real-time methodology for accurate ambulatory 3D analysis of human motion has been successfully applied in rehabilitation and ergonomics [1,2] and could possibly be applied for assisting rowing coaches in monitoring and coaching rowers coordination in vivo.

This paper examines the feasibility of this by testing whether relevant coachable coordinative issues cause recognisable kinematic data features that are larger than the smallest detectable differences found with proposed methodology.

METHODS

10 experienced (warmed up) male rowers each performed 1 or 2 (5 rowers) 20 minute rowing sessions on a RowPerfect dynamic row ergometer maintaining a minimum heart rate of 85% of HR_{max} with continuous visual heart rate feedback.

Continuous estimates were made of 3D body segment kinematics of 9 relevant body segments and 2 moving ergometer parts applying FreeMotion methodology [1,2]. This method comprises: real-time wireless recording of 3D angular velocity, linear acceleration and earth magnetic field vector of 1 inertial sensor module on each body segment (Xsens MTx, FreeMotion sensor suit), synchronized recording of 2 video streams, estimation of 3D sensor orientation in a world coordinate frame (Xsens SKF-4), translation of this data to body segment data applying a helical axes calibration procedure [1], translation of the data to a world coordinate frame aligned with the ergometer, estimating 3D joint kinematics combining data of adjacent body segments represented in the (more central) parent body segment and estimation of Euler angles both for body segments kinematics expressed in the ergometer world coordinate frame and for joint kinematics expressed in the parent segment. Also 3D angular accelerations, linear accelerations, velocities and displacements were estimated.

Stroke cycle extraction was followed by Spline interpolation to facilitate comparing and numerically analyzing stroke cycle parameter general behavior and adaptations over time. For all kinematic parameters 95% confidence intervals widths (CIW) and smallest detectable differences (SDD = $1.41 * CIW$) were estimated for individual stroke cycle trajectories, for average cycle trajectories of 1 minute of rowing (25 ± 1 cycles) and for rowing cycle parameters. Data were used from 4 evenly distributed periods of rowing.

RESULTS AND DISCUSSION

Typical SDD values (1 cycle vs average cycle) found were: $4.2^\circ; 21^\circ/s; 0.8^\circ; 4.2^\circ/s$ (trunk), $6.5^\circ; 20^\circ/s; 1.3^\circ; 4.0^\circ/s$ (legs). Calibration uncertainties in T were found to be $\pm 3^\circ$

$\pm 4^\circ$ (trunk/legs). In all 4 sections no significant differences were found between both sessions for 5 rowers.

Typical relevant coachable behavior in timing of knee and trunk stretching creates clearly identifiable features in kinematics plots much larger than found SDDs. This feature was found in all rowers (duration: 28%-58% cycle duration). Although this paper reports data in 2D it is the underlying 3D methodology that facilitates the found levels of accuracy and reproducibility. In actual rowing on water also 3D data will be of direct interest, examining asymmetric pattern of handling the oars, instabilities in 3D and the presence of other rowers. Future integration with 6-DOF force recording methods [2] promises detailed kinetic analysis.

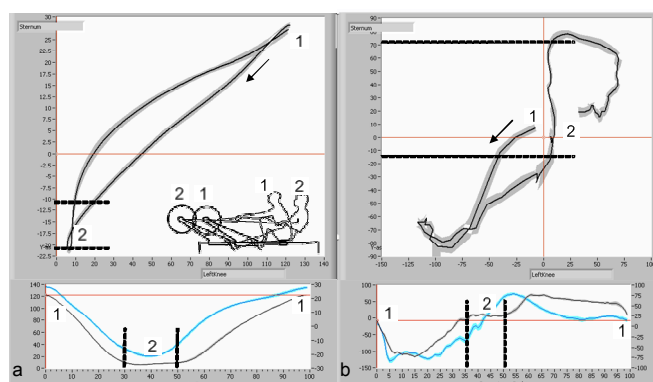
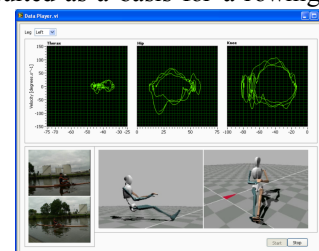


Figure 1: Typical thorax inclination vs. knee flexion data (Left plots: angles, right plots: angular velocities; top plots: thorax inclination vs. knee flexion; bottom: both plotted against % rowing cycle). All averaged over 1 minute of rowing. Grey/light blue bars indicate 95% confidence intervals of the mean (CIWm). Note the typical delay between the finish of the knee drive and back drive (plot sections between dashed lines). (SDD values are $1.4 * CIW$).

CONCLUSIONS

Kinematic pattern features related to typical coachable coordination patterns were found with magnitudes much larger than the smallest detectable difference values found.

As all estimates can be visualized in real-time and the method has already been tested successfully with 17 sensors in a skiff on water, it seems suited as a basis for a rowing coach assisting tool. This is currently examined together with members of the Dutch rowing community. Also application in other (non-)cyclical sports and activities (in rehabilitation/ergonomics are studied [2]).



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