Amplitude and power of body segments

With ***BioRow™*** system, the movements of the seat and the top of the trunk could be measured with string transducers in singles, doubles and pairs (the seat only is measured in big boats). For the trunk measurements, the sensor is mounted on a mast (Fig.1) and a string is connected to the trunk at the level of clavicle-sternum joint (between C7-T1 vertebrae), so it measures the spine movement, but not shoulders. Therefore, the shoulders movement were included in arms, but we will call it simply "arms" for conciseness.

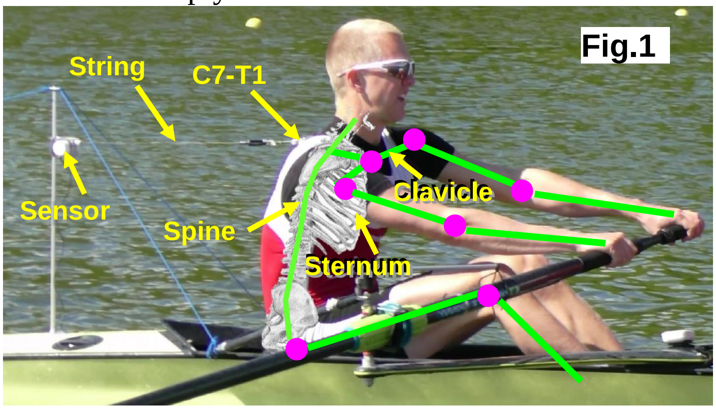

Fig.1

The legs amplitude and velocity V_{legs} was assumed to be equal to the seat movement. Trunk velocity V_{trunk} was derived as the difference between the top of the trunk V_{tt} and seat velocities. "Arms" velocity V_{arms} was derived as the difference between handle velocity V_h and V_{tt}. The handle velocity V_h was derived from oar angular velocity ω and actual inboard L_{inA}:

$$V_h = \omega L_{inA} \qquad (1)$$

The actual inboard L_{inA} was derived as normally measured inboard plus a half of the gate width (+2cm) and minus a half of the handle length (-6cm in sculling and -15cm in rowing), which makes the stroke length similar in sculling and rowing: e.g., angular amplitude 110° at inboard 88cm (L_{inA}=0.84m) in sculling and 90° at 115cm (L_{inA}=1.02m) in rowing gives a similar 1.61m arc length. Therefore, amplitudes and velocities of the handle and body segments movements were comparable in sculling and rowing.

All three body segments contribute nearly equally to the stroke length, about one third each (RBN 2002/02, new data is here, n=5437): legs 33%, trunk 31% and arms 36%. However, the most of legs and trunk movements occur during the first two thirds of the drive, when forces are high, but arms work mainly at the finish, at low forces (Fig.2). Therefore, the average shares of total power production were higher for legs (43%) and trunk (33%), but lower for arms (24%). This depends on rowing style and shape of the force curve (RBN 2006/04): consequent segments activation and front-loaded drive increases legs share; simultaneous style and late peak force increases arms (with shoulders) share. The first style is more effective, as it was proved that bigger muscles of legs and trunk are more efficient and powerful. Therefore, **the segments power of the World best rowers have higher trunk share and less arms: legs 43%, trunk 36%, arms 21%.**

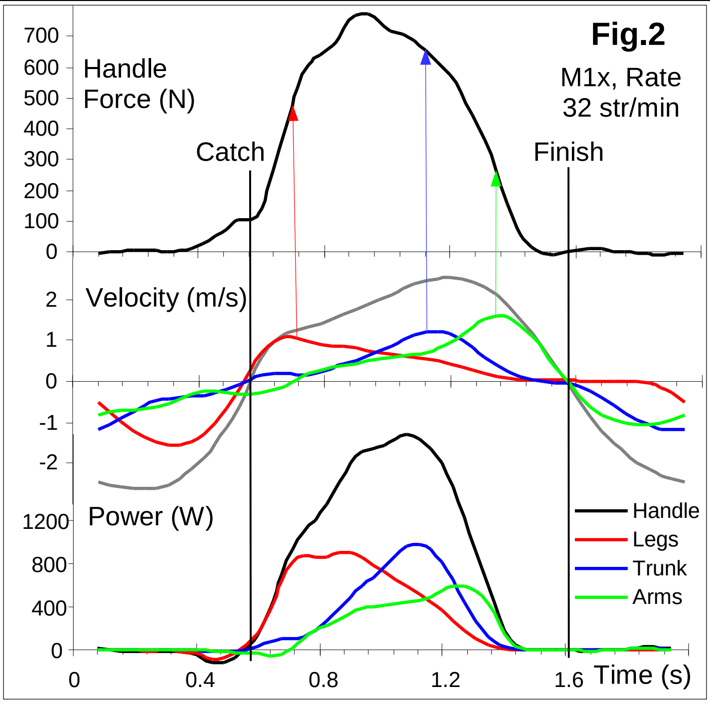

Fig.2

How these instrumented measurements are related to joints angles, which could be analysed with video? Using video footage of the 25 best rowers in small boats during the last World Championship-2014 in Amsterdam, we have analysed the trunk angles relative to the vertical axis at the catch α_1 and finish α_2 (Fig.3).

Fig.3

It was found that the average trunk angle at the catch α_1 was 22.5° (±4.6, min 12°, max 31°) and α_2 at finish was 25° (±6.2, min 8°, max 35°), so the total angular displacement of the trunk was on average 47.5° (±6.5, min 32°, max 60°). Assuming length of the trunk from hips to shoulders (C7-T1) about 0.6m, it gives us 0.50m linear displacement at the top of the trunk, which corresponds to about one third of the average stroke length 1.52m measured with telemetry, so a good agreement of two methods was found.

Longer amplitude of the trunk movement allows better utilisation of gluts and hamstrings – the two biggest and strongest muscle groups, which helps to increase power production. However, it creates significant movement of the heavy trunk mass, increases inertial losses and vertical oscillations of the boat (RBN 2013/10), so and drag resistance. Therefore, **the trunk amplitude must be optimal. The average numbers of the World best rowers (±25° from the vertical) could be a good guidance**.

Acknowledgments. *Thanks to Tihon Zamotin from Saint-Petersburg Sport University for his help with video-analysis.*